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※ A Re-examination of Natural Rate of Unemployment ※

※ 自然失業率的重新檢驗 ※

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□國際合作研究計畫國外研究報告書一份

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Abstract

In this paper, we use the modified expectation-augmented Phillips equation to estimate the NAIRU (non-accelerating inflation rate of unemployment). This model is reasonable under economic and statistical reasoning. As far as the economic reasoning is concerned, in the model, the assumption of the negative relationship between the inflation gap and the unemployment gap is consistent with the data; as far as the statistical reasoning is concerned, our model performs well in explaining the inflation gap, with the adjusted R^2 of the regression above 0.6. In addition, our estimate of the time-varying NAIRU owns two advantages. One is that it is less volatile than the overall unemployment rate. The other is that it can reflect the trend of the overall unemployment over the sample period. In addition, this estimate has some implications. First, the adjustment of the time-varying NAIRU is slow. Second, as the trend of the estimate shows, we have to tolerate a higher NAIRU and unemployment rate in the short run. Third, the high unemployment rate in recently years is largely due to the high NAIRU. Thus, without proper and complete solutions to deal with the high NAIRU, we may have to tolerate a higher unemployment rate for a long time in the future. Finally, since the gap between the overall unemployment rate and the NAIRU is positive and large and the inflation rate is still low, the central bank can continue to maintain a loose monetary policy to solve the unemployment problem.

Keywords: NAIRU, inflation, Phillips curve, time varying, monetary policy

摘要

本計畫的目的在重新檢驗非通貨膨脹引起的失業率 (NAIRU)。我們先使用預期擴充的菲律普曲線來估計。由台灣的資料，我們發現失業率與通貨膨脹的負向關係可以由資料獲得證實。而且在我們的模型中修正的判定係數可以高達 0.6 ，因此統計的配適度有相當的可信度。其次，在我們的設定中放入隨時間而變的 NAIRU 模型，這樣的設計有兩個好處：一是讓整體失業率較不隨意波動，另一是整體失業率的趨勢可以清楚的顯現出來。估計的結果顯示出整體失業率調整緩慢，我們的社會容忍短時間有高的非通貨膨脹引起的失業率。而高的非通貨膨脹引起的失業率正是引起近幾年台灣高度失業率背後的因素。在沒有其他可能的變化下，我們可能要面對長久的高失業率。最後我們也建議，在現在通貨膨脹率低的情況下，央行可以使用擴張性的貨幣政策來促進就業。

關鍵詞：非通貨膨脹引起的失業率，通貨膨脹,菲律普曲線, 因時而變, 擴張性的貨幣政策

1. Introduction

The low unemployment rate of around 4.0% in the U.S. has caused concerns about its impact on the inflation rate because in the short run, a lower unemployment rate is expected to lead to a higher inflation rate. One of the debates over the short-run tradeoff centers on whether the actual unemployment rate is greater than, equal to, or less than the natural rate of unemployment or the non-accelerating inflation rate of unemployment (NRU or NAIRU). If the actual unemployment rate is still higher than the natural unemployment rate, there would be less concern about the inflationary pressure. However, if the actual unemployment rate is less than the natural rate, the inflation rate tends to accelerate and eventually higher expected inflation will shift the short-run Phillips curve upward. A recent study of the NAIRU hypothesis by Stiglitz (1997) indicated that there are still uncertainties and areas for further research.

In Taiwan, for a long time researchers have been ignoring problems of the unemployment rate from macro perspective. The reason may be that the unemployment rate in Taiwan was quite low for years, compared to that in other industrialized countries such as in most European countries and the United States. One of the problems about the unemployment rate is the natural rate of unemployment or the NAIRU (Non-accelerating rate of unemployment). Many papers have either explored causes or developed estimation methodology for the natural rate of unemployment. Unfortunately, in Taiwan, few papers are related to these issues, and more seriously, Taiwan's unemployment rate has surged to its historical high level, which has results in lots of social problems such as suicide, homelessness, family violence and so on. As a result, the purpose of this paper is to estimate the NAIRU and examine if the high unemployment rate is due to a high NAIRU so that the central bank can use it as one of its indicators to decide if the monetary policy is too tight or not and then pursue a more adequate monetary policy to lesson the pain of the unemployment in the society; moreover, our government can have a better understanding of the high unemployment rate, making more clear and thorough policies to tackle this problem.

2. Literature Review

In this chapter, we first briefly discuss the theoretical part of the NAIRU and then the empirical part.

2.1 Theoretical Studies

2.1.1 Textbook definition of the NAIRU

In the first year of undergraduate economic courses, unemployment, based on its causes, is usually divided into three categories: frictional unemployment, structural unemployment, and cyclical unemployment.

(1) Frictional unemployment:

The frictional unemployed consist of those who are seeking for their first jobs such as college graduates and those who are changing their jobs. And most of them are capable workers so frictional unemployment is usually a short-term phenomenon.

(2) Structural unemployment:

The structural unemployed are those who lost their jobs in one declining industry but cannot find new jobs in a developing industry because of their out-dated abilities. Take Taiwan, for example. Taiwan's economy has changed from traditional and labor-intensive industries to high-tech and service industries. During this transition, many workers in their middle age were laid off from these traditional and labor-intensive industries, having no qualified education and experiences to be employed in high-tech and service industries. Since it takes time to train the structural unemployed, the persistence of structural unemployment is usually longer than that of frictional unemployment.

(3) Cyclical unemployment:

Cyclical unemployment results from business cycles. In a boom, demands for labor are increasing, which bring about decreases in cyclical unemployment and vice verse.

It is impossible for an economy to eliminate frictional and structural unemployment as there always exists some new labor market entrants and the industrial structure of an economy has always been altering due to improvements of technology. Accordingly, if adding up frictional and structural unemployment, then dividing them by the labor force and multiplying the outcome by one hundred percent, we get a so-called the natural rate of unemployment. The calculating formula is as below:

$$\textbf{\textit{Natural rate of unemployment}} = (\textbf{\textit{frictional unemployment}} + \textbf{\textit{structural unemployment}} \ / \ \textbf{\textit{the labor force}}) \times 100\%$$

Although the preceding division of unemployment and the definition of the natural rate of unemployment are very easy to understand, there still exist two problems to be dealt with. First, the conceptual division of unemployment is very clear; but in empirical studies, it is hard to distinguish structural unemployment from cyclical unemployment. Thus, the natural rate of unemployment calculated from the above definition is imprecise. Second, without analyzing the natural rate of unemployment from a broad framework such as a model or theory, few insights and implications can be obtained from the calculated natural rate of unemployment.

Consequently, in order to study the natural rate of unemployment from a broad perspective and gain insights into it, we present two different points of view about the natural rate of unemployment from two macroeconomic schools, the classical and the Keynesian.

2.1.2 Theories of the NAIRU

In the theoretical part of the natural rate of unemployment, the term "Non-accelerating Inflation Rate of Unemployment" (NAIRU), is often used as a synonym to the "natural rate of unemployment", which is one of the most popular conceptual developments in economics after it was introduced by Phelps (1967) and Friedman (1968). In Friedman's 1967 Presidential Address to the American Economic Association, he described the natural rate of unemployment as "the level that would be ground out by the Walrasian system of general equilibriums, provided there is embedded in them the actual structural characteristics of the labor and commodity markets, including market imperfections, stochastic variability in demands and supplies, the cost of gathering information about job vacancies and labor availabilities, the cost of mobility, and so on." A closely related argument made by both Friedman and Phelps involved the long-term implications of the Phillips curve. In the long run, unemployment tended to return to the natural rate of unemployment and monetary policy, in their view, could do nothing to alter the natural rate of unemployment; further, Friedman and Phelps argued that unexpected inflation could drive the level of unemployment below the natural rate of unemployment temporarily and the only way unemployment could be kept below the natural rate of unemployment was by an ever-accelerating inflation, which always kept current inflation ahead of anticipated inflation.

As for the NAIRU, the empirical and theoretical starting points for the development of the NAIRU were derived from a description of the inflation-unemployment relationship called Phillips curve. Phillips (1958) examined 97 years of British data on unemployment and nominal wag growth data, finding that, from 1861 to 1957, the growth rate of nominal wages was negatively correlated with the unemployment rate: low unemployment rates tended to be associated with rapidly rising wages while high unemployment rates were associated with slowly rising wages. Afterwards, economists who work on Phillips' finding shifted its focus slightly by examining the relationship between unemployment and inflation; and during the late 1950s and 1960s, many statistical studies showed a negative relationship between unemployment and inflation, which is known as the Phillips curve.

