The History of the Phillips Curve: An American Perspective

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Neil Sarkar was the exemplary research assistant on the empirical section of this paper.

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ABSTRACT

This history of the Phillips Curve adopts an American perspective, which is appropriate both because the literature has been dominated by Americans and because many of the empirical applications have been to American data. The early history of the US Phillips Curve through 1975 is well known, including the christening of the term by Samuelson-Solow, the introduction of long-term neutrality by Friedman, Lucas, and Phelps, and the apparent "wreckage" of the Phillips Curve evident in the positive correlation between inflation and unemployment in the 1970s.

Less well understood is the post-1975 fork in the road, with two quite different approaches to the resurrection of the Phillips Curve since then. The first approach started in 1975 with the theory of policy responses to supply shocks and continued with the development of a symmetric dynamic model in which aggregate demand and supply shocks interact with long-run neutrality and backward-looking inertia. This "mainstream" model has been successful in explaining the ups and downs of postwar US inflation. The second approach includes the work of Kydland, Prescott, Sargent, and the creators of the New-Keynesian Phillips Curve (NKPC). It emphasizes forward-looking expectations that can jump in response to actual and anticipated policy changes. The first approach is better suited to understand the postwar US inflation process, which is dominated by the role of inertia. The second, while bedeviled by persistence, is essential for understanding the ends of hyperinflations and the behavior of inflation in economies like Argentina with unstable macroeconomic environments.

The final section of the paper provides econometric evidence of the dominance of the mainstream approach over the NKPC alternative as an explanation of postwar US inflation, as measured not just by goodness of fit but, more important, by performance in post-sample dynamic simulations. The paper concludes by emphasizing its three main themes. First, two quite legitimate responses occurred after 1975 to the chaotic state of the PC literature at that time. Second, each framework is important and helps us understand how inflation behaves, albeit in different environments. Third, the two approaches need to pay more attention to each other, and this paper represents a start toward that reconciliation.

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1. Introduction

This history of the Phillips Curve (PC) unapologetically adopts an American perspective. With the exception of Phillips himself, most of the literature and controversies have been dominated by Americans, from the initial christening and interpretation by Samuelson and Solow, the invocation of monetary neutrality by Friedman, Lucas, and Phelps, and the "wreckage" and subsequent reconstruction of the PC in the wake of a strong positive correlation between inflation and unemployment that emerged in the 1970s. Most of the empirical literature that exhibits a consistent negative slope coefficient between inflation and unemployment also has been obtained with US data. In fact, we will see that the latest results using what we will later call the "mainstream" model emerges with a slope coefficient of roughly minus one-half, almost identical to that inferred from the data by Samuelson and Solow almost 50 years ago, and this estimated slope coefficient does not become flatter over time as has been suggested in some of the recent literature.

The overall theme of this paper is that the history of the PC has evolved in two phases, before and after 1975. There is general agreement on the pre-1975 evolution, which is well understood. But after 1975 the PC literature has split down two forks of the road, with little communication or interaction between the two forks.

The pre-1975 history is straightforward and is covered in Part 2. The initial discovery of the negative inflation-unemployment relation (for wages, prices, or both) by Phillips and Samuelson-Solow was followed by a brief period in which policymakers, especially in the US, assumed that they could exploit the tradeoff to reduce unemployment at a small cost of additional inflation. Then the natural rate revolution of Friedman, Phelps, and Lucas erased the policy-exploitable tradeoff in favor of long-run monetary neutrality. Those who had implemented the econometric version of the tradeoff PC in the 1960s reeled in disbelief when Sargent demonstrated the logical failure of their test of neutrality, and finally were condemned to the "wreckage" of Keynesian economics by Lucas and Sargent following the twist of the inflation-unemployment correlation from negative in the 1960s to positive in the 1970s. The architects of neutrality and the opponents of the Keynesian tradeoff emerged triumphant, except for widespread skepticism at the information barriers on which their own models rested, and the absence of evidence that the central bank could alter output only by achieving monetary surprises.

After 1975 the evolution of the PC literature split in two directions which, by and large, have failed to recognize the other's contributions. Part 3 reviews the revival of the PC tradeoff in a coherent and integrated dynamic aggregate supply and demand framework that emerged simultaneously in the late 1970s in econometric tests, in theoretical contributions, and, surprisingly, in intermediate macro textbooks. This approach, which I call "mainstream," is resolutely Keynesian, because the inflation rate is dominated by persistence and inertia in the form of long lags on past inflation. An important difference between the mainstream approach and other post-1975 developments is that the role of past inflation is not limited to the formation of expectations, but also includes ahe pure persistence effect due to fixed-duration wage and price contracts, and lags between changes in crude materials and final product prices. Inflation is dislodged from its past inertial values by demand shocks proxied by the unemployment or output gap, and explicit supply shock variables including changes in the relative prices of food, energy, imports, and the role of changes in the trend growth of productivity. The econometric implementation of this approach is sometimes called the "triangle" model, reflecting its three-cornered dependence on demand, supply, and inertia.

The other fork in the road is represented by models in which expectations are not anchored in backward-looking behavior but can jump in response to current and anticipated changes in policy. Reviewed in Part 4, important elements in this second literature include policy credibility, models of the game played by policymakers and private agents forming expectations, and the New Keynesian Phillips Curve (NKPC) which derives a forward-looking PC from alternative theories of price stickiness. The common feature of these theories is the absence of inertia, the exclusion of any explicit treatment of supply shock variables, the ability of expected inflation to jump in response to new information, and alternative barriers to accurate expectation formation due to such frictions as "rational inattention."

Which post-1975 approach is right? Which is best? The answer is surprisingly simple. Models in which expectations can jump in response to policy are essential to understanding Sargent's (1982) ends of four big inflations and other relatively rapid inflations in nations with a history of monetary instability, e.g., Argentina. But the mainstream/triangle approach is unambiguously the right econometric framework to understand the evolution of postwar US inflation. Part 5 develops and tests the triangle econometric specification alongside one recently published version of the NKPC approach. The latter can be shown to be nested in the former model and to differ by excluding particular variables and lags, and these differences are all rejected by tests of exclusion restrictions. The triangle model outperforms the NKPC variant by orders of magnitude, not only in standard goodness of fit statistics, but also in post-sample dynamic simulations.

Thus there are three main interrelated themes in this paper that have not previously received much if any attention. First, two quite legitimate responses occurred after 1975 to the chaotic state of the PC. Second, each response is important and helps us understand how inflation behaves, albeit in different environments. Third, the two approaches need to pay more attention to each other, and this paper represents a start toward that reconciliation.

2. Changing Interpretations of the Phillips Curve, 1958-75

This part of the paper reviews the evolution of the PC from Phillips' 1958 article through the development of the Friedman and Phelps natural rate hypothesis and Lucas' introduction of rational expectations. Post-1975 developments are then discussed in Parts 3 and 4. Beyond the scope of this paper are developments before 1958, in particular the many references ably surveyed by Humphrey (1991) dating back to Hume in the mid-eighteenth century regarding the long-run neutrality and short-run non-neutrality of money. The only exception to the 1958 starting cut-off in this paper is that we take note of Fisher's 1926 article which anticipates Phillips' relation albeit interprets it with the reverse direction of causation.

2.1 The Phillips Curve is Born: Phillips and Samuelson-Solow

The acceptance of new ideas and doctrines is often facilitated if they help to elucidate an outstanding empirical puzzle. Thus the acceptance in the late 1960s of Friedman's natural rate hypothesis occurred faster than otherwise, because it helped to explain the ongoing acceleration of the US inflation rate far beyond the rate forecast by the previous research that assumed a permanent negative tradeoff between inflation and unemployment. Likewise, the acceptance of the negative Phillips Curve (PC) a decade earlier was almost immediate since it appeared to resolve an ongoing puzzle about the interpretation of American inflation in the 1950s. These are two examples of the adage that cycles in the acceptance of doctrines often follow the timing of economic events. Two other examples include the role of the Great Depression in helping to explain the rapid spread of Keynesian doctrine after 1935, and the role of food and oil price shocks in facilitating the acceptance after 1975 of a dynamic inflation model which incorporated supply and demand shocks symmetrically (the subject of Part 3 below).

Implicit in pre-Phillips views of US inflation was a "reverse L" aggregate supply curve, with the joint of the reverse "L" at a level of economic activity often called "full employment." Sustained increases of "demand-pull" inflation would occur when the economy was operating at a higher level of activity than full employment. But below full employment the price level should be stable and the inflation rate should be near zero or, at very low levels of activity, should even be negative as occurred between 1929 and 1933. The early history of the postwar era was reassuring, in that inflation between 1946 and 1948 could be blamed on the pull of demand caused by the accumulation of liquid assets during the war and the complementary build up of the demand for goods of all kinds after the production of civilian goods had been largely shut down by fiat during the war. During the recession of 1949 the inflation rate was reassuringly negative (-2.0 percent at an annual rate for the GDP deflator between 1948:Q4 and 1950:Q1). Then inflation returned during the low-unemployment Korean war years 1950-53 to an extent that had to be suppressed by price controls.

Doubts emerged beginning with the failure of the inflation rate to decline for a single quarter during the 1953-54 recession, followed by its inexorable rise during 1955-57, "despite growing overcapacity, slack labor markets, slow real growth, and no apparent great buoyancy in over-all demand" (Samuelson-Solow, 1960, p. 177). No consensus emerged on the right combination of demand-pull with alternative explanations of the coexistence of inflation with perceived economic slack, theories variously named "cost-push," "wage-push," and "demand-shift." Into this fractured intellectual atmosphere the remarkable Phillips (1958) article replaced discontinuous and qualitative descriptions by a solid quantitative hypothesis based on an extraordinarily long history of evidence. Since 1861 there had been a regular negative relationship in Britain between the unemployment rate and the growth rate of the nominal wage rate. By implication, since the inflation rate would be expected to equal the growth rate of wages minus the long-term growth rate of productivity, there was a regular negative relationship between the unemployment rate and the inflation rate.

Before examining the data, Phillips made two important theoretical observations. First, the negative relationship between the unemployment rate and the rate of nominal wage change should be "highly non-linear," due to downward wage rigidity that reflects in turn the reluctance of workers "to offer their services at less than the prevailing rates when the demand for labour is low and unemployment is high" (1958, p. 283). Second, the rate of change of wages may depend not just on the level of unemployment but its rate of change, and subsequently we will discuss the role of this "rate of change" effect that is incorporated in some empirical PC models but not others.

However, Phillips surprisingly debunked a third possible correlation, that between the rate of wage change and the retail inflation rate ("working through cost of living adjustments"). He was thinking of a world in which wage rates represented four-fifths of factor costs and import prices the other one-fifth, and normally wage rates and import prices would rise at the same rate. Only when import prices rose five times as fast as productivity growth would retail prices influence wage rates. An interesting note, which we pick up below, is that Phillips was already thinking of a world in which both demand shocks (the level and change of unemployment) and supply shocks (the rate of change of import prices relative to final goods prices) both mattered in determining wage and price changes. However, the role of supply shocks was not fully integrated into PC analysis until the late 1970s.

Most of Phillips' article consists of a set of 11 graphs displaying the rate of change of the nominal wage on the vertical axis and the unemployment rate on the horizontal axis. Graphs are shown for the major subperiods (1861-1913, 1913-48, and 1948-57) and for each business cycle within the first subperiod. The accompanying text provides an explanation for each point that lies off the fitted regression line, which for 1861-1913 is

$$w_t = -0.90 + 9.64 U_t^{-1.39} \quad \textbf{(1)}$$

where, as in the rest of this paper, upper-case letters are levels, lower-case letters are rates of change, w_t is the rate of change of the nominal wage rate and U_t is the unemployment rate. Points above the line are identified as years of declining unemployment or rapidly rising import prices, and vice-versa. Note the nonlinear formulation and the fact that neither the rate of change effect nor the import price effect are explicitly incorporated into the equation. An econometric representation that included both the level and rate of change effect was soon provided by Lipsey (1960), who showed that the rate of wage change was indeed faster for any given unemployment rate when unemployment was falling than when unemployment was rising, implying counterclockwise loops around the basic Phillips relationship of equation (1).

The second major subperiod 1913-48 provides solid support for the negative Phillips relationship. Very low unemployment in World War I was accompanied by rates of wage increase ranging from 8 percent in 1915 to 28 percent in 1919, with a Friedman-like acceleration in each year. High unemployment in the 1920s and 1930s was accompanied by low wage changes ranging from -2 to +4 percent. Extreme outlier observations occur in 1921 and 1922, with rates of wage change of -22 and -18 percent, respectively, and in Phillips' typical style, he provides anecdotal links to the negative change of unemployment and negative rate of retail inflation during this episode.

Only in discussing the final period 1948-57 does Phillips use the language that was then familiar, "demand-pull" and "cost-push". The demand-pull component of wage change is identified from the prediction of the curve fitted to 1861-1913 data, while the cost-push component depends (but not 1-to-1) on retail price inflation. The change in wage rates is remarkably close to the prediction of the 1861-1913 curve except for the two years 1951-52 which were influenced by rapid increases in import prices in 1950-51 resulting from the 1949 devaluation of sterling.

Phillips' conclusion briefly translates the fitted curve into an unemployment-inflation relationship by subtracting long-term productivity growth and concludes that stable prices require an unemployment rate of roughly 2.5 percent. Notably, Phillips does not conjecture about circumstances in which the apparently stable 1861-1913 curve might shift up or down in the long-run. Also, Phillips does not mention policy implications at all, and this provides the setting in which Samuelson-Solow (1960) christen the relationship as the "Phillips' Curve" and explore the policy implications.

So widely read and discussed was the Samuelson-Solow article that the term "PC" entered the language of macroeconomics almost immediately and soon became a lynchpin of the large-scale macroeconometric models which were the focus of so much research activity in the 1960s that took advantage of the widespread availability of relatively powerful electronic computers. Much of the Samuelson-Solow article provides a critique of the pre-Phillips hypotheses and the difficulty of identifying them.

Then, turning to the Phillips evidence, Samuelson-Solow lament the absence of a similar study for the US and extract some observations from a scatter plot of US data. First, the US relationship does not work for the 1930s and the two World Wars. Second, the implied zero-inflation rate of unemployment is about 3 percent for the remaining prewar years, similar to Phillips' estimate of 2.5 percent. Third, there was a clear upward shift in the relationship from the prewar years to the 1950s, and the zero-inflation unemployment rate for the 1950s had risen from 3 percent to "5 to 6 percent."

Their conjectures to explain the postwar upward shift include powerful trade unions that are less "responsible" than their UK counterparts, and/or the expectation of permanent full employment in the US. Another conjecture is that the compact size of the UK compared to the US makes labor markets in the former more flexible. A policy conclusion is that anything that makes US labor markets more flexible will help to shift the PC downwards.