However, in the following decades, the Phillips curve failed to hold and aroused huge debate between the Keynesian and the monetarist. Then, the concept of the NAIRU grew out of some economists' attempts to reconcile the differences between Keynesian and monetarist theories on the subjects of the causes of price level and the relationship between inflation and unemployment. For example, Franco Modigliani and Lucas Papademos (1975) asserted that " the existence of NIRU" is implied by both the vertical and the non-vertical schools of the Phillips curve. And the NIRU was later renamed as the NAIRU. For Keynesians, inflation accelerates at high employment rates because tight markets systematically and repeatedly generate wage and price increases. At the Phelps-Friedman "natural rate of unemployment," the degrees of resource utilization and market tightness generate no net wage and price pressure up or down and are consistent with accustomed and expected paths, whether stable process or any other inflation rate. The consensus view accepted the notion of a non-accelerating inflation rate of unemployment (NAIRU) as a practical constraint on policy.

The NAIRU (also called the natural rate of unemployment) is defined as the rate of unemployment consistent with a stable inflation rate. Inflationary pressure tends to increase when unemployment is below the NAIRU, and decrease when unemployment is above the NAIRU. A number of explanations for this phenomenon have been proposed, but one plausible story is that, when unemployment is low, firms have to offer higher wages to attract, retain, and motivate new workers than they do when unemployment is high. Nominal wage growth is passed on to purchasers in the form of faster growth of prices. Here is the formula of the expectations-augmented Phillips curve:

$$\pi - \pi^e = -\beta(u - \bar{u})$$

where

$\pi - \pi^e =$ unanticipated inflation (the difference between actual inflation π and π^e);

$u - \bar{u} =$ cyclical unemployment (the difference between the actual unemployment rate u and the NAIRU $\bar{u}$;

$\beta =$ a positive number that measures the strength of the relationship between unanticipated inflation and cyclical unemployment.

And according to this formula, actual inflation π exceeds expected inflation π^e if the actual unemployment rate u is less than the NAIRU $\bar{u}$; and actual inflation is less than expected inflation if the unemployment rate exceeds the NAIRU.

However, the debate still continued between the two schools and two different points of view are presented below.

Espinosa and Russell (1997) mentioned Lucas's view about the Phillip curve relationship. In Lucas's model, the Phillips curve is, by construction, a very reliable statistical relationship: a relationship in which the levels of employment and output fluctuate around long-run averages that can be thought of as the analogues of the natural rate or NAIRU. However, the short-run component of the Phillips curve relationship, which is the only component that involves changes in the levels of employment and output, is generated by forces that have nothing to do with the systematic (policy-determined) component of monetary policy. As a result, deliberate, policy-induced changes in the inflation rate have no power to influence the unemployment rate in Lucas's model.

Contrast to Lucas' point of view, Tobin (1993) provided a different argument. Friedman identified his "natural rate" as Walrasian equilibrium. Keynes's "full employment" is also classical equilibrium: labor markets are clearing at existing real wages. Why is equilibrium unemployment not zero? Keynes and Friedman cite, but do not explain, "frictional" unemployment. They differ on what explains cycles. Friedman and Lucas answer: misperceptions of inflation. Markets clear at wrong prices and quantities. Today New Classicals stress variations in the natural rate itself. In Keynesian cycles markets don't clear. Excess supplies or demands trigger Phillips-curve movements of wages and prices. Unemployment and vacancies coexist in varying proportions because inter-sectoral shocks always occur. Adjustment dynamics, not representative-agent equilibrium, determine the economy's behavior at NAIRU and other unemployment rates. Money makes a difference, not because of money illusions or misperceptions but because adjustments begin with nominal wage and price responses.

In this paper, we do not intend to involve too much in this controversy but adopt a workable model to estimate the NAIRU, exploring its possible implications.

2.2 Empirical Studies

2.2.1 International Studies

Next, several literatures about the estimation of the NAIRU are described in detail.

Gordon (1997) thought that the NAIRU is meaningful only within a well-specified model of the inflation process, estimating the NAIRU by a model of the inflation process that incorporated and resurrected the Phillips curve, which is called "the triangle model." The triangle model was amended from the Phillips curve by incorporating supply shocks and a zero tradeoff between the inflation and the unemployment in the long run; in other words, the triangle model is a model that describe the dependency of the inflation rate on three basic determinants: inertia, demand and supply. A general specification of this framework would be:

$\pi_t = a(L)\pi_{t-1} + b(L)D_t + c(L)z_t + e_t$. The dependent variable π_t is the inflation rate. Inertia is conveyed by the lagged rate of inflation π_{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 indicates an absence of supply shocks), e_t is a serially uncorrelated error term, and L is a polynomial in the lag operator. In this equation, the sum of the coefficients on lagged inflation must be constrained to be exactly one for a meaningful natural rate of the demand variable to be calculated, and the 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 unemployment rate and the natural rate, and the natural rate is allowed to vary over time. In addition, the estimated NAIRU is the "no-supply-shock" NAIRU; that is, the unemployment rate is consistent with steady inflation in the absence of supply shocks. Without this qualification, then the NAIRU would jump around as supply shocks arrived and departed, which is not what most economists are trying to convey when they speak of the natural rat of unemployment.

Two issues concerning the triangle model involve the role of wage changes and the role of expectation. The original Phillips article was about the relation between wage changes and unemployment, and later formulation added a term for expected inflation. But the triangle model as summarized here has no expectation and no wages. The role of the lagged inflation terms is to capture the dynamics of inertia, whether related to expectation formation, contracts, delivery lags or anything else. Furthermore, models with separate wage growth and price markup equations do not perform as well as the equation above, in which wages are only implicit.

The estimation of the time-varying NAIRU combines the above equation, with the unemployment gap as the proxy for excess demand, with a second equation that explicitly allows the NAIRU to vary with time: $\pi_t = a(L)\pi_{t-1} + b(\mathrm{L})(\mathrm{U}_t - \mathrm{U}_t^{\mathrm{N}}) + \mathrm{c(L)z}_t + \mathrm{e}_t$ and $U_t^N = U_{t-1}^N + \varepsilon_t$. In this formulation, the error term ε_t in the second equation is well behaved, with a mean zero and a standard deviation. This model is a standard "stochastic time-varying parameter regression model" that can be estimated using maximum likelihood methods. Supply shock variables include changes in the relative price of imports and the change in the relative price of food and energy. Dummy variables are included for the "on" and "off" effects of the Nixon price controls during 1971~1975. Also included as an explanatory variable is the difference between productivity growth and its trend, reflecting the fact that, while most of any cyclical increase or decrease in productivity is reflected in a movement in profits in the same direction, a small fraction remains to influence the inflation rate in the opposite way. Then, the author calculated three alternative NAIRU series using three alternative price indexes: the chain-weighted GDP deflator, the chain-weighted deflator for personal consumption expenditures and the inflation rate of the Consumer Price Index concept. In addition, an assumption must be made about the size of the standard deviation of the error term in the equation for the

NAIRU (σ_t). For example, an assumption of $\sigma_t = 0$ implies a completely constant NAIRU series; an assumption of $\sigma_t = 0.4$ allows the NAIRU to be highly variable.

After the estimation of the NAIRU with different assumptions of σ_t and price indexes, the author uses the equations as the basis for dynamic simulations of particular historical periods to explore the stability and accuracy of the result. And the result is that it is possible to estimate inflation in 1994~96 based on pre-1987 data, which illustrates how stable the structure of the inflation process seems to have been during 1987~1996 from the perspective of the pre-1987 period.

According to Staiger, Stock and Watson (1997b), one difficulty with empirical examinations of the Phillips curve tradeoff between inflation and unemployment is the lack of a perfect measure of inflation. In their paper, the authors used the gross domestic product (GDP) deflator to stand for the other broad measures of inflation, the personal consumption expenditure (PCE) price index, excluding expenditures on food and energy to represent for the other narrow measures of inflation. In addition, the model employed here is somewhat different to the one used by Gordon (1997)： $\Delta\pi_t = \beta_1(u_{t-1} - \bar{u}) + \beta_2(u_{t-2} - \bar{u}) + rX_t + v_t$, where π_t is the rate of price inflation, u_t is the unemployment rate, and X_t denotes additional control variables that includes one or more lags of past changes in inflation rate and supply shock measures. $\bar{u}$, the NAIRU, enters as an unknown parameter. The model can be rewritten as $\Delta\pi_t = \mu + \beta_1 u_{t-1} + \beta_2 u_{t-2} + rX_t + v$, where $\mu = -(\beta_1 + \beta_2)\bar{u}$. Given ordinary least squares estimates of the constant term μ and coefficients β_1 and β_2, the NAIRU can be estimated as $-\mu/(\beta_1+\beta_2)$. This model and technique can be extended to as many lags of unemployment as seems appropriate and is the conventional method for the estimation of the NAIRU as used by Gordon (1982), the Congressional Budget Office (1994), Eisner (1995a), Tootell (1994), Weiner (1993, 1994), Fuhrer (1995) and others. However, this formulation does not allow for time variation in the NAIRU. One approach is to model the natural rate of unemployment as having discrete jumps at certain points in time, an approach used by Gordon (1982), Weiner (1993) and tootell (1994). Here, the authors employed a more flexible approach in which the NAIRU is modeled by a flexible polynomial, a so-called "spline."

Based on quarterly data for 1962-1995, the authors estimated the NAIRU and its 95% Fieller confidence interval using four lags of unemployment, four lags of inflation and two supply shock control variable：one to capture the Nixon wage and price controls, and the other to capture supply shocks to food and energy prices. In addition to GDP inflation and core PCE inflation, the authors estimated the NAIRU and its 95% confidence interval using different price indexes, finding that the point estimates of the NAIRU based on these different inflation series are similar; however, there are substantial differences in the precision of the estimates, and the 95 percent confidence intervals are wide enough to include most observed values of unemployment, with the exception of some cyclical peaks and troughs. But, the authors emphasized that although the NAIRU is imprecisely estimated, the empirical estimates confirmed a clear, negatively sloped Phillips curve. For example, the predicted effect of a decrease in the unemployment rate from 5.5 to 4.5 percentage points, relative to a base case of constant 5.5 percent unemployment, is an increase in the inflation rate of 0.9 percentage points over the first year and an increase of 1.5 percentage points cumulatively over the first two years. The slope of this Phillips relation is negative and is estimated fairly precisely (the t-statistic on the sum of the coefficients on lagged unemployment is –4.1).

After having estimating the NAIRU and its 95% confidence intervals, the authors investigated the robustness of the results using different model specifications. One modification is to include contemporaneous values of unemployment, not just lagged values. When contemporaneous unemployment is included, the basic results do not change, although the time variation in the NAIRU becomes statistically significant using six of the eight inflation series. The second specification modification is to consider alternative models of inflationary expectations. In their paper, the authors used the inflation of the previous year as the expected inflation so the change in inflation equals unexpected inflation. Alternatively, one can proxy expected inflation either by a more complex model of how expectations might depend on past inflation rates or by real time forecasts of inflation published in contemporaneous surveys of economists and forecasters. And because some real-time survey forecasts systematically underestimate inflation, using these alternative series for inflationary expectations sometimes affects the point estimates of the NAIRU. Otherwise, the basic conclusions remain unchanged. The third modification is to consider alternative measures of unemployment. The authors re-estimated the NAIRU using married male unemployment or unemployment among males aged 25-55, the basic conclusions are still largely unchanged (except that the NAIRU is estimated to be lower because unemployment is lower for these groups). The one difference is that the hypothesis that NAIRU was constant over the entire sample period typically cannot be rejected for these groups. The fourth modification is to employ alternative models of how the NAIRU can vary over time. The results for break models with three time periods, where each time period has a constant NAIRU, are qualitatively similar to those for the model presented here. A quite different approach, used in King, Stock and Watson (1995), Staiger, Stock and Watson (1997a) and Gordon (1997) is to model the NAIRU as varying in each period, but to treat that time variation as a stochastic function of time, rather than as a deterministic function as in the models presented here. The result is estimates of the NAIRU that are similar to the preceding result, but with wider confidence intervals. These confidence intervals are wider because they incorporate an additional source of uncertainty by explicitly treating the NAIRU as evolving over time in a way that cannot be perfectly predicted.

After considering different model specifications, the authors employed recursive least squares to evaluate the original model's forecasting performance by assuming different values for the NAIRU, reporting the root mean squared error (RMSE) of their forecasts over this period, which provides a measure of a typical forecast error. Although different assumptions of the NAIRU perform slightly different in forecasting different inflations, the average forecast accuracy of the different assumptions would have been very similar and also produce similar forecasts. Also, the recent history of the unemployment rate helps to predict inflation over the next year, and it is less valuable over the next two years.

Then, the authors run a total of 71 forecasting models, and the results suggest that some other variables are at least as valuable as unemployment for predicting inflation such as the capacity utilization rate in manufacturing, the National Association of Purchasing Managers' index of new orders and the federal funds rate. In addition, combing information in other series with the information in unemployment can enhance forecasts of inflation. These results reinforce the commonsense view that monetary policy should be informed by a wide range of variables, not just the unemployment rate.

Contrast to the above two literatures where the authors estimated the NAIRU and examined its usefulness in forecasting inflation, Perez (2000) tried to estimate the NAIRU and explained why the NAIRU changes over time in the United States simultaneously by extending the basic framework outlined by Staiger, Stock, and Watson (1997a, p.197) to incorporate possible determinants of the NAIRU. Using a Kalman filter, he estimated a state-space model allowing the gap between actual unemployment and an unobservable NAIRU to affect changes in inflation while estimating the effects of demographics and labor market conditions on the NAIRU. The estimation results show that the NAIRU is significantly and positively affected by the lagged average rate of unemployment, the proportion of women in the labor force, the proportion of the labor force that is non-white, the proportion of the labor force between the age of 16 and 24, changes in the level of labor productivity, and the average level of unemployment over the previous year, and significantly and negatively affected by the average duration of unemployment and the real minimum wage rate. The model employed in his paper is as follows:

$$\Delta\pi_t = a(L)\Delta\pi_{t-1} + b(L)(U_t - U_t^N) + c(L)Z1_t + e_t,$$

$$U_t^N = U_{t-1}^N + D(L)Z2_t + v_t,$$

$$U_t = fU_t^N + G(L)(U_{t-1} - U_{t-1}^N + u_t)$$

where b(L) and c(L) are polynomials in the lag operator, and in this paper Z1 contains the second difference of the commodities CPI($\Delta^2 PE$), and dummy variables to account for the Nixon price controls ; D(L) is a polynomial in the lag operator, Z2 contains variables thought to affect U^N over time, which is the innovation of this paper. These variables include the variables that account for demographic changes: the proportion of the labor force that are non-white (LFNW), the proportion of the labor force that are women (LFW), the proportion of the labor force that are teenagers (LFT), the real minimum wage (MWR) and changes in labor productivity (Δ PROD) that investigate a "wage aspiration" effect and the general effect of changes in productivity, the average of unemployment over the last year (UA) that investigate a possible hysteresis like effect and the average duration of unemployment account for reservation wage effects. And f is a parameter, G (L) is a polynomial in the lag operator, and u_t is a random error. The last equation incorporates the idea that the actual unemployment rate has a tendency to return to the NAIRU. After written in state-space form, the above equation system can be estimated using a Kalman filter. The estimation result of the NAIRU generally conforms to the definition of NAIRU as inflation generally rises when the actual unemployment rate was less than the NAIRU and generally falls when the actual unemployment was above the NAIRU.

In addition to the above papers, which only focus on the estimation of the NAIRU solely, Apel and Jansson (1999) proposed a new system-based strategy for estimating potential output together. The system has two key elements: (1) a Phillips-type equation which, under a specified set of conditions, defines the NAIRU as the long-run unemployment rate consistent with steady inflation; and (2) a standard version of Okun's law which states that deviations of unemployment from the NAIRU induce deviations of the level of output from its potential level. Taken together, these key elements give an empirical system which is consistent with the common definitions of potential output and the NAIRU, and thus can be used to derive economically interpretable estimates of these key unobservable macro variables.

The authosr uses Swedish quarterly data covering the time period 1970:1-1996:3 and the empirical results are as follows: (1) Estimating potential output and the NAIRU subject to co-variation restrictions on cyclical output and cyclical unemployment considerably improves the statistical fit of the model; (2) incorporating information on inflation through a well-specified Phillips-type equation further helps in increasing the accuracy of the estimates of potential output and the NAIRU; (3) while different specifications yield estimates that are qualitatively similar and generally in accordance with economic theory, the point estimates of the current output gap and NAIRU differ considerably across different specifications; (4) the trend process of potential (and actual) output in Sweden is smooth, resembling a deterministic linear trend-this result appears robust with respect to reasonable alterations of the specified process for potential output; (5) the recent shift form high to low inflation in Sweden gives rise to econometric complications and necessitates a careful interpretation of the current estimates of the output gap and the NAIRU. The main problem is that, even though several compelling arguments indicate that a permanent shift in the inflation regime actually has taken place, an insufficient number of observations under the new regime makes it difficult to verify this empirically.

Fabiani and Mestre (2001) measured the NAIRU for the euro area and assessed the robustness and precision of the obtained estimates. The empirical framework adopted is based on systems combining an Okun-type relationship between cyclical unemployment and the output gap with a Phillips curve and stochastic laws of motion for the NAIRU and potential output, and the systems have been estimated using Kalman-filter technique. The results obtained point to an estimate of the area-wide NAIRU that is robust to change in the underlying models. And this robustness is shown to hold both in terms of the mean, which are the resulting NAIRU and the variance of the process.

2.2.2 Domestic Studies

In Taiwan, the estimation of the NAIRU is rare in the academics, and we have found two papers, whose purposes are to estimate this unobservable variable. In the following paragraphs, we describe their findings in detail, explaining why it is necessary to estimate it again using a different method.