Samuelson-Solow have rightly been criticized for posing a tradeoff available to policymakers to choose between low inflation together with high unemployment as contrasted with high inflation together with low unemployment. In classes where I taught the pre-1968 tradeoff view, I referred to these alternative outcomes as the "Republican" vs. the "Democratic" choices. As the authors conclude: "We rather expect that the tug of war of politics will end us up in the next few years somewhere in between their selected points. We shall probably have some price rise and some excess unemployment" (Samuelson-Solow, 1960, p. 193).

While Samuelson-Solow conclude by warning that the PC relationship could shift over the longer run, their example involves a "low-pressure" (i.e., high-unemployment) economy in which expectations of low inflation could shift the PC down or could aggravate structural unemployment, thus shifting the PC up. They regard either outcome as possible, and they notably fail to reason through the long-run implications of a high-pressure economy with its implications of a steady increase in inflation expectations and an associated steady upward shift in the PC. That inference had to wait another eight years for the contributions of Friedman and Phelps.

An interesting side-issue is the antecedent of Phillips' article published by Irving Fisher in an obscure journal in 1926, reprinted and brought to a wider audience in 1973.[1] Recall that Samuelson-Solow lamented the availability of a detailed statistical study of the US analogous to Phillips' UK research, yet Fisher had already provided such

1. The article was unearthed by Jacob Mincer, and as Co-Editor of the *JPE* during 1971-73, I was responsible for the decision to reprint it and give it the dramatic title listed in the reference list of this paper.

research more than 30 years earlier.[2] A notable difference with Phillips is that Fisher reversed the direction of causation, with the changes in the rate of inflation causing the changes in the level of the unemployment rate. Fisher explained the mechanism in textbook terms -- because costs of production (including interest, rent, salaries, and wages) are fixed in the short run "by contract or by custom," a faster rate of inflation raises business profits and provides an incentive to raise output. "Employment is then stimulated – for a time at least" (1973 reprint, p. 498). Because of the lag of costs behind prices, Fisher emphasizes that the relationship is between unemployment and the inflation rate, not the price level, and that the price level has "nothing to do with employment." He uses the analogy of driving, in which it takes more gasoline per mile to climb a hill than descend it, but exactly the same amount to navigate a "high plateau as on the lowlands."

Fisher's statistical study is limited to the years 1915-25 but is based on monthly data. When the influence of inflation is represented by a short distributed lag over five months, the correlation coefficient is 90 percent between the unemployment rate and the short distributed lag of inflation. An important weakness of the Fisher study is evident in his Chart II but is not discussed by the author. The 90 percent correlation applies to 1915-25 but his chart extends back to 1903. During the period 1903-15 unemployment is almost as volatile as during 1915-25 but the variance of inflation is much lower, implying that the relationship is not stable and that Fisher's main result may be picking up the special features of World War I and its aftermath (just as Phillips' UK correlation is strong during World War I and most of the 1920s).

2.2 Aspects of Phillips Curve Economics in the 1960s

During the early to mid 1960s at least three aspects of the PC emerged that would have subsequent consequences. First, the PC tradeoff was taken seriously as providing policymakers with a menu of options. The policy advisors of the Kennedy and Johnson Administrations, led by Walter Heller with support roles by Robert Solow and James Tobin, argued that the previous Republican Administration had chosen a point too far southeast along the PC tradeoff, and that it was time to "get the country moving again" by moving to the northwest. Heller's group convinced President Kennedy to recommend major cuts in Federal income taxes, and these were implemented after his death by the Johnson Administration in two phases during 1964 and 1965. However, in late 1963 the economy was already operating at an unemployment rate of 5.5 percent that Samuelson-Solow had calculated was consistent with zero inflation, and so the expansionary Kennedy-Johnson fiscal policy would have implied an acceleration of

2. An amusing commentary on the research technology of the 1920s is Fisher's comment that "During the last three years in particular I have had at least one computer in my office almost constantly at work on this problem (1926, p. 786).

inflation even without the loosening of the fiscal floodgates with Vietnam war spending in 1965-66.

Figure 1 plots the US inflation and unemployment rates in quarterly data since 1960, and we shall refer to it here to examine the period 1960-71 and then below to link the evolution of PC debates to the post-1971 behavior of inflation and unemployment.[3] The unemployment rate fell below 5.5 percent in 1964 and remained below 4 percent between 1966 and 1970. The sharp acceleration of inflation from less than 2 percent in 1963 to 5.5 percent in 1970, consistent with current econometric estimates of the 1963 natural rate of unemployment (the rate that is consistent with steady inflation rather than zero inflation) in the range of 5.5 to 6.0 percent (Dew-Becker and Gordon, 2005, Table 5, p. 89).

A second aspect of this period was the development of mainframe electronic computers that made it practical for the first time to specify and estimate large-scale econometric models (a book-length policy analysis using the Brookings model is contained in Fromm-Taubman, 1968). The specification of the inflation process in these models always consisted of at least two equations. The PC was embodied in an equation for the rate of change of the nominal wage in which the main explanatory variables were the unemployment rate, sometimes its rate of change, some measure of expected inflation based on a backward-looking set of lags, and perhaps various tax rates, especially the social security tax rate that would be expected to be positively correlated with changes in a wage measure that included employer payroll tax contributions.

Then the estimated change in wages was typically translated into the inflation rate in an equation that related the price *level* to the wage *level* adjusted for the level in actual and/or trend productivity, so-called "standard unit labor cost." The price-labor cost ratio or "markup" was allowed to respond to a measure of demand, usually not the unemployment rate but rather a measure more directly related to the product market, such as the ratio of unfilled orders to shipments or capacity. The reduced form of this approach, which was embodied in numerous large-scale models as well as articles looking only at the partial-equilibrium properties of the inflation process, implied that the inflation rate depended on the level and rate of change of unemployment, perhaps other measures of demand, and lagged inflation. We return below to the problems encountered by these models in confronting the data of the late 1960s and in dealing with the challenge of the Friedman-Phelps natural rate hypothesis.

A third and perhaps peripheral feature of this era was the rivalry between the economics departments at the University of Chicago and MIT in general, and between Milton Friedman and Franco Modigliani in particular. In 1965 more than 100 pages in

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3. In Figure 1 the inflation rate is the four-quarter change in the deflator for personal consumption expenditures.

the *American Economic Review* were devoted to a debate between them and their co-authors over the issue of whether "only monetary policy mattered" or "only fiscal policy mattered," a debate that seemed bizarre to the mainstream consensus that taught the IS-LM model in which both monetary and fiscal policy mattered except in certain extreme cases.[4] The rivalry between Friedman and Modigliani (and also Tobin) set the stage for the dramatic impact of Friedman's (1968) Presidential Address and the futile effort of the large-scale econometric modelers to deny or overturn its implications.

2.3 The Natural Rate Revolution

Prior to the publication of the Friedman and Phelps articles, theoretical questions had been raised about the PC framework. Why did the nominal wage adjust slowly, particularly in a downward direction, and what determined the speed with which it responded to inadequate demand? Why did the PC lie so far to the right, that is, why did nominal wages rise so fast at a low unemployment rate and why was such a high unemployment rate required to maintain zero inflation? Perhaps most relevant in anticipation of Friedman and Phelps, how could the PC be so stable over history when there were so many episodes of hyperinflations fueled by permissive monetary and fiscal policy? I have always thought that the development of the natural rate hypothesis at Chicago, rather than at Harvard or MIT, reflected the deep involvement of several Chicago economists as advisers to several countries in Latin America, where the lack of correlation between inflation and unemployment was obvious.

Friedman's (1968) Presidential Address contained two sections that each had a main point, closely interrelated. First, the central bank could not control the nominal interest rate if that implied faster inflation, because the implied reduction in the real interest rate would add fuel to the inflationary fire. The second section was most important for the PC debate, his then-startling conclusion that policymakers had no ability to choose any unemployment rate in the long-run other than the natural rate of unemployment, the rate which would be "ground out" by the microeconomic structure of labor and product markets. A more practical interpretation of the natural rate was the unemployment rate consistent with accurate inflation expectations, which implied a steady rate of inflation.

Conventional analysis based on a policy tradeoff ignored the adjustment of expectations. Consider an economy operating at the natural rate of unemployment and with an initial inflation rate of one percent that was accurately anticipated. Any policymaker attempting to reduce the actual unemployment rate below the natural rate would move the economy northwest along the short-run PC, pushing the unemployment rate lower but the actual inflation rate higher. Once agents notice that

4. Spectators at the time called the *AER* debate the "battle of the radio stations," after the AM-FM initials of the protagonists, Ando-Modigliani vs. Friedman-Meiselman.

the actual inflation rate is higher than the initially anticipated rate of one percent, then expectations will adjust upward and shift the entire short-run PC higher. This process will continue until the unemployment rate rises back to the initial natural rate of unemployment.

The timing of Friedman's address was impeccable and even uncanny. The Kennedy-Johnson fiscal expansion, including both the tax cuts and Vietnam war spending, had pushed the unemployment rate down from 5.5 percent to 3.5 percent, and each year between 1963 and 1969 the inflation rate accelerated, just as Friedman's verbal model would have predicted. The acceleration of inflation bewildered the large-scale and partial equilibrium econometricians, who had previously estimated a rate of "full employment" of 4 percent and whose forecasts of inflation had been exceeded by the actual outcome in every year of the late 1960s.

Well aware of their own failure to forecast the late 1960s acceleration of US inflation, Friedman's detractors attacked the verbal model that Friedman used to motivate the natural rate hypothesis. In what later became known as the "fooling" model, Friedman postulated employers with expectations of the price level that were always accurate, but workers with an expected price level that did not respond until after a substantial lag to a higher actual price level. In a business expansion, firms would raise the wage but raise the price level by more, implying the reduction in real wage that employers needed to offset the diminishing marginal product of the additional workers. But workers would see the higher nominal wage and interpret it as a higher actual real wage, because they had failed to adjust their expectation of the price level to match the increase in the actual price level. Friedman's model was attacked as grossly implausible, because workers have access to monthly announcements of the CPI and indeed shop every week or every day and would know about any price increases almost as soon as they occur. In Friedman's world, there could be no business cycle.

Phelps (1967, 1968) is credited with co-discovering the natural rate hypothesis. In contrast to Friedman's distinction between smart firms and dumb workers, in Phelps's world everyone is dumb, i.e., equally fooled. Both firms and workers see the price rise in their industry and produce more, not realizing that the general price level has risen in the rest of the economy. Phelps developed one model in which firms are fooled while the workers are not. In another model, workers are isolated from information about the rest of the economy. Normally there is frictional unemployment, as workers regularly quit one firm to go look for more highly paid work at other firms. But in a situation in which their own firm raises the wage, they stay with that firm instead of quitting. Thus the unemployment rate decreases even though, without their knowledge, all other firms in the economy have raised the wage by the same amount at the same time. The workers are fooled into a reduction in frictional unemployment, and the macroeconomic data register a decline in the unemployment rate. Hence there is a short-term correlation between the rate of wage change and the unemployment rate, but this lasts only as long as expectations are incorrect.

Whether firms or workers or both are fooled, the criticisms directed against the Friedman fooling model apply to Phelps as well. Workers and their employers buy many goods on a weekly or even daily basis; they obtain news on the CPI every month; and perhaps most important if periods of high real GDP and low unemployment had always been accompanied by an increase in the aggregate price level, workers and firms would learn from these past episodes and use their experience to form expectations accurately.

2.4 Rational Expectations and the "Policy Ineffectiveness Proposition"

Both the Friedman and Phelps models were based on the twin assumptions of continuous market clearing and imperfect information. Soon thereafter Lucas extended their model by adding a third component, that of rational expectations. In several influential articles (1972, 1973) Lucas advocated replacing slowly-adjusting adaptive expectations with rational expectations. Thus workers and firms would use their knowledge of past history to work out the implications of an observed fall or rise in wages on the overall wage level. Rational expectations implied that workers would not make the same expectational errors repeatedly.

Lucas collapsed the distinction between firms and workers and treated all economic agents as alike, "yeoman farmers" who face both idiosyncratic shocks to their own *relative* price and macro shocks caused by fluctuations in monetary growth and other factors. The agents use rational expectations to deduce from past history how much of an observed change in the local price represents an idiosyncratic shock to that particular agent and how much represents the influence of macro shocks. When local price shocks have a high correlation with macro shocks, agents will not adjust production, knowing that no change in relative prices has occurred, and Lucas used this insight to explain why the PC in a country like Argentina with high macro volatility would be much steeper than in a country like the US with low macro volatility.

The concept of rational expectations led Lucas and his followers to make a startling prediction. He argued that *anticipated monetary policy cannot change real GDP in a regular or predictable way,* a result soon known as the "policy ineffectiveness proposition." In common with Friedman and Phelps, the Lucas approach implied that movements of output away from the natural level require a price surprise, so that the central bank cannot alter output by carrying out a predictable change in monetary policy, only by creating a surprise (the formal development of the proposition was carried out in Sargent-Wallace 1975.)

By the end of the 1970s the Lucas approach was widely criticized. The problem was not Lucas' introduction of rational expectations, but rather the twin assumptions inherited from Friedman and Phelps, namely continuous market clearing and imperfect information. Deviations of the current actual price level from the expected price were the *only* allowable source of business cycle movements in real GDP. The assumption of imperfect information implied that business cycles would be eliminated if we had accurate current information about the aggregate price level, and such information was available every month when the latest CPI data were released.

Thus, despite the widespread appeal of the Friedman-Phelps-Lucas approach, it ran aground on the shoals of an inadequate theory of business cycles. With monthly information available on the aggregate price level, the business cycle could last no more than one month.[5] In the recent evaluation of Sims (2008, p. 4), the microeconomic underpinnings of the Lucas supply curve were "highly abstract and unrealistic – for example models of `island economies' in which people had to infer the value of the economy-wide interest rate or money stock from the price level on their own island."

2.5 The Demise of the Empirical Case Against Monetary Neutrality

Whatever the model used to explain the business cycle, the natural rate hypothesis and long-run monetary neutrality are intact if empirical coefficients imply that a reduction of the unemployment rate below a certain level (whether it is called the natural rate or the full employment rate) leads to continuously accelerating inflation. In the first few years after the Friedman-Phelps articles, those who had developed econometric models denying a permanent long-run tradeoff claimed that the validity of long-run neutrality could be tested by estimating whether the sum of coefficients on the lagged dependent variable in an inflation equation was equal to unity or was significantly below unity. Here we ignore the distinction between wage and price changes and examine the relationship between the inflation rate (p_t), its lagged value (p_{t-1}), and the unemployment rate (U_t):

$$p_t = \alpha p_{t-1} + \beta U_t + e_t \qquad \textbf{(2)}$$

Here the response of inflation to unemployment (β) is negative. If the sum of coefficients on lagged inflation is significantly below unity, then in the long run when $p_t = p_{t-1}$ there is a long-run tradeoff between inflation and unemployment:

$$p_t = \beta U_t/(1-\alpha) \qquad \textbf{(3)}$$

5. Lucas (1973, equation (3), p. 327) created a serially correlated business cycle by introducing a lagged value of cyclical output into the equation explaining cyclical output by the price surprise. This lagged term is gratuitous and neither called for by the theory not consistent with it.