Following Friedman's notion of the natural rate of unemployment, considering the effect of the structural change of the labor market on the employment, Hsu (1998) developed two methods to estimate Taiwan's natural rate of unemployment. The first one is the method of the demographic change of the workforce: considering gender and changes of the age structure, changes of supplies and demands in the labor market and unemployment in the economic boom. The second is the method adjusted from the methods in Rissman (1986) and Lilien (1982): taking the demographics of the workforce and the employment structure in industrial terms into consideration. The similarity between these two method is that both of them estimate the natural rate of unemployment based on the structural changes of the labor market; the difference is that the former focuses on the demographics of the workforce and the unemployment rate in the economic boom, but the latter, without considering the unemployment in the economic boom, purely focuses on changes of the demographics of the labor force and the industrial unemployment structure.

In addition to these two methods, the author also made two assumptions: (1) Compared with the employment level of male laborers aged between 30 and 49, laborers in other age groups have more volatile employment level due to the pressure from supplies and demands of the market and adjustments of the industrial structure. (2) The unemployment rate in the economic boom can be regarded as the approximation of the natural rate of unemployment since a laborer can be employed easily if willing to accept the prevalent wage in the economic boom.

Next, the author estimated a set of the natural rate of unemployment using the first method. In the first method, two estimated values, the estimated labor participation rate and the estimated unemployment rate for ten male age groups and ten female age groups, are generated by two regression equations, equation 11 and 13 in his paper. Then, the author viewed the unemployment rate in the economic boom as the natural rate of unemployment and a benchmark unemployment rate. Then, by the method of the interpolation, the first set of the natural rate of unemployment is calculated, the maximum value 2.47% and the minimum value 1.27%.

However, in his second regression, equation 13, there exists linear correlation between explanatory variables and dependant variable may be non-stationary. Moreover, Regarding the unemployment rate in the economic boom as the natural rate of unemployment in the economic boom is not persuasive; in fact, till now, no theory or evidence can corroborate this assertion. In addition, the two regression equations and their estimation results are too simplified, needing further explanation. Thus, based on the above arguments, the first set of the natural rate of unemployment may be spurious.

In the author's second method, like what he did in the first method, one set of the natural rate of unemployment is estimated by two linear equations, equation 15 and 16 in his paper. In the first equation, the author sets five age-group weighted unemployment rates, which includes four lagged values, as the explanatory variables and the unemployment rate as the independent variable to estimate a set of the adjusted unemployment rate based on changes of the demographics. Then, in the second regression equation, treating the estimated values as the independent variables, the author incorporates the employment growth, the demand of the labor market, the unexpected changes of money supply and time trend into the right hand side of the regression equation, estimating one set of the natural rate of unemployment by setting the coefficients of the variables of the unexpected changes of money supply equal to zero.

But, in the first regression equation, the problem, similar to what I have proposed about the first method, is that the dependent variable, the overall unemployment, is non-stationary, which will be shown in the unit root test of our paper; and under econometric reasoning, it is not compelling to regard the estimated values as what the author claimed, the adjusted unemployment rate based on changes of the demographics. More importantly, after simple calculations, I found that the so-called age-group weighted unemployment rate is identical to the unemployment rate. Thereby, these estimated values are problematic.

In fact, there is no formal theory to support the credibility of the above two methods; the interpretation of the outputs of the regression models is problematic; more, the author has abused the linear regression to generate the natural rate of unemployment. What is more, one can manipulate the outcome by deliberately adding or deleting some variables or devising a different model based on personal belief or logic. Consequently, using a more formal model to estimate the natural rate of unemployment is necessary.

In contrast to the preceding paper, the following paper estimate Taiwan's natural rate of unemployment or, more precisely, its NAIRU, based on the expectation-augmented Phillips curve, which has been employed to estimate the NAIRU or the natural rate of unemployment in many literatures recently.

Chen (2001) empirically analyzed the structure of Taiwan's natural rate of unemployment, finding that the data-generating process could come from two or three regimes and the Markov-switching model is well suited to characterize this feature. In his paper, the author proposed three competing hypotheses: the constant natural rate of unemployment, the unit root hysteresis of unemployment, and the endogenous natural rate with infrequently-changing mean of unemployment, claiming that the endogenous natural rate with infrequently-changing mean of unemployment is plausible, according to the following arguments. First, the unit root test is used to examine if either the constant natural rate of unemployment or the unit root hysteresis of unemployment is correct. That is, if the null hypothesis of the unit root test is rejected, the constant natural rate of unemployment may be plausible. Otherwise, the unit root hystersis of unemployment is accepted. Here, the author considers two kinds of unit root tests: one is the augmented Dickey-Fuller test; the other is a test from Elliott et al (1996). Unfortunately, the author found the opposite results from these tests. Consequently, Perron and Vogelsang's (1992b) test is considered to test if there exists infrequent changes from one state to another, which, according to the author' claim, probably causes the persistence of high unemployment. However, the evidence[1] is too weak to support this claim and, the author went on to justify his claim by the kernal density estimate, finding that the series of the unemployment rate could come from two states.. Then, in his estimation, following Bianchi and Zoega (1997, 1998), the author employed the two-state markov-switching model with AR (1) specification to estimate the natural rate of unemployment, and the estimation results suggest dichotomizing the natural rate of unemployment into the low-unemployment (regime 1) and high-unemployment (regime 2) with corresponding mean rates of 1.439% and 3.907%, respectively. Moreover, worried about possible misspecifications, the author used the three-state markov-switching model with AR (1) specification, classifying these regimes as the low-unemployment (state 1), medium-unemployment (state 2) and high-unemployment states (state 3) with rough mean rates of 1.50%, 2.78% and 3.96%, respectively. In addition to these estimations, by the turning point criterion, proposed by Hamilton and Perez-Quiros (1996), the author found out that the unemployment rate is a good indicator to describe Taiwan's business fluctuations and is counter-cyclical to Taiwan's business cycles.

Yet, one critic of this paper remarks that the kernal density estimate can be very sensitive and results in inappropriate selection of number of regimes. Accordingly, it may be problematic to apply this conception, the endogenous natural rate with infrequently-changing mean of unemployment to the estimation as the author did.

Apparently, from the above literatures, most of recent literatures which focus on the estimation of the NAIRU adopt an modified Phillips curve to yield this unobservable series and the modifications differ slightly in each literature. Consequently, unlike Hsu (1998), who considers the characteristics of the labor market when estimating the natural rate of unemployment, we would like to adopt the Phillips curve relation to estimate Taiwan's NAIRU. In addition, from the above estimation results, most literatures estimate a time-varying NAIRU rather than a constant one. So we also follow this fashion. However, many statistical techniques have been used to model this time-varying series; and each one has its own advantages and is suitable for some specific models. In this paper, following Sekhon (2001), we incorporate the Hermite polynomial series into the modified Phillips curve so that the estimation can be done by the ordinary least square estimation and the package software, E-view. Technical details are presented in the next chapter.

3. Econometric Methodology

In this section, it is divided into two parts. In the first part, the negative relationship between the inflation gap and the unemployment rate in the previous is shown using the data from 1961 to 2000 for Taiwan. In the second part, the econometric models adopted in this paper are introduced and described in detail.

3.1 Preliminary Look at the Data

To begin with, the expectation-augmented Phillips curve, which is necessary for the further discussion, is presented here again. The relationship implied by this curve is that when the actual unemployment rate u is less than the NAIRU $\bar{u}$, actual inflation π exceeds expected inflation π^e; and when the unemployment rate exceeds the NAIRU, actual inflation should be less than expected inflation. Therefore, the formula of this expectation-augmented Phillips curve is:

$$\pi - \pi^e = -\beta(u - \bar{u}), \tag{1}$$

where

$\pi - \pi^e =$ unanticipated inflation (the difference between actual inflation π and π^e);

$u - \bar{u} =$ cyclical unemployment (the difference between the actual unemployment rate u and the NAIRU $\bar{u}$;

$\beta =$ a positive number that measures the strength of the relationship between unanticipated inflation and cyclical unemployment.

To make the expectation-augmented Phillips curve clearer, the time index should be added; then, Equation 1 can be written as

$$\pi_t - \pi_t^e = -\beta(u_{t-1} - u^*), \qquad (2)$$

where t is the time period; π_t represents the inflation rate in the current period; π_t^e stands for the expectation of the inflation rate in the current period; u_{t-1} is the unemployment rate in the previous period; u^* is a constant NAIRU. In Equation 2, two implications are worth to be mentioned: the lagged influence of the unemployment gap and the constant NAIRU. First, the lagged influence of the unemployment gap means that it takes time for the inflation gap to reflect the conditions of an economy; that is, if an economy is in a boom, and the unemployment rate is lower than the NAIRU, then the inflation rate will be higher than expected in the next period; conversely, if an economy is in a recession, and the unemployment rate is higher than the NAIRU, then the inflation rate will be lower than expected in the next period. Second, u^*, which does not have the time index, implies that the NAIRU here is constant over time. Yet, the constant assumption of the NAIRU is temporary and used for this preliminary look at the data and the estimation of the constant NAIRU since this can allow us to concentrate on the relationship between the inflation gap and the unemployment gap and other possible explanatory variables for the inflation gap without being distracted by the consideration of the time-varying NAIRU.

In Equation 2, it is necessary to make one more assumption and answer the following question simultaneously: how does the expectation of the inflation rate form? The discussion of this problem will be accomplished in Section 3.2.2, and now we assume that the expectation rate of the inflation in the current period is equal to the inflation rate in the previous period and use $\Delta\pi_t$ to denote this inflation gap, so that $\pi_t^e = \pi_{t-1}$ and $\Delta\pi_t = \pi_t - \pi_{t-1}$. Thus, Equation 2 can be arranged as

$$\Delta\pi_t = -\beta(u_{t-1} - u^*), \tag{3}$$

Further, this equation can be transformed as a linear form by multiplying $-\beta$ into the parentheses:

$$\Delta\pi_t = \mu - \beta u_{t-1}, \tag{4}$$

where $\mu = \beta u^*$,

And, according to Equation 4, which is derived from the expectation-augmented Phillip curve, the relationship between $\Delta\pi_t$ and u_{t-1} should be negative and the slope of this line is downward sloping.

Now, based on Equation 4, we show that this negative relationship does exist in the data for Taiwan. Yet, in Figure 1, in order to present this negative relationship clearer in the scatter diagram from 1961 to 2000, several observations have been dropped out: 1961, 1974, 1975, 1980, 1982.

In Figure 1, there are 35 observations, the annual data for Taiwan from 1961 to 2000 excluding 4 observations, which make this negative relationship insignificant in this diagram but are still considered in the later estimation; the x-axis is the unemployment rate in the previous year denoted by ru (-1); and the y-axis is the inflation gap between the current year and the previous year denoted by $\Delta\pi_t$. In addition, an ordinary least squares regression line where $\Delta\pi_t$ is the explained variable and u_{t-1} is the explanatory variable with a constant term is added in Figure 1 to present this negative relationship. The intersection of this line with the unemployment axis is the ordinary least square estimate of the NAIRU for which inflation is predicted to be constant; that is, when $\Delta\pi_t = 0$, $u_{t-1} = u^*$, the constant NAIRU. The estimate of the constant NAIRU is about 2.5%. Clearly, in Figure 1, the ordinary least square regression line has a negative slope, which is in accordance with the negative relationship between $\Delta\pi_t$ and u_{t-1} derived from the expectation-augmented Phillip curve. Hence, the property of the expectation-augmented Phillip curve does exist in the data for Taiwan.

However, among these 40 observations including those having been dropped out in Figure 1, 15 observations have a higher unemployment rate than the estimate of the constant NAIRU, but only 8 of them have a lower inflation rate in the next year. In addition, 25 observations have a lower unemployment rate than 2.5%, but only 9 of them have a positive inflation gap. Consequently, from the above comparison, a constant NAIRU may be incorrect or the assumption of the expectation rate of inflation is problematic or the inflation gap cannot be explained solely by the unemployment rate in the previous year and additional explanatory variables should be incorporated to improve the fitness of the model.

From the above discussion, a more plausible way to estimate the unobservable NAIRU can be to add some explanatory variables on the right hand side of the expectation-augmented Phillip equation or allow a time-varying NAIRU or use different specifications for the expectation rate of inflation. In the following discussion, these modifications are considered one by one: first, the best choice of the expectation rate of inflation is decided; second, new explanatory variables are incorporated into the expectation-augmented Phillips equation to estimate a constant NAIRU; finally, a time-varying NAIRU, which is the ultimate goal of this paper, is considered.

3.2 Econometric Model

3.2.1 Models for Unit Root Tests

Before the estimation of the NAIRU by applying the data for Taiwan to the following models, unit root tests are performed first by two approaches, the augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller (1979, 1981) and the Phillips-Perron test proposed by Phillips and Perron (1988).

Peel and Speight (1995) summarized the advantages and disadvantages of the two tests, suggesting that it is necessary to perform both of them. The Augmented Dickey-Fuller (ADF) test is appropriate in the presence of autoregressive moving average (ARMA) error processes of unknown order (Said and Dickey, 1984) given the inclusion of a number of lagged differences in the dependent variable sufficient to make the error process uncorrelated. As an alternative test, Phillips and Perron (1988) have proposed a non-parametric correction to the Dickey-Fuller (DF) procedure to deal with a broad class of serial correlation types, and MA errors which the ADF test may not be able to accommodate in particular. However, it has been demonstrated that although size distortions of the Phillips-Perron statistics are small in the presence of MA errors displaying positive autocorrelation, size distortions become large for negatively autocorrelated MA errors (Phillips and Perron, 1988; Park and Choi, 1988; Schwert, 1989). Further, it has been shown that of these tests, in the presence of autoregressive (AR) errors, the ADF test is reasonably well-behaved while Phillips-Perron test statistics suffer serious size distortions (DeJong et al., 1992a). Additionally, Campbell and Perron (1991) have argued that the ADF test possesses greater power in the small samples typical of postwar data. Consequently, the choice of the test in any given application cannot be made independently of the error structure associated with the test autoregression or the sample size available. Therefore, it is better to report both ADF and Phillips-Perron statistics for the data.

Next, the equations used for these two tests are presented below. The equation used for the Augmented Dickey-Fuller test procedure is:

$$\Delta x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_j \Delta x_{t-j} + u_{t,} \qquad (5)$$

The equation used for the Phillips-Perron test procedure is:

$$\Delta x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_2 t + u_t \qquad (6)$$

where p is the value necessary to render $\hat{u}_t$ white; the intercept α_0 and the trend t are optional.

While the ADF test corrects for higher order serial correlation by adding lagged differenced terms on the right-hand side, the Phillips-Perron test makes a correction to the t-statistic of the α_1 coefficient from the AR(1) regression to account for the serial correlation in u_t.

The asymptotic distribution of the Phillips-Perron t-statistic is the same as the ADF t-statistic. The null hypothesis of a unit root is the hypothesis that $\alpha_1 = 0$; if the absolute value of t-statistic of $\hat{\alpha}_1$ is greater than the 5% or 1% critical value from MacKinnon (1991), then the null hypothesis of a unit root is rejected; if the absolute value of t-statistic of

$\hat{\alpha}_1$ is no greater than the critical value, then the null hypothesis of a unit root is not rejected.

3.2.2. Modifications for Expectation-Augmented Phillips Curve

Among three possible modifications for the expectation-augmented Phillips curve, which we have mentioned before , the formation of the expectation rate of the inflation is discussed first, and then the selection of the additional explanatory variables and the incorporation of the time-varying NAIRU.

(a) Models for Inflationary Expectations

Staiger, Stock, and Watson (1997a) provided three alternative approaches to model inflationary expectations: the first one is the AR (1) expectation, $\pi_t^e = c + \alpha\pi_{t-1}$; the second one is the recursive AR (p) expectation, $\pi_t^e = c + \alpha(L)\pi_{t-1}$; and consensus or median forecast survey. Here, AR denotes autoregressive and the survey forecasts refer to real-time forecasts as collected by contemporaneous survey of economists and forecasters. The premise of the AR (1) expectations model is that inflation is a highly persistent so this inflationary expectation can capture the long-term movements in inflation. And a simple approach is to set $\alpha = 1$. In addition, three methods are proposed in their paper to determine c: setting $c = 1$; estimating c over the full sample for fixed α; estimating c recursively for fixed α to simulate real-time expectations formation. The recursive AR (p) expectations are formed by first estimating a pth order autoregression for inflation and using the predicted values as π^e_{t-1}. This is implemented by recursive least squares estimation of the AR (p), which simulates the real-time forecasts that would be produced under the autoregressive assumption. The consensus or median forecasts survey can be the median value of forecasts from a panel of professional forecasts, which constitute a true real-time forecast of inflation or the mean forecast of the inflation rate over the six months following the survey date.

However, Staiger, Stock, and Watson (1997b) pointed out that the basic conclusions of the estimation results using different specifications of inflationary expectations remain unchanged. The only difference is that some real-time survey forecasts systematically underestimate inflation so using these alternative series for inflationary expectations sometimes affects the point estimates of the NAIRU.

Thus, according to Staiger, Stock and Watson (1997a, 1997b), although several specifications are possible candidates to model the inflationary expectations, the estimation results are, in fact, insensitive to these different specifications; consequently, the poor fitness of the expectation-augmented Phillips curve of the annual data for Taiwan cannot be contributed to specifications of inflationary expectations; and, therefore, considering different specifications of inflationary expectations is not necessary in estimating the NAIRU. So, In this paper, a "random walk" model for inflationary expectations is adopted, which is widely used in many literatures such as Congressional Budget Office (1994); Fuhrer (1995); Gordon (1990); Staiger, Stock and Watson (1997); Tootell (1994); Weiner (1993). In this random walk model, π^e_t is set to be equal to π_{t-1} so that $\pi_t - \pi_t^e = \pi_t - \pi_{t-1} = \Delta\pi_t$, which is the same as the assumption used in the previous discussion.

The conclusion from the preceding paragraphs about inflationary expectations is that the random walk model for inflationary expectations is suitable for the further estimation of the NAIRU without arousing any problems.