Numerous research papers written in the late 1960s and early 1970s placed major emphasis on the finding that the α coefficient was significantly below unity, implying a permanent tradeoff as in equation (3). However, these results were ephemeral and quickly abandoned for two reasons. First, as the sample period extended over more of the period of accelerating wage and price change in the late 1960s, the α coefficient kept creeping up and by 1972 had reached unity in several papers, particularly when the coefficient was allowed to vary over time.[6]

The second and more important reason to abandon this attempt to defend the long-run tradeoff was Sargent's simple but devastating econometric point. Here we simplify Sargent's exposition by suppressing the difference between wages and prices, and by making expected inflation depend only on a single lag of inflation rather than a distributed lag. The original specification is not (2) but rather

$$p_t = \alpha Ep_t + \beta U_t + e_t \quad \textbf{(4)}$$

where Ep_t is the expected rate of inflation. An observable proxy for expected inflation must be obtained, and almost always this requirement is satisfied by backward-looking or adaptive expectations :

$$Ep_t = v\, p_{t-1} \quad \textbf{(5)}$$

When we substitute (5) into (4), we obtain:

$$p_t = \alpha v\, p_{t-1} + \beta U_t + e_t \quad \textbf{(6)}$$

Now Sargent's point becomes clear ; the single equation (6) cannot be used to estimate both α and v. The only way that α can be interpreted as the coefficient on expected inflation is for an extraneous assumption to be introduced, in particular that $v = 1$.

Yet, Sargent argues, there is no reason for v to be unity, and rather if the inflation rate can be approximated as a covariance-stationary stochastic process, v must be less than unity. For v to be unity, the inflation rate would display extremely strong serial correlation or « drift », but during most of US history the inflation rate has displayed relatively little serial correlation. Thus it is quite possible that α was equal to unity throughout the postwar era but that v gradually increased with the higher serial correlation of inflation in the 1960s than in the 1940s and 1950s. In short, Sargent made a convincing case that the previous econometric estimates of α in the context of equation

6. Eckstein and Brinner (1972) produced the first paper to emerge with a specification in which the α coefficient was unity. Gordon (1972) concurred, based on a different parameterization of a time-varying coefficient and provided comparisons of his approach with those of Eckstein-Brinner and Perry (1970).

(2) had absolutely no relevance to the validity of the natural rate hypothesis. Not surprisingly, such econometric exercises ceased quite abruptly after 1972.

3. Post-1975 Mark I: The Dynamic Demand-Demand Model with Inertia

The 1960s were the glory years of the PC interpreted as a negative correlation between inflation and unemployment, initially interpreted as incorporating a permanent negative tradeoff, and subsequently interpreted as a significant negative slope in the expectational PC in which the natural rate hypothesis was embedded. But almost from the beginning, the decade of the 1970s seemed to overturn any thought that the negative PC tradeoff was intact or stable. The nature of the problem is evident when we look again at Figure 1, which plots the inflation and unemployment rates in quarterly data since 1960. For the 1970s as a whole, the inflation-unemployment correlation is strongly positive, not negative, and in Figure 1, sharp changes in the inflation rate appear to lead by about one year sharp changes in the same direction of the unemployment rate..

When plotted in Figure 2 on a scatter diagram from 1960 to 1980 the inflation and unemployment rates appeared to be uncorrelated, with a combination of negative and positive correlations that seem to range all over the map. The negative PC tradeoff appeared to be completely sabotaged. In flowery language that amounted to a simultaneous declaration of war and announcement of victory, Lucas and Sargent (1978, pp. 49-50) described "the task which faces contemporary students of the business cycle [is] that of sorting through the wreckage . . . of that remarkable intellectual event called the Keynesian Revolution."

The year 1975 marks a breakpoint in the history of the PC. Viewed in retrospect, a clear consensus has emerged regarding the pre-1975 evolution of PC doctrine from Samuelson-Solow through Friedman-Phelps-Lucas. Nobody defends a permanent negative tradeoff. Everyone accepts that the position of the PC evolves in response to actual events. However, since 1975 the development of PC doctrine has followed two divergent paths with no sign of convergence, and indeed little sign that the two sides are paying attention to each other.

On one side, treated in Part 3 of this paper, we have the resurrection of Keynesian economics in the form of a what I call the "mainstream" PC model that incorporates long-run neutrality, that incorporates explicitly the role of supply shocks in shifting the PC up or down, and that interprets the influence of past inflation as reflecting not just changes in expectations but rather a generalized inertia. The dependence of current inflation on lagged inflation, the generalized inertia effect, results not just from expectation formation but also the role of slowly changing wage and price contracts and long lags in the transmission of changes in crude and intermediate goods prices to final goods prices. This approach is Keynesian because the role of inertia is to make the inflation rate slow to adjust to changes in nominal demand, and as a result real GDP changes emerge as a residual, not as an object of choice as in Friedman-Phelps-Lucas. A vast theoretical literature under the rubric of "New Keynesian Economics" starting in the late 1970s provided numerous models to motivate the inertia mechanism by explaining real and nominal rigidity of wages and/or prices, and many of these explicitly incorporated rational expectations.

The other side of the post-1975 evolution, examined in Part 4 below, features an approach developed by Kydland, Prescott, and Sargent. As summarized below, inflation depends on expectations, and expectations respond rationally to actual and expected changes in monetary and fiscal policy. This two-way game between policy and expectation formation leaves no room for supply shocks or inertia. The idea that expectations respond directly to policy changes, without any inertial role of past actual inflation, is crucial in understanding the remarkable ends of hyperinflations and other rapid inflation episodes as chronicled by Sargent (1982). A descendant of the policy-based expectations approach is the more recent New-Keynesian Phillips Curve (NKPC) developed over the past decade.

We return below to the difficult question posed by the two forks in the road after 1975 and the fact that two incompatible models have emerged. The view taken below is that the Keynesian mainstream approach is the right model to apply to the United States with its inertia-bound inflation process, and that the policy-based expectations approach is the right model for rapid inflations in unstable macroeconomic policy environments such as those documented by Sargent (1982).[7] The choice between the two models is closely related to Lucas' (1973) result showing that the slope of the PC is steeper in countries where the variance of macro shocks is high relative to the variance of idiosyncratic shocks faced by individual agents, while the slope of the PC is flatter in countries with relatively low variance of macro shocks. This may help to explain why the mainstream approach is more appropriate for the postwar US and the policy-based expectations approach is more appropriate to discuss hyperinflations and other high-inflation episodes.

3.1 The Demise of New Classical Macro and the Resurrection of the PC

The year 1975 marks a clear break in the history of the Phillips Curve. Surveys written at that time focus on the demise of the short-run tradeoff and the emergence of the consensus expectational natural-rate PC (see for instance Laidler and Parkin, 1975). Two complementary reasons lead us to mark 1975 as the transition year for PC doctrine.

7. As an example of the lack of recognition of the Keynesian mainstream approach, a recent survey by Lacker and Weinberg jumps directly from Kydland-Prescott-Sargent in the late 1970s to the NKPC model in the late 1990s without any recognition that anything had happened in between to explain the positive correlation of inflation and unemployment in the 1970s (and 1990s).

First, it was the year of the publication of the policy-ineffectiveness proposition summarized above, which was the beginning of the end of business cycle theory based on expectational errors. Second, 1975 was a year in which both the US inflation and unemployment rates experienced the maximum impact of supply shocks, calling for a revised PC theory that explicitly incorporated supply shocks.

The term "New Classical Macroeconomics" (NCM) describes two different sets of contributions that share the assumption of continuous market clearing. The first set, sometimes called NCM "Mark I," includes the Friedman-Phelps-Lucas model that makes business cycles depend on imperfect information, as well as the associated policy ineffectiveness proposition. NCM "Mark II" is the real business-cycle theory, and this is beyond the scope of this paper since its basic contributions are expressed entirely in real terms, with no demand side, monetary sector, nor price level. The demise of NCM Mark I occurred in two stages. First, as a theory it was flawed by its inability to reconcile multi-year business cycles with one-month lags faced by agents in obtaining complete information about the aggregate price level. Second, the attempt to develop an empirical counterpart of the policy-ineffectiveness proposition was a research failure. It floundered on the inability to develop a symmetric explanation of output and price behavior. Barro (1977) showed that output was not related to anticipated monetary changes but could not demonstrate the required corollary – the full and prompt responsiveness of price changes to anticipated nominal disturbances. This failure was not a matter of arcane methodological debates.

Several years before the famous "wreckage" pronouncement by Lucas and Sargent, the resurrection of the PC began. The first and perhaps most important element was the new theory of policy responses to supply shocks, developed independently by Gordon (1975) and Phelps (1978) in two slightly different models that were later merged by Gordon (1984). These models start from the proposition that the price elasticity of demand of the commodity experiencing the adverse supply shock, e.g. oil, is less than unity, so that following an increase in the relative price of oil, the expenditure share of that commodity must increase and the expenditure share of all other components of spending must decrease. For instance, energy's share of nominal US GDP tripled between 1972 and 1981.

The required condition for continued full employment is that a gap open up between the growth rate of nominal GDP and the growth rate of the nominal wage (Gordon, 1984, p. 40) to make room for the increased nominal spending on oil. If nominal wages are flexible, one option is for the growth rate of wages to become negative, allowing the growth rate of nominal GDP to remain fixed. At the alternative extreme with rigid wages, an accommodating monetary policy must boost nominal GDP growth by the amount needed to "pay for" the extra spending on oil, but this will lead to an inflationary spiral if expectations respond to the observed increase in the inflation rate. A third alternative, and the one that actually occurred in the 1970s, was a combination of wage rigidity with a partial response of nominal GDP growth, pushing down real non-oil spending and employment.

By 1976 this model had made its way into the popular press when a *New York Times* headline announced, "A New Theory: Inflation Creates Recession." Indeed, we can see in Figure 1 that throughout the period 1974-81, there was a clear lead of roughly one year of inflation relative to unemployment. This real-world result, that an adverse supply shock can depress real output and employment, had been christened by Okun in 1974 discussions as a "macroeconomic externality."

By 1977 supply shocks had been incorporated into the natural-rate expectational Phillips Curve. This theoretical formulation (Gordon, 1977, equation 13), except for the absence of explicit lagged terms, is identical to the econometric "mainstream" model developed subsequently and described below:

$$p_t = Ep_t + b(U_t - U^N_t) + z_t, \quad \textbf{(7)}$$

where the notation is the same as above with the addition of U^N_t to represent the natural rate of unemployment and z_t to represent « cost-push pressure by unions, oil sheiks, or bauxite barons » (Gordon, 1977, p. 133). Other types of supply shocks include the imposition and termination of price controls (as in the US in 1971-74), changes in the relative price of imports, and changes in the trend growth of productivity. Episodes in which political events cause sharp changes in wages, such as the French general strike of 1968, also qualify as adverse supply shocks.

The process of integrating supply shocks into macroeconomics took place simultaneously during 1975-78 on three fronts, theoretical as described above, empirical as described below, and in an unusual development, through a new generation of intermediate macroeconomic textbooks. An explanation was needed to reconcile the dominant role of demand shocks as the explanation of the Great Contraction of 1929-33 in the same model as would explain the positive correlation of inflation and unemployment in 1974-75. Once recognized, it became obvious, especially to those who regularly taught a course in elementary principles of economics. Just as the output and price of corn or wheat could be positively or negatively correlated depending on the importance of microeconomic demand or supply shocks, so the aggregate level of output and unemployment and the rate of inflation could be positively or negatively correlated, depending on the relative importance of aggregate demand or supply shocks.

The textbooks appeared simultaneously in 1978 and both used alternative versions of a simple diagram that can be traced back to a classroom handout that

Dornbusch had used at the Chicago Business School in early 1975.[8] The diagram, which had the inflation rate on the vertical axis and either the unemployment rate or the output gap on the horizontal axis, combined three elements – the expectational Phillips curve of Friedman-Phelps, an identity that decomposed nominal GDP growth into inflation and output growth, and Okun's insight that supply shocks can have macroeconomic externalities. The textbook version includes an algebraic appendix showing that the dynamic aggregate demand-supply model has as its reduced form a simple first-order difference equation. Following a permanent upward or downward shift in nominal GDP growth, any lags in the formation of expected inflation cause the economy to cycle through loops to its new long-run equilibrium at the same level of output or unemployment and a permanently higher or lower rate of inflation.[9]

3.2 Econometric Implementation of the Mainstream Model

We defer to Part 5 below a discussion of the detailed specification of the "mainstream" econometric model and its contrast with econometric versions of the New-Keynesian Phillips Curve (NKPC). In this section our focus is on general issues in the development of the empirical mainstream PC since the late 1970s.

As in equation (7) above, the mainstream specification of the inflation process contains three sets of explanatory variables, leading me to call this the "triangle" model. Replacing the expected inflation term is a set of long lags on past inflation, reflecting the view that the influence of past inflation reflects generalized inertia, not just the formation of expectations. Important sources of inertia include the set of explicit and implicit contracts that dampen short-term changes in prices and wages (as recognized explicitly by Fisher, 1926), and the input-output supply chain that creates thousands of links of unknown magnitude and duration between changes in crude and intermediate

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8. The 1978 rival textbooks were by Dornbusch and Fischer and by myself. The dynamic version of the demand-supply model in the form of a first-order difference equation was confined to intermediate level textbooks, with many imitators published soon after. Elementary macro principles textbooks limited themselves to the display of static aggregate demand and aggregate supply curves, starting with Baumol and Blinder in 1979.

9. The algebra remains intact in the eleventh edition of my textbook, copyright 2009. In the long run the inflation rate is determined by the growth rate of nominal GDP minus the growth rate of natural (or potential) real GDP. The simplest version of the model plots the inflation rate versus the output gap (log ratio of actual to natural real GDP), as this eliminates an extra equation to translate the output gap into the unemployment rate. Two schedules interact to determine the inflation rate and the output ratio. The dynamic supply equation is the short-run PC dependent on the output gap and on lagged inflation. The dynamic demand equation is a negative 45 degree line that shifts in response to nominal GDP growth and the lagged level of the output gap. In the output gap version, loops following a increase in nominal GDP growth are counter-clockwise. Loops following a supply shock depend on the response of monetary policy and the extent to which expectations treat the supply shock as temporary or permanent.

goods prices and the prices of final goods, as emphasized by Blanchard (1987). All of these channels interact to create the "inertia" effect, the first leg of the triangle.

Because firms have no way to estimate in advance how much and when the prices of their inputs will change, they act like the man from Missouri (where the state motto is "show me"), waiting by the mailbox for news of input price increases. Sometimes such news may arrive almost instantaneously, as in the case of airlines that observe daily changes in the price of fuel. Sometimes news may arrive with a long delay, as increases in the price of oil in the spring of 2008 led DuPont to increase its products by an average of 20 percent, leaving producers of final goods to guess which of their intermediate goods suppliers would be influenced by the DuPont price increase, by how much, and when.

The second set of explanatory variables is represented by the level and change of the output gap or alternatively the unemployment gap. As we have seen above, both Fisher and Phillips recognized the role of the "rate of change" effect that at any given unemployment rate makes the inflation rate higher when the unemployment rate is falling than when it was rising. Because the unemployment gap is always entered in the triangle model not just as the current value but with additional lags, the zig-zag of the estimated lagged coefficients between negative and positive incorporates the rate of change effect. The third is a set of explicit supply shock variables, establishing a contrast between the mainstream approach and other recent empirical models that hide the supply shock variables in the error term. As we shall see below, in econometric estimation the explicit supply shock variables are all defined so that the absence of supply shocks is represented in (7) as $z = 0$. Such variables, for instance, would include changes in the *relative* price of oil or changes in the *relative* price of non-oil imports; then these relative prices exhibit zero change, there is no upward or downward pressure on the inflation rate from supply shocks.

In contrast to the pre-1975 PC, the triangle model incorporates two differences in addition to the explicit inclusion of supply shocks, the absence of an explicit reference to expectations and the absence of a separate wage equation. New Keynesian theory (as contrasted with the later NKPC) developed first in the late 1970s by Fischer (1977), Taylor (1980), and then by many others after them, showed that price and wage inertia is fully compatible with rational expectations. Any model in which the inflation rate depends on backward-looking inertia, with no room for jumps in expectations in response to perceived changes in government policy, is resolutely Keynesian, hence the label "New Keynesian economics." Prices are prevented from mimicking changes in nominal GDP growth both by inertia – long lags on the influence of past inflation – and by the finite Phillips curve adjustment coefficient. With excess nominal GDP growth (that is, in excess of natural output growth) treated as exogenous, the output gap is determined as a residual rather than as a choice variable as in New Classical Macro.

The work on inflation determination as a game between policymakers and private expectations ignores the fact that the speed of price adjustment and the speed of expectation formation are two totally different issues. Price adjustment can be delayed by wage and price contracts, and by the time needed for cost increases to percolate through the input-output table, and yet everyone can form expectations promptly and rationally based on full information about the historical response of prices to its own lagged values, to demand shocks, and to supply shocks.

Since the original Phillips (1958) article was about wage changes, not price changes, it is noteworthy that the triangle model is a single reduced form equation for the inflation rate, with no mention of wage changes. The usual assumption that inflation is equal to nominal wage changes minus productivity growth assumes a fixed value of labor's share in national income. But labor's share rose sharply in the late 1960s and has drifted down since then. The goal of the central bank is to control inflation, not wage changes, so changes in labor's income share across business cycles imply a loose relation between inflation and wage changes that is fruitfully ignored. It appears in retrospect that large increases in wages in 1966-71, which undermined the attempt to defend previous econometric PC equations from the Friedman-Phelps neutrality proposition, reflected in substantial part the secular upswing in labor's share. An important contribution to the demise of the wage equation was made by Sims (1987), who argued that wage and price equations have no separate structural interpretations, and that a price equation is a wage equation stood on its head, and vice-versa.

3.3 Empirical Results: Strengths and Weaknesses

The current econometric version of the mainstream or triangle model was originally developed in the late 1970s and first published in Gordon (1982). It has been maintained essentially intact since then, with the same set of explanatory variables and lags, in order to allow post-sample simulations to identify forecasting errors that may call for rethinking the specification. The first challenge to the model arrived almost immediately in the form of the Volcker disinflation of 1979-86. As shown in Figure 1, the inflation rate collapsed from nearly 10 percent in 1981 to only 3 percent in 1983-84, much faster than had been forecast by commentators using an expectational PC with heavy emphasis on wage rigidity.

The "sacrifice ratio" is a convenient summary measure of the speed of inflation adjustment in response to high unemployment. This ratio is defined as the cumulative years of output gap during the disinflation divided by the permanent reduction of inflation expressed as an absolute value. Some *ex-ante* forecasts of the sacrifice ratio made in 1980-81 were as high as 10, but the actual sacrifice ratio in retrospect turned out to be between 3.5 and 4.5.[10] The key to the surprisingly low value of the output ratio turned out to be the role of supply shocks, and in particular the 1981-86 decline in the relative price of energy, and the 1980-85 appreciation of the dollar which reduced the relative price of imports. In a remarkable forecasting success achieved in the middle of the disinflation, Gordon-King (1982) estimated a six-equation VAR model that combined the triangle inflation equation with equations that allowed monetary policy to influence endogenous oil prices and the exchange rate, and their main result was a sacrifice ratio in the range of 3.0 to 3.5, much below the prevailing wisdom of the time.

The Gordon-King result is consistent with the Kydland-Prescott-Sargent interpretation reviewed in the next section that make no mention of supply shocks but rather emphasize the interplay between the credibility of the central bank and the expectations of the public. No doubt a major role in the speed of the disinflation, and the resulting relatively small sacrifice ratio, was the widespread perception that the Fed's monetary policy changed after 1979 and its anti-inflation stance became much more credible than before. The advantage of the Gordon-King method is that the channels of monetary policy are explicitly traced, not just through high unemployment but also through the effect of the monetary-fiscal policy mix in causing an appreciation of the dollar in 1980-85, with an accompanying decline in the relative price of imports and of oil.

Returning now to Figure 1, we see that the Volcker disinflation was followed in the late 1980s by a repeat of the negative inflation-unemployment tradeoff already experienced in the 1960s, albeit with a smaller acceleration of inflation and a higher level of unemployment. Similarly, the negative tradeoff is evident in the slowdown of inflation in 1990-93 in response to a marked increase in the unemployment rate during the same period.

At first glance, the behavior of the PC in the 1990s appears to be puzzling. Unemployment in the late 1990s fell to the lowest rate since the 1960s, but there was no parallel acceleration of inflation. Instead, inflation was lower in 2000 than in 1993. As shown by Gordon (1998) and Dew-Becker and Gordon (2005), low inflation in the late 1990s can be explained by beneficial supply shocks that pushed the PC down in contrast to the adverse supply shocks of the 1970s. As shown in Figure 1, the "twin peaks" of inflation and unemployment were followed by the "valley" of inflation and unemployment during 1997-2000.

Despite these research successes, the evolution of the data required one change in the 1982 specification of the triangle model. In 1994-95 post-sample simulations revealed that the model's predictions had started to drift in the direction of predicting

10. My current series for the output gap (log difference between actual and natural real GDP) over 1980-86 cumulates to a negative 28.2 percentage points, which in absolute value divided by a 6 percent permanent decline of inflation yields a sacrifice ratio of 4.7.

too high a level of inflation, given actual values of the unemployment gap. These errors turned out to be due not to a flaw in the model but to a data choice, that is, the false assumption that the natural rate of unemployment was fixed, allowed to change only in response to the demographic composition of the unemployment rate.[11]

For several decades the natural rate of unemployment had been called by its nickname, the "NAIRU," standing for "Non-Accelerating Inflation Rate of Unemployment," and in 1997 two papers appeared simultaneously that allowed the NAIRU to vary over time. This improvement in the specification of the mainstream model to incorporate a time-varying NAIRU (or TV-NAIRU) combined an econometric method introduced by Staiger, Stock, and Watson (1997) that was applied to a version of my mainstream model, and simultaneously I published a paper which used their method applied to my model (Gordon, 1997). The estimated TV-NAIRU exhibited a pronounced downward drift after 1990 that explained in a mechanical way why the inflation rate was lower in the 1990s than had previously been predicted with a fixed NAIRU. An initial set of explanations of the decline in the NAIRU was provided by Katz and Krueger (1999).

4. The Game between Policymakers and Private Expectations in a World of Policy-Dependent Expectations

We now turn to the alternative post-1975 research approach that emphasizes jumps in expectations in response to policy actions. As we have seen, this idea that expected inflation can jump in response to actual or anticipated policy changes is crucial to understanding the ends of hyperinflations (Sargent, 1982). It begins with the unarguable proposition, embedded in the Friedman-Phelps natural rate hypothesis, that the choice by a policymaker of a particular short-run combination of inflation and unemployment rates can alter expectations, causing the tradeoff to change.

4.1 The Policy Game

Kydland-Prescott (1977) distinguished between policy discretion and rules, where discretionary policymakers reassess the desired response to alternative inflation rates in each successive time period, in contrast to a rule which is fixed for all future time periods. They show, not surprisingly, that the long-run inflation rate is higher under a discretionary policy than a rules-based policy. How does this approach explain the positive correlation of inflation and unemployment in the 1970s without mention of supply shocks? Papers written by Sargent (1999), Cogley and Sargent (2005), and

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11. The pre-1994 estimate of the NAIRU incorporated changes in the difference between the official unemployment rate and the demographically-adjusted unemployment rate, originally introduced by Perry (1970).

Sargent *et al.* (2006), begin with the standard presumption that choices by discretionary policymakers will cause the PC to shift and policy options to change.[12] The attempt to conduct policy without knowledge of the current position of the Phillips curve can lead a policymaker to make choices that yield persistently high inflation outcomes.

"Credibility" is an important concept in the game involving policymakers and private agents setting inflation expectations. Because expectations can jump in response to changes in policymakers'actions and perceived intentions, the outcome of actual inflation will be higher if agents infer that the policymaker is trying to manipulate unemployment along the short-run PC tradeoff. A credible policy is one which promises to maintain a low inflation rate in the long run; agents are convinced that a policy is credible if the policymakers pursues an inflation target and regularly raises the interest rate when inflation exceeds its target but does not lower interest rates in response to an increase in unemployment. Doubts by agents that the policymaker is committed to low inflation in the long-run can raise the unemployment cost of reducing inflation.

One problem with this line of research is that ignores additional information available to policymakers – that oil or farm prices have risen, that the dollar has been devalued, that price controls have been imposed or ended, or that trend productivity growth has slowed. Indeed it is striking that Sargent *et al.* (2006) claim to be able to explain the entire upsurge of inflation in the 1970s and early 1980s without any mention of supply shocks, despite the fact that the word "shocks" appears in the title of their paper: ". . . allow the model to reverse engineer a sequence of government beliefs about the Phillips curve which, through the intermediation of the Phelps problem, capture both the acceleration of U. S. inflation in the 1970s and its rapid decline in the early 1980s."

An equally fundamental problem is that this approach ignores the policymaker's fundamental dilemma in the face of an adverse supply shock. As shown in Gordon (1975, 1984) and Phelps (1978), unless wages are perfectly flexible, the policymaker cannot escape a choice between holding inflation constant at the cost of substantial extra unemployment, or a holding constant at a cost of higher and accelerating inflation, or something in between.

Related work by Primiceri (2006) includes the government's underestimate of the natural unemployment rate in the 1970s as a cause of high inflation, but he does not provide any explicit analysis of supply shocks as the cause of this underestimate. Sims (2008) has suggested that Primiceri is guilty of an asymmetry, because he allows only for uncertainty about coefficient values in a model that policymakers assume is correct, instead of allowing for the fact that the model may be wrong. In fact, the discussion

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12. See also Cogley and Sargent (2005) and Sargent, Williams, and Zha (2006).

above of the mainstream model suggests that Primiceri and others working on policy-expectations interactions may indeed have chosen the wrong model, at least for the US, by assuming that expectations can jump in response to policy announcements and ignoring the role of backward-looking inertia and supply shocks.

4.2 The New-Keynesian Phillips Curve (NKPC)

The NKPC model has emerged in the past decade as the centerpiece of macro conference and journal discussions of inflation dynamics and as the "workhorse" of the evaluation of monetary policy. The point of the NKPC is to derive an empirical description of inflation dynamics that is "derived from first principles in an environment of dynamically optimizing agents" (Bårdsen *et al.* 2002).

The theoretical background is that monopolistically competitive firms have control over their own prices due to product differentiation. They are constrained by a friction in the setting of prices, of which there are many possible justifications that are inherited from the theoretical NK literature. For instance, we have already cited Taylor’s (1980) model which merges rational expectations with fixed-duration contracts. More frequently cited, as in Mankiw’s (2001) exposition, is Calvo's (1983) model of random price adjustment, in which prices are fixed for random periods. The firm's desired price depends on the overall price level and the unemployment gap. Firms change their price only infrequently, but when they do, they set their price equal to the average desired price until the next price adjustment. The actual price level, in turn, is equal to a weighted average of all prices that firms have set in the past. The first-order conditions for optimization then imply that expected future market conditions matter for today's pricing decision. The model can be solved to yield the standard NKPC specification that makes the inflation rate (p_t) depend on expected future inflation $(E_t p_{t+1})$ and the unemployment (or output) gap:

$$p_t = \alpha E_t p_{t+1} + \beta(U_t - U^*_t) + e_t, \qquad \mathbf{(8)}$$

where U is the unemployment rate. The constant term is suppressed, and so the NKPC has the interpretation that if α=1, then U^*_t represents the NAIRU.

Notice that the NKPC in equation (8) is identical to the post-1975 PC written in (7) above, with two differences. First, there is no explicit treatment of supply shocks; these are suppressed into the error term. Second, expectations are explicitly forward-looking in equation (8), whereas in (7) expectations could be either forward-looking or backward-looking, or both. Because of frictions of the Taylor or Calvo type, policy changes that raise or lower the inflation rate have short-run effects on the unemployment or output gap. The Taylor NK framework assumes fixed contract lengths of pricing intervals, while the Calvo model makes price changes dependent on a fixed gap between the actual and desired price levels. But Sims (2008) points out that this "theory has simply moved the non-neutrality from agent behavior itself into the constraints the agent faces, the frictions." In real-world situations in which macro shocks create Argentina-like instability, contract lengths would surely change in response to the expected inflation rate.