(c) Models for the constant NAIRU

Staiger, Stock, and Watson (1997a, 1997b) presented a modified expectation-augmented Phillips curve to estimate the NAIRU:

$$\pi_t - \pi_t^e = \beta(L)(u_{t-1} - u^*) + \delta(L)(\pi_{t-1} - \pi_{t-1}^e) + \gamma(L)X_t + \varepsilon_{t,} \tag{7}$$

where u_t is the unemployment rate, π_t is the inflation rate, π_t^e is the expected inflation rate, u^* is the NAIRU, L is the lag operator, $\beta(L)$, $\delta(L)$, and $\gamma(L)$ are lag polynomials, X_t is a vector of supply shock variables or other control variables such as price controls and ε_t is a serially uncorrelated error term.

This model includes the lagged effects of the unemployment gap and the supply shock variables and the possibility of serial correlation in the error term. And at this moment, the NAIRU is set to be constant over time; the random walk model is adopted for inflationary expectations.

When the NAIRU is treated as constant over time, it can be estimated directly from the coefficients of the unrestricted regression including an intercept; that is, Equation 7 can be rewritten in a form which can be conveniently estimated by ordinary least square (OLS):

$$\Delta\pi_t = \mu + \beta(L)u_{t-1} + \delta(L)\Delta\pi_{t-1} + \gamma(L)X_t + \varepsilon_{t,} \tag{8}$$

where $\mu = -\beta(1)u^*$ and $\beta(1) = \sum_{i=1}^{p}\beta_i$ with p being the order of the lag polynomial $\beta(L)$.

Here, the NAIRU is a nonlinear function of the coefficients μ and $\beta(1)$. Thus, the estimate of the NAIRU can be derived from this nonlinear function:

$$\hat{u}^* = -\hat{\mu} / \hat{\beta}(1) \tag{9}$$

where $\hat{\mu}$ is the estimated intercept from the unrestricted regression; $\hat{\beta}(1) = \sum_{i=1}^{p}\hat{\beta}_i$ and $\hat{\beta}_i$ is the estimated parameter of the explanatory variable, u_{t-i}.

The above method only works for the constant assumption of the NAIRU. If permitting the time-varying NAIRU, we have to find other methods to yield this unobservable series.

(d) Models for the time-varying NAIRU

As we have mentioned before, in recent literatures, several different methods have been employed to model the time-varying NAIRU.

Staiger, Stock, Watson (1997a) propose three alternative statistical models for the time-varying NAIRU: (1) the spline NAIRU: $u_t = \bar{\phi}' S_t$; (2) the break NAIRU: $u_t = u_i$ if $t_{i-1} < t \le t_{i-1,}$ $i = 1,\ldots,I$; (3)

the TVP (time-varying parameter) model: $u_t = u_{t-1} + \eta_t,$ IID $N(0, \lambda\sigma_\varepsilon^2)$. These models use no additional economic variables to identify the NAIRU so additional statistical assumptions are required to determine the NAIRU. In addition, these models represent different sets of statistical assumptions with a similar motivation, specifically, that the NAIRU potentially varies over time, but that this variation is smooth and in particular these movements are unrelated to the error term ε_t in the modified expectation-augmented Phillips curve. Staiger, Stock, Watson (1997a, 1997b) employed the spline model; Gordon (1997) and Perez (2000) adopted the TVP model; Chen (2001) employed the two-regime markov-switch model to generate the estimate of the NAIRU alternating between two constant NAIRUs.

In this paper, based on Sekhon (2001), the estimation approach outlined in Equation 6 can be altered directly to estimate the time-varying NAIRU by replacing μ with $\sum_{j=1}^{l} \alpha_j H^{j-1}(t)$ where H^j is a Hermite polynomial of order i and where t is the time argument centered around 0. Hence,

$$\Delta\pi_t = \sum_{j=1}^{l} \alpha_j \mathrm{H}^{j-1}(t) + \beta(L)u_{t-1} + \delta(L)\Delta\pi_{t-1} + \gamma(L)X_t + \varepsilon_t, \tag{10}$$

And the estimate of the time-varying NAIRU is

$$\hat{u}_t^* = -\sum_{j=1}^{l} \hat{\alpha}_j H^{j-1}(t) / \hat{\beta}(1) \tag{11}$$

where $\hat{\alpha}_j$ is the estimated coefficient of H^{j-1}; $\hat{\beta}(1) = \sum_{i=1}^{p} \hat{\beta}_i$ and $\hat{\beta}_i$ is the estimated coefficient of the explanatory variable, u_{t-i}.

Selection of the order of the Hermite polynomial can be done using Mallows' Cp.

In Equation 10 , the Hermite polynomial is incorporated to estimate the time-varying NAIRU.

Sekhon (2001) briefly introduced the Hermite polynomial . The Hermite polynomial is often used to implement cubic splines (de Boor, 1978). Hermite polynomial forms one of the families of classical orthogonal polynomial (Szego, 1975). The variance-covariance matrix is often well-conditioned (Hinich and Roll, 1981). The Hermite polynomial may be defined for $j > 0$ by the recurrence relation:

$$H^{j+1}(t) = 2tH^{j}(t) - 2jH^{j-1}(t) \tag{12}$$

where t is the time argument, j is the order and $H^{0}(t) = 1$; the argument, t, must be centered around 0 because the polynomials are orthogonal on the symmetric interval $(-\infty, \infty)$ with respect to the weighting function $w(t) = e^{-t^2}$,

$$\int_{-\infty}^{\infty} H^{j}(t)H^{k}(t)e^{-t^2}dt = 2^{k}k!\pi^{\frac{1}{2}}\delta^{jk}, \qquad j,k \geq 0 \tag{13}$$

A few Hermite polynomials which are used in the later estimation are calculated and listed below:

$$H^{1}(t) = 2tH^{0}(t)$$

$$= 2t \tag{14}$$

$$H^{2}(t) = 2tH^{1} - 2H^{0}(t)$$

$$= 4t^{2} - 2 \tag{15}$$

$$H^{3}(t) = 2tH^{2}(t) - 4H^{1}(t)$$

$$= 8t^{3} - 12t \tag{16}$$

$$H^4(t) = 2tH^3(t) - 6H^2(t)$$

$$= 16t^4 - 48t^2 + 12 \tag{17}$$

$$H^5(t) = 2tH^4(t) - 8H^{j-1}(t)$$

$$= 32t^5 - 160t^3 + 120t \tag{18}$$

$$H^6(t) = 2tH^5(t) - 10H^4(t)$$

$$= 64t^6 - 480t^4 + 720t^2 - 120 \tag{19}$$

$$H^7(t) = 2tH^6(t) - 12H^5(t)$$

$$= 128t^7 - 1344t^5 + 3360t^3 - 1680t \tag{20}$$

As these equations show, the polynomials increase in size very quickly; and this is one reason why the parameters associated with the polynomials are extremely difficult to interpret. However, Sekhon (2001) pointed out that this method is similar to the spline model used in Staiger, Stock, Watson (1997a, 1997b) where the NAIRU is approximated by a cubic spline in time, but less computation is required for Hermite polynomials than for cubic splines. Moreover, in our opinion, when we are estimating the time-varying NAIRU, no statistical evidence can prove which one is the best mehtod; and the method used in recent literatures depends on the author's choice. Therefore, the best way to justify the usefulness and credibility of this method is to evaluate estimation results in economic reasoning or its forecasting performance.

4. Empirical Results

4.1 Data Description

The data are monthly observations from the AREMOS data bank including the unemployment rate (RU), the consumer price index (CPI), the import price index (MPI), the consumer price index excluding energy and food (CPIEEF). The monthly data of the unemployment rate, the CPI, the MPI covers the periods from 1978: m1 to 2002: m2; however, the consumer price index excluding energy and food only ranges from 1981: m1 to 2002: m2, which causes the loss of the observations from 1978: m1 to 1980: m12, 36 observations. Therefore, after the adjustment of endpoints, the estimation sample period for the constant NAIRU is from 1981: m9 to 2002: m2, which is 246 observations and for the time-varying NAIRU from 1982:m3 to 2002:m2, 240 observations. Figure 2 is the monthly unemployment rate for Taiwan from 1978: m1 to 2002: m2. As we can see, the unemployment rate climbed from around 1% to 2% in the late 1970s and early 1980s to around 2% to 4% in the middle 1980s. After the peak of 4.1% in August 1985, the unemployment rate declined gradually below 2% in the late 1980s and, again, fluctuated around 1 to 2 percent for around five years; from 1996, the unemployment rate started to rise quickly and fluctuated around 3% for four years. In July 2000 to July 2001, it only took one year for the unemployment rate to surge from around 3% to almost 5%. Since July

2001, the unemployment rate has stayed around 5% for one year.