NKPC models vary in their inclusion of the single variable that supplements future expected inflation. Sometimes this is modeled as the unemployment gap, as in (8), and sometimes as the closely related output gap. Most NKPC papers focus on the output gap, but the high negative correlation between the output and unemployment gaps allows them to be used interchangeably. Mankiw's (2001) exposition followed here uses the unemployment gap. Another version of the NKPC replaces either gap with the change in marginal cost, that is, the real wage divided by productivity. Some papers in the NKPC literature treat changes in marginal cost as exogenous, which is unacceptable as the change in marginal cost, e.g., the real wage divided by productivity, is inherently endogenous and requires separate equations for wage change, productivity change, and price change. Thus far empirical implementation of the marginal cost version of the NKPC has not undertaken this complex task; in contrast Dew-Becker and Gordon (2005) have examined joint feedback between prices and wages in the context of examining changes in labor's share in national income.

4.3 The Challenge of Persistence

As we shall see below in comparing empirical results for the triangle and NKPC models, inflation persistence in the form of very long lags on past inflation rates is a central feature of postwar US inflation behavior. As a result, in the US environment expectations are unlikely to jump except in response to widely recognized supply shocks, such as the surge of oil prices in 2007-08. The recognition that, in the absence of supply shocks, the inflation rate is dominated by persistence creates a challenge for policymakers to reduce inflation by altering public expectations *directly*, as contrasted with the indirect adjustment of expectations that will occur slowly in response to lower actual inflation caused by high unemployment. How can policymakers convince the public that inflation will spontaneously decrease, without any cost of higher unemployment or lost output, when the public knows that inflation behavior is dominated by persistence?

As we show in section 5.1 below, in practice the NKPC is simply a regression of the inflation rate on a few lags of inflation and the unemployment gap. As pointed out by Fuhrer (1997), the only sense in which models including future expectations differ from purely backward-looking models is that they place restrictions on the coefficients of the backward-looking variables that are used as proxies for the unobservable future expectations. We illustrate the form of these restrictions below. In Fuhrer's words:

"Of course, some restrictions are necessary in order to separately identify

> the effects of expected future variables. If the model is specified with unconstrained leads and lags, it will be difficult for the data to distinguish between the leads, which solve out as restricted combinations of lag variables, and unrestricted lags." (p. 338)

Galí and Gertler (1999), two of the inventors of the NKPC approach, have introduced a "hybrid" NKPC model in which the public consists both of forward-looking and backward-looking agents, and in their empirical version current inflation depends on both expected future inflation and past inflation. However, since future inflation is always proxied by some transformation of past inflation, there is little difference in practice between the "pure" forward-looking NKPC and the hybrid version, except for the form of the restrictions that emerge. Further, if there are enough backward-looking members of the population, then forward-looking members cannot ignore the persistence introduced by backward-looking agents. This dependence of future contract outcomes on the inheritance of ongoing contracts with staggered expiration dates has been explicit in the theoretical NK literature since its introduction by Taylor (1980).

4.4 Constraints on the Formation of Expectations

Recent research has revived the discussion of barriers to the formation of expectations. As we have seen, the original formulations of Friedman, Phelps, and Lucas were based on information barriers that prevented one set of agents (Friedman's workers) or all agents (Phelps' desert island residents) from having access to government data on income, output, money, and prices that are released frequently at zero cost to all agents in the economy. This entire literature was flawed because it placed the information barriers in the wrong place, in an inability to perceive costless macro information instead of where the information barriers really exist, at the micro level of costs and supplier-producer relationships.

Producers of final goods are unable to perceive cost increases of crude and intermediate materials that may be in the pipeline, and they have no choice but to wait until they receive notification of actual cost changes. This approach based on supplier-producer arrangements was introduced in Blanchard (1987) and was christened the "input-output" approach in Gordon (1990), who identifies a four-cell matrix of information barriers of supply and demand shocks at both the macro and micro level. A fundamental source of persistence is not just explicit wage contracts as analyzed by Taylor, but also explicit or implicit price contracts between suppliers and producers of final goods. Even without contracts, persistence and inertia are introduced by lags between price changes of crude materials, intermediate goods, and final goods, in a complex network involving for some final goods, e.g., cars or aircraft, literally thousands of separate parts.

The recent literature has by and large ignored the *micro* uncertainty embodied in the input-output approach and instead has attempted to find credible explanations for imperfect *macro* information. One approach is that agents take time to learn about the structure of the economy (see Orphanides and Williams, 2007). This information barrier is consistent with the triangle approach, in which changes in the TV-NAIRU are not observed in real time but only after the fact, as are changes in coefficients on the PC slope or the coefficients on such supply shocks as oil prices.

A second barrier may be imperfect information regarding the goals of the central bank (see, among others, Kiley, 2008). Clearly in the US context the Fed has changed goals several times, and this became evident only after the fact. The Volcker policy shift in 1979-80 was widely noticed at the time, but there was no historical antecedent to allow predictions of its consequences. Likewise, studies of the Taylor Rule indicate that the Fed shifted around 1990 from a policy that mainly responded to inflation to a policy that mainly responded to the output gap, and no empirical Taylor rule can explain why the Federal Funds rate was so low in 2001-04.

The third barrier consists of costs or constraints on information acquisition and processing. One version of this approach emphasizes costs of obtaining information that lead to infrequent adjustments in expectations (Reis, 2006). Another approach (see Sims, 2006) is called "rational inattention" and also emphasizes constraints on information processing capabilities. However, all of these barriers concern constraints on the ability of private agents to adjust their expectations accurately to reflect the current stance of monetary policy and anticipated future changes in policy, and none reflect any of the sources of persistence and inertia, particularly lack of information at the micro level of the input-output table, that we have emphasized throughout parts 3 and 4 of this paper. Rational inattention makes sense at the micro level, when translated into the minimization of managerial cost by avoiding daily deliberations about price changes required by changes in supplier costs and instead making decisions infrequently.

4.5 Which Model Applies to Which Episodes?

This survey has contrasted the inertia-bound triangle approach to explaining US inflation with alternative frameworks in which the expectations of private agents can jump in response to perceived changes in monetary policy. Which model best describes which historical situations? As indicated above, the mutual interplay between policy decisions and expectations formation is essential to understanding episodes of rapid inflation, including Sargent's (1982) ends of four big inflations. This approach is in fact essential to an understanding of the inflation process in any nation which has experienced high inflation volatility in the past due to shifts in policy (as contrasted with the influence of supply shocks). A prime example would be a country like Argentina in which private agents know that the government's ability to restrain monetary growth depends on fiscal decisions made at the level of states and localities.

Relatively little research has been done to establish a dividing line between situations suitable for analysis with the policy-expectations game approach vs. the inertia-bound triangle approach. The convergence of inflation rates within the European Monetary Union between 1980 and 1998 provides another example in which an inertia-dominated PC is inadequate, as countries with similar unemployment rates experienced very different time paths of inflation. After experiencing inflation rates of over 20 to 25 percent in the mid 1970s, Italy and the UK converged to low single digits of inflation, and this could only have happened if private agents incorporated expectations of policy both within those countries and the fact that Europe-wide monetary policy was dominated by the low-inflation stance of the Bundesbank.

Another issue in extending the PC framework to fit the postwar European experience is the question of whether the standard PC relation between the inflation rate and the level of unemployment needs to be supplemented by a hysteresis mechanism between the inflation rate and the change of unemployment. Recently Ball (2008) has suggested that the hysteresis idea, after languishing since its invention by Blanchard and Summers (1986), should be revived. Some versions of hysteresis imply that inflation depends not on the level of unemployment but on its rate of change, that ancient idea supported in the results of both Fisher (1926) and Phillips (1958) and incorporated in the triangle model specification.

The empirical results presented in part 5 below suggest that the triangle model, which combines demand and supply shocks with inertia, does a much better job in explaining postwar US inflation than simpler NKPC variants that omit lags and supply shocks. However, how far back can the triangle-type PC specification be pushed in US data? Samuelson and Solow (1960) had already noticed that the American PC relationship does not work in the Great Depression and during the two World Wars. A quantitative answer to this question was provided by Gordon (1982) in a unique set of interpolated quarterly data extending back to 1892. His results (Table 3) estimate PC equations for 1892-1929, 1929-53, and 1954-80, in a framework which allows the inflation rate to depend not just on the level of the output gap, but on changes in expected and unexpected nominal GDP, lagged inflation, and a series of dummy variables.

Gordon's results suggest that prior to 1954 there were substantial shifts in the American PC process that are consistent with a role for an interplay between the expectations of private agents and perceived changes in policy and the macroeconomic environment more generally. The PC relation, in the form of the coefficient on the output gap, has roughly the same coefficient before 1929 as after 1954 but is zero during the middle period. In all three periods the anticipated and unanticipated change in nominal GDP is highly significant, and this "rate of change effect" dominates the explanation of inflation in the middle period when the PC relationship is absent (see also Romer 1999 for an analysis of price changes in the 1930s). Particularly interesting, and consistent with Sargent's (1971) distinction between the coefficient of inflation on expected inflation, and the coefficient of expected inflation on lagged inflation, is that the coefficient on lagged inflation increased in each of the three periods, from 0.4 in the first, to 0.6 in the second, to 1.0 in the third.

The role of policy in shifting the inflation rate (whether this is perceived as working through expectations or not) is evident in very large positive dummy variables for World Wars I and II, the Korean War, and the New Deal's NRA, in addition to the Nixon control dummy that appears in postwar versions of the triangle model reviewed in section 5 below.[13]

5. The New-Keynesian and Triangle Specifications of the Phillips Curve: Specification and Results

What difference does it make if we explain US inflation using the mainstream triangle model or the NKPC? We now turn to the detailed specification of the NKPC and triangle alternatives. Then we examine their performance in US data spanning 1962-2007.

5.1 The NKPC Model

A central challenge to the NKPC approach is to find a proxy for the forward-looking expectations term in equation (8) above $(E_t p_{t+1})$. Surprisingly, there is little discussion in the literature of this aspect, or the implications of the usual solution, which is to use instrumental variables or two-stage least squares (2SLS) to estimate (8). In particular, no paper in the NKPC that I have reviewed contains an explicit treatment of the two stages of the 2SLS estimation and an interpretation of the reduced-form equation that results when the first stage is substituted into the second stage. The first-stage equation to be included in the 2SLS estimation is:

$$E_t p_{t+1} = \sum_{i=1}^{4} \lambda_i p_{t-i} + \phi(U_t - U^*_t). \quad \textbf{(9)}$$

Substituting the first-stage equation (9) into the second-stage equation (8), we obtain the reduced-form

$$p_t = \alpha \sum_{i=1}^{4} \lambda_i p_{t-i} + (\alpha\phi + \beta)(U_t - U^*_t) + e_t \quad \textbf{(10)}$$

13. Both the NRA and Nixon dummies are entered in the form of "on effects" summing to 1.0 followed by "off" effects summing to -1.0, implying no permanent impact. For more on the Nixon control effects, see section 5.4 and Table 1 below.

Thus in practice the NKPC is simply a regression of the inflation rate on a few lags of inflation and the unemployment gap. We have already cited Fuhrer (1997) as pointing out that the only sense in which models including future expectations differ from purely backward-looking models is that they place restrictions on the coefficients of the backward-looking variables.

The Roberts (2006) version of the NKPC is of particular interest here, because of his finding that the slope of the PC has declined by more than half since the mid 1980s. Roberts describes his equation as a "reduced form" NKPC and indeed it is identical to equation (10) above with two differences, the NAIRU is assumed to be constant, and the sum of coefficients on lagged inflation is assumed to be unity. Thus the Roberts (2006, equation 2, p. 199) version of (10) is:

$$p_t = \sum_{i=1}^{4} \lambda_i p_{t-i} + \gamma + \beta U_t + e_t \qquad \textbf{(11)}$$

where the implied constant NAIRU is $-\gamma/\beta$.

5.2 The Triangle Model of Inflation and the Role of Demand and Supply Shocks

The inflation equation used in this paper is almost identical to that developed 25 years ago (Gordon, 1982). It builds on earlier work (Gordon, 1975, 1977) that, as reviewed above in section 3.1, combined the Friedman-Phelps natural rate hypothesis with the role of supply shocks in directly shifting the inflation rate and creating macroeconomic externalities in a world of nominal wage rigidity. The term "triangle" model refers to a Phillips Curve that depends on three elements, inertia, demand, and supply, and in which wages are implicitly solved out of the reduced form. This general framework can be written as:

$$p_t = a(L)p_{t-1} + b(L)D_t + c(L)z_t + e_t . \qquad \textbf{(12)}$$

As before lower-case letters designate first differences of logarithms, upper-case letters designate logarithms of levels, and *L* is a polynomial in the lag operator.

As in the NKPC and Roberts approaches, the dependent variable p_t is the inflation rate. Inertia is conveyed by a series of lags on the inflation rate (p_{t-1}). D_t is an index of excess demand (normalized so that $D_t=0$ indicates the absence of excess demand), z_t is a vector of supply shock variables (normalized so that $z_t=0$ indicates an absence of supply shocks), and e_t is a serially uncorrelated error term. Distinguishing features in the implementation of this model include unusually long lags on the dependent variable, and a set of supply shock variables that are uniformly defined so that a zero value indicates no upward or downward pressure on inflation.

The estimated version of equation (12) includes lags of past inflation rates, reflecting the influence of several past years of inflation behavior on current price setting, through some combination of expectation formation, overlapping wage and price contracts, and buyer-supplier relations. If the sum of the coefficients on the lagged inflation values equals unity, then there is a "natural rate" of the demand variable (D^N_t) consistent with a constant rate of inflation.[14] The basic equations estimated in this paper use current and lagged values of the unemployment gap as a proxy for the excess demand parameter D_t, where the unemployment gap is defined as the difference between the actual rate of unemployment and the natural rate, and the natural rate (or NAIRU) is allowed to vary over time.

The estimation of the time-varying NAIRU combines the above inflation equation, where the unemployment gap serves as the proxy for excess demand, with a second equation that explicitly allows the NAIRU to vary with time:

$$p_t = a(L)p_{t-1} + b(L)(U_t - U^N_t) + c(L)z_t + e_t, \qquad \textbf{(13)}$$

$$U^N_t = U^N_{t-1} + \eta_t,\ E\eta_t = 0,\ var(\eta_t) = \tau^2 \qquad \textbf{(14)}$$

In this formulation, the disturbance term η_t in the second equation is serially uncorrelated and is uncorrelated with e_t. When this standard deviation $\tau_\eta = 0$, then the natural rate is constant, and when τ_η is positive, the model allows the NAIRU to vary by a limited amount each quarter. If no limit were placed on the ability of the NAIRU to vary each time period, then the time-varying NAIRU (hereafter TV-NAIRU) would jump up and down and soak up all the residual variation in the inflation equation (13).[15]

The triangle approach differs from the NKPC and Roberts approaches by including long lags on the dependent variable, additional lags on the unemployment gap, and explicit variables to represent the supply shocks (the z_t variables in (11) and (12) above), namely the change in the relative price of non-food non-oil imports, the effect on inflation of changes in the relative price of food and energy, the acceleration in the trend rate of productivity growth, and dummy variables for the effect of the 1971-74 Nixon-era price controls.[16] Lag lengths were originally specified in Gordon (1982) and

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14. While the estimated sum of the coefficients on lagged inflation is usually roughly equal to unity, that sum must be constrained to be *exactly* unity for a meaningful "natural rate" of the demand variable to be calculated.
15. This method of estimating the TV-NAIRU was introduced in simultaneous papers by Gordon (1997) and Staiger-Stock-Watson (1997). SSW developed the technique while adopting Gordon's previous triangle model, and so those two papers were a merger of technique and substance.

16. The relative import price variable is defined as the rate of change of the non-food non-oil

have not been changed since then.

5.3 Estimating the TV-NAIRU

The time-varying NAIRU is estimated simultaneously with the inflation equation (13) above. For each set of dependent variables and explanatory variables, there is a different TV-NAIRU. For instance, when supply-shock variables are omitted, the TV-NAIRU soars to 8 percent and above in the mid-1970s, since this is the only way the inflation equation can "explain" why inflation was so high in the 1970s. However, when the full set of supply shocks is included in the inflation equation, the TV-NAIRU is quite stable, shown by the dashed line plotted in Figure 3, remaining within the range of 5.7 and 6.5 percent over the period between 1962 and 1988.

However, beginning in the late 1980s, the TV-NAIRU drifts downwards until it reaches 5.3 percent in 1998, and then it displays a further dip in 2004-06 to 4.8 percent. One hypothesis to be explored below is that the Roberts NKPC implementation reaches the conclusion that the Phillips curve has flattened because the NAIRU is forced to be constant, and that a decline in the TV-NAIRU is an alternative to a flatter PC in explaining why inflation has been relatively well-behaved in the past 20 years.[17]

Some of the NKPC literature estimates the TV-NAIRU by directly applying an H-P filter to the time series of the unemployment rate.[18] As shown in Figure 3 using the traditional H-P parameter of 1600, this "direct" approach to estimating the TV-NAIRU results in an unexplained increase in the TV-NAIRU from 3.9 percent in 1968 to 8.3 percent in 1985, whereas the triangle approach has no such unexplained increase because of its introduction of explicit supply shock variables.[19] In contrast the Roberts implementation of the NKPC forces the NAIRU to be constant at an estimated 7.0

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import deflator minus the rate of change of the dependent variable, e.g., PCE deflator. The relative food-energy variable is defined as the difference between the rates of change of the overall PCE deflator and the "core" PCE deflator. The Nixon control variables remain the same as originally specified in Gordon (1982). Lag lengths remain as in 1982 and are shown explicitly in Table 2. The productivity trend is a Hodrick-Prescott filter (using 6400 as the smoothness parameter) minus a six-year moving average of the same H-P trend. The only changes from the previous published paper on this approach (Gordon, 1998) is in the treatment of the productivity effect, see Dew-Becker and Gordon (2005).

17. As indicated above, Katz and Krueger (1999) suggest a set of explanations for the decline in the TV-NAIRU during the 1990s.

18. After developing the technique described above for estimating the TV-NAIRU, the recent work of Stock and Watson has abandoned that approach in favor of using a direct Hodrick-Prescott filter to estimate the NAIRU in equations which omit explicit supply shock variables. See Staiger-Stock-Watson (2001) and Stock-Watson (2006).

19. Basistha-Nelson (2007) are among those authors who exclude explicit supply shock variables from their equations and derive estimates of the TV-NAIRU that are extremely high, e.g., 8 percent in 1975 and 10 percent in 1981 (2007, p. 509, Figure 6).

percent.

How much difference do the explicit supply shock variables make in the predictions of the triangle specification? Figure 4 displays predictions made with the actual supply shock variables and with the supply shock variables zeroed out (but with the other variables, including the unemployment gap, taking their historical values and estimated coefficients. Evidently the supply shock variables explain *all* of the twin peaks of inflation in the 1973-81 period, and in addition they explain more than half of the Volcker disinflation (with supply shocks predicted inflation drops by 7 percentage points between 1980:Q1 and 1985:Q1, but by only 3 percentage points without supply shocks). Notice also that without (beneficial) supply shocks, the influence of low unemployment would have caused inflation to rise by 1.3 percentage points between 1994 and 2001, whereas with supply shocks inflation is predicted to be roughly constant.

5.4 Roberts NKPC vs. Triangle: Coefficients and Simulation Performance

We next turn to the estimated coefficients, goodness of fit, and simulation performance of the Roberts NKPC and triangle PC specifications. Table 1 displays the estimated sums of coefficients and their significance levels for both the Roberts NKPC and triangle specifications for equations in which the dependent variable is the quarterly change in the PCE deflator. In both specifications the sum of coefficients on the lagged inflation terms is very close to unity, as in previous research.[20] The sum of the unemployment gap variables in the triangle approach is around -0.6 for the PCE deflator, which is consistent with a stylized fact first noticed by Samuelson and Solow (1960) that the slope of the short-run Phillips curve is roughly minus one-half. An elementary textbook on specification bias would explain why the Roberts NKPC unemployment coefficient is lower than in the triangle specification. The excluded supply shock variables are positively correlated with inflation and negatively correlated with the unemployment gap, and so the omission of these supply shock variables causes the coefficient on the unemployment gap to be biased downward toward zero. We note that the sum of squared residuals (SSR) for the triangle model is barely one-quarter that of the Roberts NKPC specification.

The explicit supply shock variables in the triangle model, missing from the Roberts NKPC specification (and indeed from *every* empirical NKPC research study), are all highly significant and have the correct signs; except for the productivity trend variable, all of these enter exactly as specified in 1982, and with the same lags, and thus their significance has not been diminished by an extra 25 years of data. The change in

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20. The inclusion of lags 13-24 (years four through six) is strongly significant in an exclusion test at the 0.0000 confidence level. As stated in the notes to Table 1, we conserve on degrees of freedom by including six successive four-quarter moving averages of the lagged dependent variable at lags 1, 5, 9, 13, 17, and 21, rather than including all 24 lags separately.

the relative import price effect has a highly significant coefficient of 0.06.[21] The food-energy effect has a coefficient of 0.89, close to the expected value of 1.0. The productivity trend variable has the expected negative coefficient and helps to explain why inflation accelerated in 1965-80 and was so well-behaved in 1995-2000. The Nixon control coefficients as in previous research indicate a significant impact of the controls in holding down inflation by a cumulative -1.6 percent in 1971-72 and boosting inflation by 1.8 percent in 1974-75.

Rather than relying on the usual statistical measures of goodness of fit, a dynamic model heavily dependent on the contribution of the lagged dependent variable is best tested by the technique of dynamic simulations. These generate the predictions of the equation with the lagged dependent variable generated endogenously rather than taking the actual values of lagged inflation. To run such simulations, the sample period is truncated ten years before the end of the data interval, and the estimated coefficients through 1997:Q4 are used to simulate the performance of the equation for 1998-2007, generating the lagged dependent variables endogenously. Since the simulation has no information on the actual value of the inflation rate, there is nothing to keep the simulated inflation rate from drifting far away from the actual rate in a positive or negative direction.[22]

The bottom section of Table 1 displays results of a dynamic simulation for 1998:Q1 to 2007:Q4 based on a sample period that ends in 1997:Q4. Two statistics on simulation errors are provided, the mean error (ME) and the root mean-squared error (RMSE). The simulated values of inflation in the triangle model are extremely close to the actual values, with a mean error over 40 quarters of only 0.29, meaning that over the forty quarters the actual inflation rate on average is 0.29 percentage points higher than the predicted value. However, the mean error for the Roberts NKPC model is a huge -2.75, and as displayed in Figure 5, this error reflects that model's wild overprediction that the inflation rate should have reached nearly 8 percent by late 2007. The RMSE of the triangle simulation is a bit above the SEE for the 1962-1997 sample period, whereas for the Roberts NKPC model the RMSE is almost three times as large.

The Roberts NKPC and triangle results agree on only one aspect of the inflation process, that the sum of coefficients on the lagged inflation terms is always very close to unity. However, the Roberts coefficients on the unemployment rate are much lower than the triangle coefficients on the unemployment gap. This is an artifact of the exclusion restrictions in the Roberts approach which are statistically rejected in the triangle approach.

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21. This can be compared to an import share in nominal GDP of 10 percent at the midpoint of the sample period in 1985.

22. I have been running dynamic simulations of Phillips curves for at least 25 years and cannot understand why this has not become a standard testing technique in models where there is a strong dependence of results on the lagged dependent variable.

The triangle model outperforms the Roberts/NKPC model by several orders of magnitude, as displayed in Table 1 and Figure 5. This raises a question central to future research on the US Phillips curve: what are the crucial differences that contribute to the superior performance of the triangle model? The three key differences are the inclusion in the triangle model of longer lags on both inflation and the unemployment gap, the inclusion of explicit supply-shock variables, and the allowance for a time-varying (TV) NAIRU in place of the Roberts NKPC assumption of a fixed NAIRU. In the Appendix we quantify the role of these differences, taking advantage of the fact that the Roberts NKPC model is fully nested in a version of the triangle model that assumes a constant NAIRU. Each exclusion restriction in the Roberts model can be tested by standard statistical exclusion criteria, and every one of the Roberts NKPC exclusion criteria is rejected at high levels of statistical significance.[23]

5.5 The Fragility of the Conclusion that the PC Slope has Become Flatter

The NKPC research of Roberts and others at the Federal Reserve has been influential in spreading the belief that the Phillips Curve has become flatter over the past two or more decades. Yet we have seen that every aspect of the Roberts NKPC specification (and more broadly other similar parsimonious NKPC estimates) are rejected at high levels of statistical significance.

Has the Phillips Curve flattened? The Roberts NKPC specification says "yes" and the triangle specification says "no". Figure 6 evaluates changes in coefficients by Roberts' own preferred method (2006, Figure 2, p. 202), rolling regressions that shift the sample period of the regression through time in order to reveal changes in coefficients. The number of quarters in our basic results in Table 1 is 184 (1962:Q1 to 2007:Q4), and we cut this roughly in half to 90 quarters and run rolling 90-quarter regressions which alternatively start in each quarter from 1962:Q1 to 1985:Q3.

As shown in Figure 6, the Roberts NKPC unemployment coefficient rises from -0.17 in 1962 to a peak value of -0.41 in 1974, and then declines back to roughly zero in 1982-84. This appears to support the basic conclusion that the Phillips Curve has flattened. Yet with the triangle model that fits the data so much better and provides a greatly superior post-sample dynamic simulation performance, there is no evidence at all of a decline in the slope of the Phillips curve. The Phillips curve based on the triangle model has a roughly stable PC slope of about -0.6 to -0.7 from 1963 to 1977, and then the slope *rises* toward about -0.7 to about -0.9 in the simulations starting in 1982, then drifts back to -0.7 in the final year. As indicated above, the NKPC slope estimate is biased toward zero by differing amounts in each period, due to the omission of supply shocks,

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23. Dew-Becker (2006) has previously traced the statistical significance of stripped-down Phillips Curves and reached conclusions that are similar to those arrayed in Appendix Table A-1.

the influence of which is different in each period.

6. Conclusion

This history of the Phillips Curve has, from start to end, taken the American perspective. This is appropriate, since the authors who have made the most impact on the PC literature have been American, and also because the empirical testing of the PC has experienced its greatest successes and failures on American data.

The paper makes several unique contributions. It contrasts the pre-1975 history of the PC with that since 1975. The evolution of PC doctrine before 1975 is widely accepted and no longer elicits much debate. The discovery by Phillips and his disciples Samuelson-Solow of an inverse relationship between inflation and unemployment set forth suggestions of an exploitable policy tradeoff that was destroyed by the Friedman-Phelps natural rate hypothesis of the late 1960s. Exploitable tradeoffs were out, and long-run neutrality was in (it had never disappeared in many environments, including Latin America and the University of Chicago). The econometric models developed in the 1960s to support the policy tradeoff were rejected both empirically and logically by Sargent's trenchant argument that this econometric literature was subject to an identification problem – it could not distinguish the response of inflation to expected inflation from the response of expected inflation to lagged inflation.

Debates in the early 1970s centered mainly about the models in which Friedman and Phelps had embedded the natural rate hypothesis, and particularly the assumption of arbitrary barriers that prevented individual workers or agents in general from learning the values of macro data – output, money, and prices – provided costlessly by the government. There was also controversy about the implications of the further development of the Friedman-Phelps paradigm by Lucas, who introduced rational expectations into macroeconomics. The Lucas model implied the policy-ineffectiveness proposition, which held that anticipated changes in money had no effect on output and were entirely reflected in price changes. Empirical work rejected this framework, showing that monetary surprises had little effect on output, were incapable of explaining the serial correlation of output, and were inconsistent with persistence of inflation.

After 1975 the PC literature split apart into two lines of research which since then have communicated little with each other. Several years before the declaration by Lucas and Sargent that Keynesian economics in the form of the PC tradeoff lay in a state of "wreckage," the PC was revived by importing micro demand and supply analysis into macroeconomics. There was no assumption that output and inflation would be positively correlated. Demand shocks would create an initial and temporary positive correlation, and supply shocks would create an initial negative correlation that then evolved according to the policy response. As early as 1975 the theoretical literature on policy responses to supply shocks was developed and showed that adverse supply shocks forced policymakers to choose between higher inflation, lower output, or a combination. Soon a formal dynamic aggregate supply and demand model was developed and almost immediately appeared in macro textbooks, and by the early 1980s an econometric specification of this AD-AS framework was available that joined demand and supply shocks with long-run neutrality and a strong role for persistence and inertia.

An important difference between the mainstream approach and other post-1975 developments is that the role of past inflation is not limited to the formation of expectations, but also includes the pure persistence due to fixed-duration wage and price contracts, and lags between changes in crude materials and final product prices. Inflation is dislodged from its past inertial values by demand shocks proxied by the unemployment or output gap, and explicit supply shock variables including changes in the relative prices of food, energy, imports, and the role of changes in trend growth of productivity. The econometric implementation of this approach is sometimes called the "triangle" model, reflecting its three-cornered dependence on demand, supply, and inertia.

After 1975 there was a separate line of research which paid no attention to, nor rarely cited, the dynamic aggregate demand and supply framework. The other fork in the road is represented by models in which expectations are not anchored in backward-looking behavior but can jump in response to current and anticipated changes in policy. Reviewed in Part 4, important elements in this second literature include policy credibility, models of the game played by policymakers and private agents forming expectations, and the New Keynesian Phillips Curve (NKPC) which derives a forward-looking PC from alternative theories of price stickiness. The common feature of these theories is the absence of inertia, the exclusion of any explicit supply shock variables, the ability of expected inflation to jump in response to new information, and alternative barriers to accurate expectation formation due to such frictions as "rational inattention."