After the collection of these monthly data, the CPI inflation (INFCPI) is represented by the percentage change of the CPI; In addition, we also calculated the percentage change of the MPI (INFMPI) and the percentage change of the CPI excluding energy and food (INFCPIEEF). Then, the difference between the overall CPI inflation and the percentage change of the CPI excluding energy and food was calculated and denotes the percentage change of the energy and food price index (INFCPIEF). The percentage change of the energy and food price index (INFCPIEF) and the percentage change of the MPI (INFMPI) are the candidates for the supply shock variables, X_t.

4.2 Unit Root Tests

Before the estimation, two unit root tests are performed to investigate time series features of the above series. And the regression equations employed for the unit root tests are described in Equation 5 and 6.

As Table 2 shows, ADF test statistics fail to reject the null of non-stationary in the levels of the unemployment rate, the INFCPI, and the INFCPEEEF under 1% and 5% critical values and in the difference of the unemployment rate under 1% critical value. Phillips-Perron test statistics confirm the non-stationary in the level of the unemployment rate under 1% and 5% critical values but clearly reject non-stationary in the levels of INFCPI, INFCPEEEF, INFMPI, INFCPIEF, and INFMPI and in the differences of all series.

In a word, the ADF test and the Phillips-Perron test both confirm the unit root property of the monthly unemployment rate, but as for the DRU, INFCPI, INFCPIEEF, the results are contradictory: the ADF test fail to reject the null hypothesis but the Phillips-Perron significantly reject the null hypothesis. However, Chen (2001) pointed out that the failure to reject the unit root hypothesis might come from the limited power performance of the ADF test. Thus, the results from the Phillips-Perron test are accepted; and we may conclude that the monthly unemployment rate exhibits hysteresis, which means that one-time disturbances of the unemployment rate permanently affect its path. Moreover, from the results of the two tests, without any question, the dependent variable in the our estimation, DINFCPI, is stationary.

4.3 Estimations of the NAIRU

4.3.1 Estimation of the Constant NAIRU

In Staiger, Stock, and Watson (1997a, 1997b), the data used in the regression equations includes twelve lags of the monthly data or four lags of the quarterly data.

In my regression equation, the dependent variable is the difference of the CPI inflation (DINFCPI), the explanatory variables include a constant term (C), twelve lags of the unemployment rate (RU), twelve lags of the difference of the CPI inflation (DINFCPI), six lags of the difference of the percentage change of the energy and food index (DINFCPIEF), which are the only one supply shock variable. Notice that contemporaneous variables are not incorporated in this regression equation. The estimation is accomplished by the ordinary least squares (OLS). The estimation results are presented in Table 4.

In Table 4, several points are worth mention. First, the adjusted R^2, $\overline{R}^2$, is around 0.624, which is higher than 0.431 in Staiger, Stock and Watson (1997a) so that the model is fitted better in Taiwan than in the United States. More, since the p-value of the F-statistic for the whole model is less than 0.01, the whole model is significant. Thus, the model is supported by not only its own economic reasoning but also the statistical evidence. Second, among the twelve lags of the DINFCPI, except the eleventh and twelfth lags, which have the p-value of 0.1332 and 0.7765 respectively, are insignificant, the rest are significant with the first nine lags having the p-value less than 0.01 and the last one less than 0.05. This phenomenon shows that the lagged influence of the DINFCPI lasts almost one year; As for the lags of the DINFCPIEF, having the p-value less than 0.06, all of them are significant; accordingly, we may conclude that the lag influence of the DINFCPIEF only persists for half a year. However, most of the lags of the unemployment rate have very large p-values and insignificant except RU (-7); and RU (-5), and RU (-8) with the p-value of 0.0591 and 0.0601 slightly larger than 0.05. So we may conclude that the lagged influence of the unemployment rate appears after around half a year.

After the estimation, the constant NAIRU can be calculated by Equation 9: $\hat{u}^* = -\hat{\mu} / \hat{\beta}(1)$; in our regression results, the $\hat{\mu}$ is replaced by $\hat{c}$, which is –0.219753; the $\hat{\beta}(1) = \sum_{i=1}^{12} \hat{\beta}_i = 0.091026$. Although most of the lags of the unemployment rate are insignificant, $\hat{\beta}(1) = 0.091026$, which is positive, is consistent with the assumption of the negative relationship between the inflation gap and the unemployment gap in the original Expectation-Augmented Phillips Curve and the modified one. So the estimate of the constant NAIRU is positive and equal to 2.414%.

4.3.2 Estimation of the Time-Varying NAIRU

After the estimation of the constant NAIRU, to yield the time-varying NAIRU, Hermite polynomial is incorporated into the regression equation. In our regression equation, the order of Hermite polynomial is two and equation 10 can be written as:

$$\Delta\pi_t = \alpha_1 H_0(t) + \alpha_2 H_1(t) + \alpha_3 H_2(t) + \beta(L)u_{t-1} + \delta(L)\Delta\pi_{t-1} + \gamma(L)X_t + \varepsilon_t, \qquad (21)$$

The supply shock variable employed in Equation 21 is the same as that used in estimating the constant NAIRU; and the number of the lags of the explanatory variables is also twelve and six for the INFCPIEF. Identically, the estimation is done by the ordinary least squares (OLS). The estimation results are presented in Table 5.

In Table 5, first, the adjusted R^2, $\bar{R}^2$, is around 0.635, which is similar to the one in the estimation output of the constant NAIRU; moreover, the p-value of the F-statistic for the whole model is less than 0.01. Therefore, we can ensure the significance of the whole model. Secondly, The first eleven lags of the DINFCPI are significant with p-value less than 0.01; the last lag of the DINFCPI is insignificant with p-value 0.1916 Among the six lags of the DINFCPIEF, all of them are significant with p-value less than 0.05. The significance of the lags of the unemployment is that: the fifth and seventh lags are significant; the others are insignificant. In fact, in the estimation of the time-varying NAIRU, the results of the significance of these explanatory variables are almost identical to those in the estimation of the constant NAIRU. After the estimation, the time-varying NAIRU can be derived from Equation 12: $\hat{u}_t^* = -\sum_{j=1}^{3} \hat{\alpha}_j H^{j-1}(t)/\hat{\beta}(1)$. And the estimate of the time-varying NAIRU is presented in Figure 3 with the monthly unemployment rate and the estimate of the constant NAIRU.

5. Discussion

In this section, the significance of the selected explanatory variables and the adoption of order 2 of the Hermite polynomial are ensured by the likelihood ratio test and the model comparsion using different orders. Then, the different estimates of the NAIRU are compared, including the constant and time-varying ones estimated in this paper, two-stage time-varying NAIRU estimated in Chen (2001) and the two estimates of the natural rate of unemployment estimated in Hsu (1998). Finally, implications of the estimate of the time-varying NAIRU are presented.

5.1 Specification and Diagnostic Tests

Before comparing and explaining different estimates of the NAIRU in economic reasoning, we cast some doubts on the model specification and diagnose it by the likelihood ratio test.

Based on the estimation results, some possible misspecifications may exist. To begin with, as we have pointed out that most of the lags of the unemployment rate are insignificant with the p-value less than 0.05; but we still incorporate them in the regression equation, using their estimated coefficients to calculate the constant NAIRU. In addition, the supply shock variables are represented only by the six lags of the DINFCPIEF, the difference of the percentage change of energy and food price index; however, some other supply shock variables may be useful and significant to explain the dependent variables, the DINFCPI. Third, in estimating the time-varying NAIRU, other orders of the Hermite polynomial may fit the data better than order 2. Thus, in this section, the likelihood ratio test is employed to examine for redundant and omitted variables; and the results are presented in Table 6. Next, other orders of the Hermite polynomial are considered in estimating the time-varying NAIRU; The estimation results are compared in Figure 4.

First of all, the likelihood ratio test is performed to check if the twelve lags of the unemployment rate are jointly insignificant and redundant. The estimation results show that the p-value of the likelihood ratio test is 0.001; the p-value of the redundant variables test of the first six lags of the unemployment rate is 0.002; the p-value for the last six lags is 0.041. Thus, although most of the twelve lags of the unemployment rate are insignificant, they are jointly significant and cannot be dropped out from the regression equation. Second, using the likelihood ratio test, the twelve lags of the INFMPI are examined to see if they should not be omitted from the original model. The estimation results are that the p-value 0.969 is greatly larger than 0.05 so this additional set of regressors is not omitted variables. In addition to the above diagnoses, the jointly significance of the twelve lags of the DINFCPI and the six lags of the DINFCPIEF are tested. Undoubtedly, their p-value is very small and less than 0.01; Consequently, without question, they are both jointly significant.