Which post-1975 approach is right? Which is best? The answer is surprisingly simple. Models in which expectations can jump in response to policy are essential to understanding Sargent's (1982) ends of four big inflations and other relatively rapid inflations in nations with a history of monetary instability, e.g., Argentina. But the mainstream/triangle approach is unambiguously the right econometric framework to understand the evolution of postwar US inflation. Part 5 develops and tests the triangle econometric specification alongside one recently published version of the NKPC approach. The latter can be shown to be nested in the former model and to differ by excluding particular variables and lags, and these differences are all rejected by tests of exclusion restrictions. The triangle model outperforms the NKPC variant by orders of magnitude, not only in standard goodness of fit statistics, but also in post-sample dynamic simulations.

Thus there are three main interrelated themes in this paper that have not previously received much if any attention. First, two quite legitimate responses occurred after 1975 to the chaotic state of the PC at that time. Second, each response is important and helps us understand how inflation behaves, albeit in different environments. Third, the two approaches need to pay more attention to each other, and this paper represents a start toward that reconciliation.

Appendix: The "Translation Matrix" between the Roberts/NKPC and Triangle Specifications

Which differences matter in explaining the poor performance of the Roberts NKPC specification in Table 1 and Figure 5? In this appendix we start with the Roberts NKPC specification and gradually change, step by step, to the triangle specification, allowing alternatively the NAIRU to be constant and to vary over time. In everything that follows, the sample period is 1962:Q1 to 2007:Q4.

Appendix Table A1 provides the "translation matrix" that guides us between the Roberts NKPC specification and the triangle specification.[i] There are 24 lines that allow us to trace the role of each specification difference, and the individual lines of alternative specification are evaluated based not just on the SSR measure of goodness of fit, but also on the post-sample simulation performance in 1997-2006 based on coefficient estimates for 1962-1996.

We have already seen in Table 1 that the performance of the Roberts NKPC specification for the PCE deflator is inferior to that of the triangle specification by both the criterion of goodness of fit (SSR) and also the less conventional criterion of dynamic simulation performance (ME and RMSE). In Table A1 the basic Roberts variant is on line 1 and the basic triangle variant is on line 21. Roberts' line 1 and the triangle line 21 have SSR's of 244.0 and 64.6, exactly the same as in Table 1 above.

Table A1 allows the three main differences between the Roberts/NKPC and triangle specifications to be evaluated, step-by-step. Is the crucial difference contributing to the better statistical performance of the triangle model dependent on the longer lags, on the supply shocks, on the TV-NAIRU, or an interaction of these differences?

In the 24 lines of Table A1, the first 12 lines exclude supply shock variables, and lines 13-24 include the supply shock variables. Scanning down the column for "SSR", we find that the variants on lines 13-24 including supply shocks all have SSR's below 100, while most of the SSR's that exclude supply shocks have values above 200. Thus our first conclusion is that the exclusion of explicit supply shocks in the Roberts NKPC research is the central reason for its empirical failure either to explain postwar inflation or to track the evolution of inflation in post-sample 1997-2006 simulations.

What difference is made by long lags and by the TV-NAIRU? When supply shocks are omitted as in lines 1-12 of Table 3, there is little difference among the alternative variants which yield SSR's ranging from 183.8 to 244.0. Simulation mean errors (ME) range from -2.04 to -2.75 when the NAIRU is fixed. Much lower ME's are obtained when the NAIRU is allowed to vary over time.

The set of results that include supply shocks are displayed on lines 13 to 24 in Table A1. When supply shocks are included but lag lengths are short, as in lines 13-14, 17-19, and 22, the post-sample simulation errors are very large. When supply shocks are included, the best results are on lines 15-16 with a fixed NAIRU and on lines 20-21 with a TV-NAIRU. Long lags on the dependent variable (inflation) matter in the specification of a PC including supply shocks.

The right section of Table A1 contains a large number of significance tests on the exclusion of variables which are omitted in the Roberts NKPC specification and included in the triangle specification. Starting on line 3, even without supply shock variables, the significance value of excluding lags 9-24 on the lagged dependent variable is 0.01 and on lags 1-4 of the unemployment gap is 0.03. Throughout lines 1-12 of Table 3, we learn that excluding short lags (e.g., excluding lags 5-8 from equations containing inflation lags 1-4) is insignificant, whereas excluding lags 9-24 yields highly significant exclusion tests.

Lines 13-24, which all include the full set of supply shock variables, differ only in the length of lags included on the lagged dependent (inflation) variable and on lagged unemployment, and also on whether the NAIRU is forced to be fixed or is allowed to vary over time. We can interpret the bottom half of Table A1 by looking at blocks of four rows.

The first group of four rows, 13 through 16, share in common the inclusion of supply shocks, the assumption of a fixed NAIRU, and alternative lags on the dependent variable. The mean error in the dynamic simulations falls by 80 percent when lags up to 24 are included, and the exclusion of lags 9-24 is rejected at a 0.00 significance value. The same result occurs in lines 22-25 when with a time-varying NAIRU the significance of long lags on the dependent variable are strongly supported at significance levels of 0.00.

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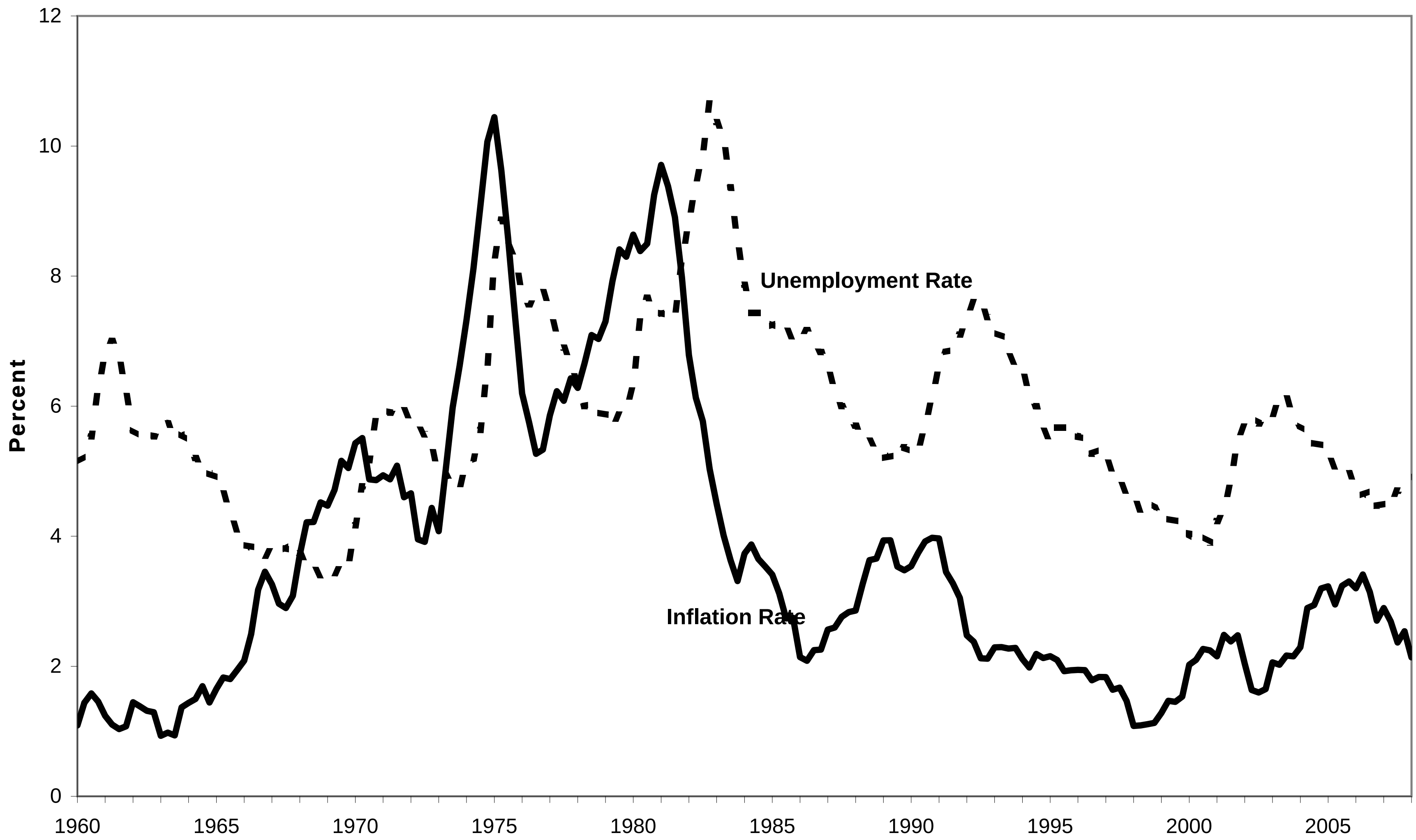
TABLE 1
Estimated Equations for Quarterly Changes in the PCE Deflator, 1962:Q1 to 2007:Q4

Variable	Lags	Roberts NKPC	Triangle
Constant		1.16 **	
Lagged Dependent Variable	1-24[a]		1.01 **
	1-4	0.95 **	
Unemployment Gap	0-4		-0.56 **
Unemployment Rate	0	-0.17 *	
Relative Price of Imports	1-4		0.06 **
Food-Energy Effect	0-4		0.89 **
Productivity Trend Change	1 5		-0.95 **
Nixon Controls "on"	0		-1.56 **
Nixon Controls "off"	0		1.78 **
R2		0.78	0.93
S.E.E		1.17	0.64
S.S.R		244.0	64.6
Dynamic Simulation 1998:Q1 - 2007:Q4	Note b		
Mean Error		-2.75	0.29
Root Mean-Square Error		3.20	0.70

a) Lagged dependent variable is entered as the four-quarter moving average for lags 1, 5, 9, 13, 17, and 21, respectively

b) Dynamic simulations are based on regressions for the sample period 1962:Q1-1997:Q4 in which the coefficients on the lagged dependent variable are constrained to sum to unity.

Figure 1. The Unemployment and Inflation Rates, Quarterly Data, 1960-2007



Source : Bureau of Labor Statistics and Bureau of Economic Analysis *NIPA Tables* .

Figure 2. Scatter Plot of the Unemployment and Inflation Rates, Quarterly Data, 1960-80

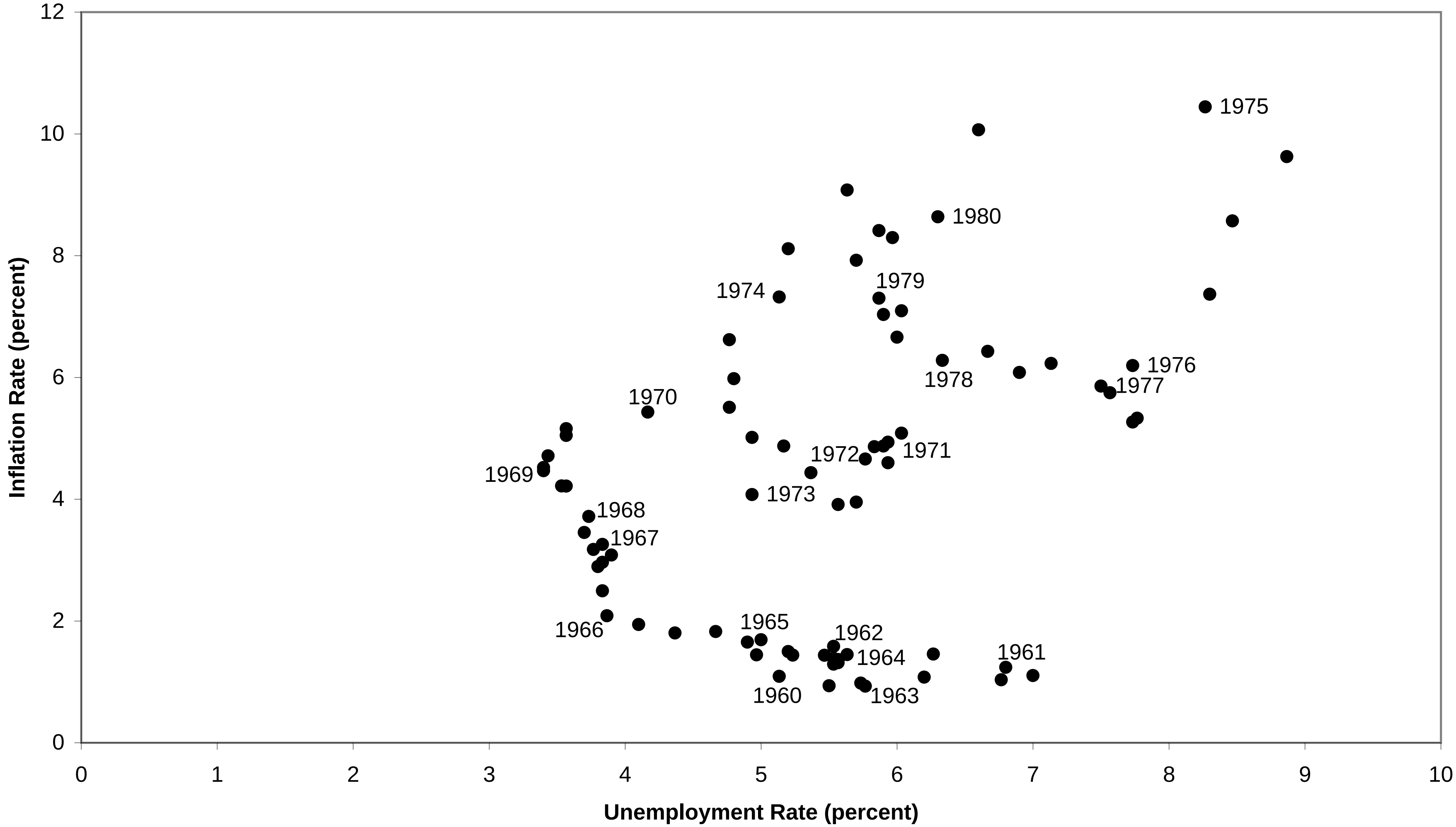


Figure 3. Actual Unemployment Rate vs. Time-Varying NAIRU, 1962:Q1 to 2007:Q4

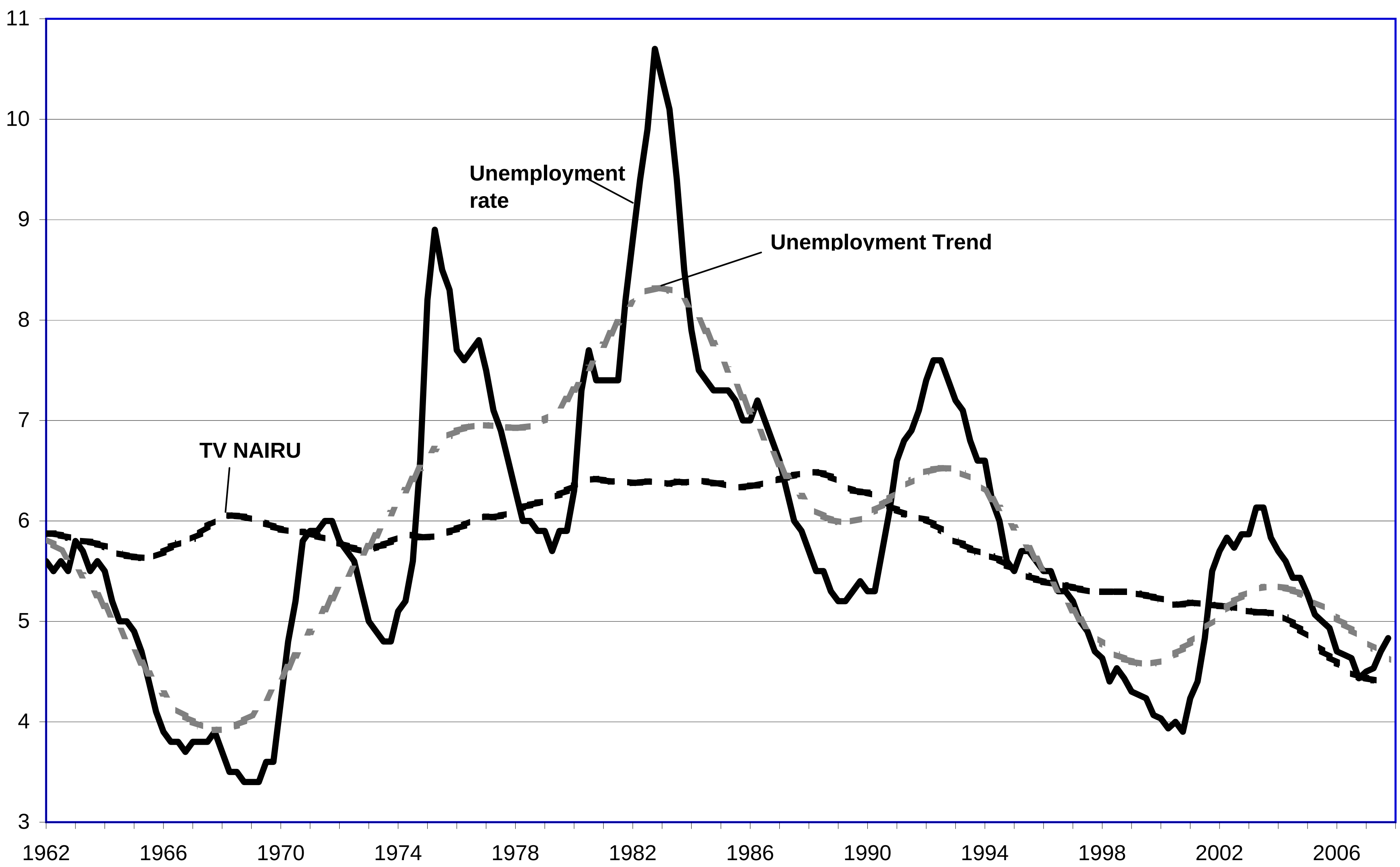


Figure 4. Predicted Inflation in Triangle Model with and without Supply shocks, 1962:Q1 to 2007:Q4

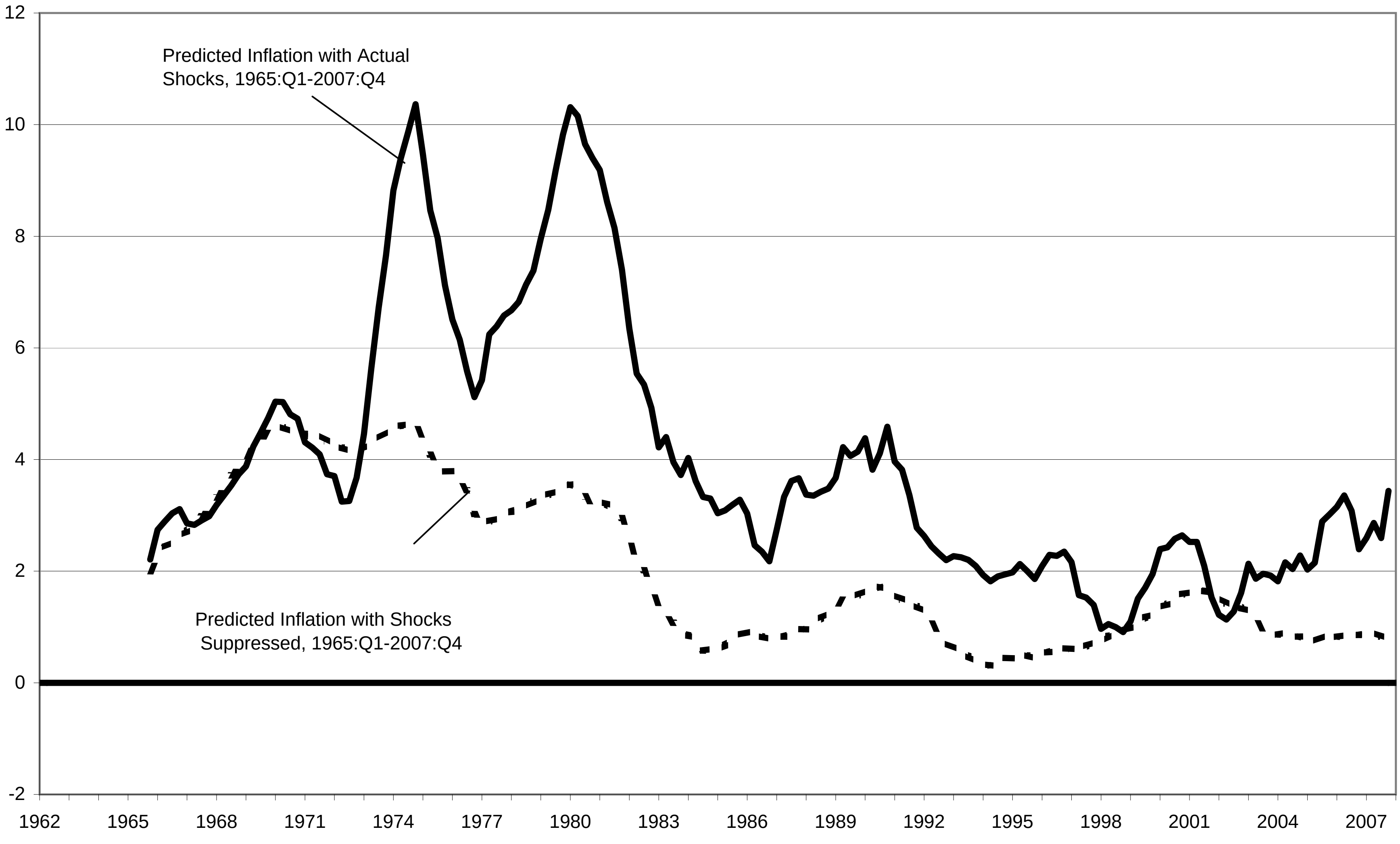
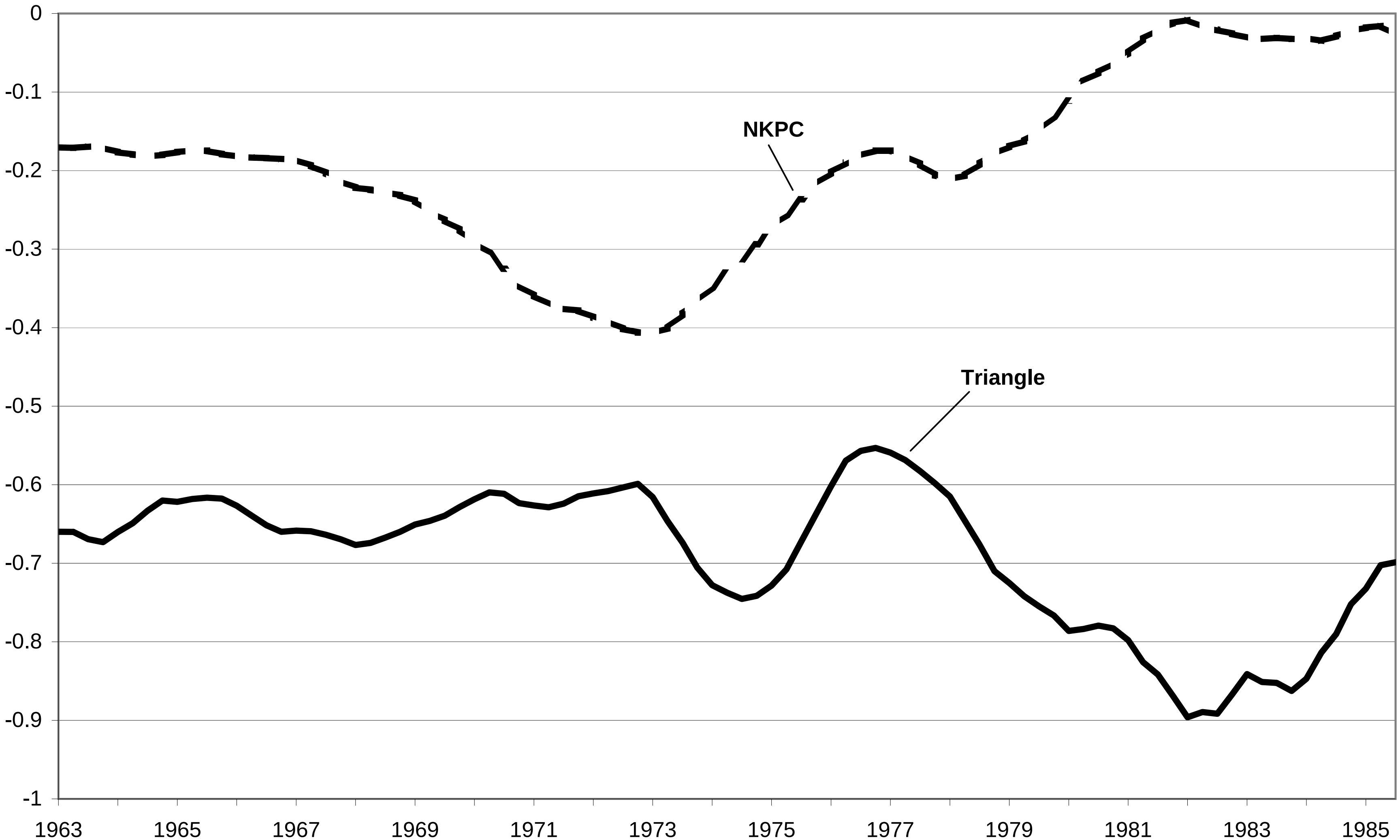


Figure 5. Predicted and Simulated Values of Inflation from Triangle and NKPC Equations
1962:Q1 to 2007:Q4

Figure 6. NKPC vs. Triangle Unemployment Coefficients on 90 Quarter Rolling Regressions from 1962:Q1 to 1985:Q3



Appendix Table A1
Transformation of Philips Curve from Roberts NKPC (line 1) to Triangle (line 21), 1962:Q1-2007:Q4

					Regression Statistics			Simulation Errors		Exclude inf lags 5-8		Exclude inf lags 9-24		Exclude U lags 1-4		Exclude Supply Shocks	
	Inf Lag	U lag length	Fixed or TV NAIRU	Supply shocks	R2	SEE	SSR	ME	RMSE	F Stat	Sig Level	F Stat	Sig Level	F Stat	Sig Level	F Stat	Sig Level
1	1 to 4	0	Fixed	No	0.78	1.17	244.0	-2.75	3.20								
2	1 to 8	0	Fixed	No	0.78	1.17	237.9	-2.73	3.15	1.11	0.35						
3	1 to 24	0	Fixed	No	0.80	1.11	195.0	-2.04	2.41			2.18	0.01				
4	1 5 9 13 17 21	0	Fixed	No	0.78	1.16	238.5	-2.19	2.53								
5	1 to 4	0 to 4	Fixed	No	0.79	1.15	229.2	-2.27	2.68					2.81	0.03		
6	1 to 4	0 to 4	TV	No	0.79	1.13	224.8	0.26	1.43								
7	1 to 8	0 to 4	TV	No	0.79	1.14	222.0	0.36	1.46	0.55	0.70						
8	1 to 24	0 to4	TV	No	0.80	1.10	188.7	0.15	1.33			1.71	0.05				
9	1 5 9 13 17 21	0 to 4	TV	No	0.79	1.14	225.6	0.03	1.33								
10	1 to 8	0 to 4	Fixed	No	0.78	1.15	226.0	-2.11	2.53	0.61	0.66						
11	1 to 24	0 to 4	Fixed	No	0.81	1.09	183.8	-2.18	2.54			2.21	0.01				
12	1 5 9 13 17 21	0 to 4	Fixed	No	0.80	1.12	216.7	-2.23	2.56								
13	1 to 4	0	Fixed	Yes	0.90	0.78	100.3	-2.45	3.06							18.20	0.00
14	1 to 8	0	Fixed	Yes	0.90	0.78	99.0	-2.60	3.15	0.52	0.72					17.39	0.00
15	1 to 24	0	Fixed	Yes	0.92	0.71	73.8	-0.18	1.00			3.09	0.00			18.31	0.00
16	1 5 9 13 17 21	0	Fixed	Yes	0.92	0.71	82.2	-0.24	0.97							23.85	0.00
17	1 to 4	0 to 4	Fixed	Yes	0.90	0.78	97.3	-2.11	2.72					1.22	0.31	16.79	0.00
18	1 to 4	0 to 4	TV	Yes	0.91	0.76	94.1	-1.14	1.47							17.31	0.00
19	1 to 8	0 to 4	TV	Yes	0.91	0.76	92.1	-1.15	1.40	0.84	0.50					17.12	0.00
20	1 to 24	0 to4	TV	Yes	0.93	0.65	59.6	0.30	0.74			4.84	0.00			23.66	0.00
21	1 5 9 13 17 21	0 to 4	TV	Yes	0.93	0.64	64.6	0.29	0.70							30.70	0.00
22	1 to 8	0 to 4	Fixed	Yes	0.90	0.78	96.6	-2.23	2.77	0.30	0.88					16.18	0.00
23	1 to 24	0 to 4	Fixed	Yes	0.92	0.69	67.2	-0.50	1.08			3.85	0.00			18.81	0.00
24	1 5 9 13 17 21	0 to 4	Fixed	Yes	0.93	0.68	73.4	-0.56	1.06							23.88	0.00