After the significant test, different orders of the Hermite polynomial are consider in estimating the time-varying NAIRU. In the preceding estimation, we selected order 2 to estimate the time-varying NAIRU. Here, in Figure 4 three additional time-varying NAIRU are estimated and presented using the Hermite polynomial of order one, three and four. In Figure 4, the tvnairu2 is our original estimate, the tvnairu1 stands for order one, the tvnairu3 for order 3 and the tvnairu4 for order 4. Comparing these four different estimates of the time-varying NAIRU, we find out that the tvnairu2 is the most reasonable one in these four estimates based on economic reasoning. The economic reasoning is that the estimate of the time-varying NAIRU should be quite stable and reflect the trend of the unemployment rate. The reasons are below. According to the textbook definition of the NAIRU, the NAIRU can be divided into two unemployment rate, the frictional unemployment rate and the structural unemployment rate, and the gap between the overall unemployment rate and the time-varying NAIRU is the cyclical unemployment rate. Hence, it should be less volatile than the overall unemployment. Second, in addition to the stability, if the estimate of the NAIRU can not reflect the trend of the unemployment rate, then the gap between the estimated NAIRU and the overall unemployment rate should be viewed as the cyclical unemployment rate, which is hard to explain, especially when the gap is very large.

In Figure 4, four estimates of the time-varying NAIRU are all more stable than the overall unemployment rate. The tvnairu1 reflects the rising trend of the recent unemployment rate; yet, it does not reflect the trend of the overall unemployment in the late 1980s and early 1990s, which descended from about 3 to 4 percent to 1 to 2 percent and stayed there by 1996. In addition, the trends of the tvnairu3 and tvnairu4 are basically consistent with that of the overall unemployment rate, but inconsistent in Year 2000 and 2001. In Year 2000 and 2001, the overall unemployment rate ascended drastically from around 3% to 5%, but the tvnairu3 and tvnairu4, after having increased in the mid-1990s and late 1990s, started to fall during these two years. This inconsistence with the recent trend makes us choose order 2 of the Hermite polynomial and reject the possibility of other orders. Additionally, we have tried to estimate the time-varying NAIRU based on higher orders of the Hermite polynomial, discovering that the higher the order is, the more inconsistent the trend is in Year 2000 and 2001. As a matter of fact, as we have mentioned in the section of the econometric methodology, selection of the order of the Hermite polynomial can be done using statistical reasoning, Mallows' Cp. Yet, the economic reasoning in this section is strong enough to support the adoption of order 2. And even though statistical reasoning had supported other order, we would not have adopted this order because any estimate based on other orders is meaningless under economic reasoning.

5.2 Comparison of Different Estimates

In this section, several estimates of the NAIRU are compared and contrasted.

In our paper, two types of the NAIRU are estimated: the constant one with the estimate of 2.414% and the time-varying one with the trend similar to the overall unemployment. Using two methods, Hsu (1998) estimated two different estimates of the time-varying NAIRU: one is very similar to the overall unemployment rate; the other is less volatile, reflecting the trend of the overall unemployment rate. In his paper, the results are shown in Figure 7. Chen (2001) estimates two-stage time-varying NAIRU: one stage is 1.538%; the other stage is 2.771%.

We judge these five estimates of the NAIRU using three criteria: the reasonable NAIRU should be more stable than the overall unemployment rate; the reasonable NAIRU should reflect the trend of the overall unemployment rate; the model employed in the estimation should be logical. The first and second criteria are based on the textbook definition of the NAIRU; that is, the NAIRU is composed of the frictional unemployment rate and the structural unemployment rate; and the difference between the overall unemployment rate and the NAIRU is the cyclical unemployment rate. The cyclical unemployment rate is considered to be more volatile, causing the volatility of the overall unemployment rate. Therefore, the time-varying NAIRU should be more stable than the overall unemployment rate but still can reflect the long-term trend of the overall unemployment rate. Moreover, if the model employed in the estimation is spurious, then the estimation results may not be correct.

Based on the above three criteria, the estimate of the time-varying NAIRU estimated in our paper may be the most reasonable one in these five estimates. To begin with, in Figure 3, we can find out that our estimate is less volatile than the overall unemployment rate and does reflect the trend of the overall unemployment rate. Second, the model used to generate this estimate can explain the inflation gap well: the adjusted $\bar{R}^2$ of the regression is above 0.6. Our constant estimate is, as its name shows, constant over the sample period, and clearly cannot reflect the long-term trend of the overall unemployment rate. In his paper, Hsu (1998) presented his two estimates in Figure 7. As we can see, resembling the overall unemployment rate, one of his estimates is as volatile as the overall unemployment rate. So this estimate is not likely to be the real NAIRU. The other is less volatile and can reflect the long-term trend of the overall unemployment rate. However, in Section 2.2.2, we have pointed out the problems of the model the author used in generating this estimate: first, we have not found any recent literature using the same or similar models to estimate the NAIRU; second, no theory can support his model; third, the author does not explain his regression results properly in econometric reasoning; Fourth, the overall unemployment rate, the dependant variable in his model, is non-stationary. Therefore, we do not think these two estimates are reasonable. Chen (2001) presented his two-stage time-varying NAIRU in Figure 7 in his paper. The problems of this estimate is that it cannot reflect the trend of the overall unemployment rate in Year 2000 and 2001; and, over the sample period, this two-regime NAIRU also cannot show the transition from one stage to the other. To put it more clearly, in Year 2001 and 2001, the overall unemployment rate surged from around 3% to 5%. Yet, the estimate of the NAIRU in the high-NAIRU stage is only 2.771 percent. Thus, as Figure 7 shows in his paper, two-stage time-varying NAIRU may reflect the trend of the overall unemployment rate by Year 2000 but cannot reflect the trend after Year 2000. Moreover, in this two-stage NAIRU model, the estimate jumps from one regime to the other directly so we cannot know what happened in the transition. And there also exist some problems in the author's model, which have been discussed in Section 2.2.2: first, the author supported his model by rejecting the unit root hypothesis of the overall unemployment rate. However, in our unit root tests, the overall unemployment rate does have the unit root property; second, the author also estimated three-regime NAIRU, claiming that this estimate was also possible. As a result, we also do not think his estimate is reasonable.

5.3 Implications and Policy Suggestions

Our estimate of the time-varying NAIRU has four implications. First, it takes years for the NAIRU to rise or fall by 1%. In Figure 3, the NAIRU took around four years to decrease by 1%, around from 1983 to 1987; it also took around four years to increase by 1%, around from 1995 to 1999. Hence, when the NAIRU is low, in the short run, it is expected to be low; contrarily, when high, in the short run, it is expected to be high and is not possible to descend suddenly. Second, the estimate shows that our NAIRU have exceeded 3 percent since 1999 and mounted to 4 percent in 2001; and from the trend, the NAIRU is expected to ascend further after 2001. Consequently, if this estimate is correct, we will have a even higher NAIRU in the future; furthermore, because of the slow adjustment of the NAIRU, this phenomenon is expected to maintain in the short run. And even if the NAIRU starts to descend in 2002, it have to take around 4 years to decrease by 1%. This means that we will not have a lower NAIRU, around 3 percent, until 2006. The third implication is that the central bank can continue to maintain a loose monetary policy. The overall unemployment rate has exceeded the NAIRU since 2001, and the gap between them seems to expand gradually. Moreover, the annual inflation rate is still low and fluctuating around zero. Thus, without the threat of inflation, the central bank can continue to pursue a loose monetary policy, trying to minimize cyclical unemployment. The fourth implication is that in recent years the increase in the overall unemployment rate and the outcome of a higher overall unemployment rate were greatly caused by the increase in the NAIRU. Consequently, although our government can continue to maintain a loose monetary policy to tackle cyclical unemployment, without the adoption of other solutions, such as reeducation of the unemployed, adjustments of labor laws, acceleration of the structural adjustment of the industry, we may have to tolerate a higher unemployment rate not only in the short run but also in the long run.

6. Conclusions

In this paper, the modified expectation-augmented Phillips equation is employed to estimate the NAIRU. Compared with the models used in Hsu (1998) and Chen (2001), this model is reasonable under economic and statistical reasoning. As far as the economic reasoning is concerned, in the model, the assumption of the negative relationship between the inflation gap and the unemployment gap is consistent with the data; as far as the statistical reasoning is concerned, our model performs well in explaining the inflation gap, with the adjusted R^2 of the regression above 0.6. In addition, our estimate of the time-varying NAIRU owns two advantages. One is that it is less volatile than the overall unemployment rate. The other is that it can reflect the trend of the overall unemployment over the sample period. In addition, this estimate has four implications. First, the adjustment of the time-varying NAIRU is slow. Second, as the trend of the estimate shows, we have to tolerate a higher NAIRU and unemployment rate in the short run. Third, since the gap between the overall unemployment rate and the NAIRU is positive and large and the inflation rate is still low, the central bank can continue to maintain a loose monetary policy to solve cyclical unemployment. Fourth, the high unemployment rate in recently years is largely due to the high NAIRU. Thus, without proper and complete solutions to deal with the high NAIRU, we may have to tolerate a higher unemployment rate for a long time in the future.

Finally, readers who are interested in the estimation of the NAIRU can employ different models to see if estimates are sensitive to model specifications, and if these estimates have different implications and policy suggestions for the high unemployment rate in recent years in Taiwan.

Appendix

Figure 1.
Year-to-Year Change in CPI Inflation vs. Total Unemployment in the Previous Year and Regression Line, Annual Data for Taiwan, 1961-2000.

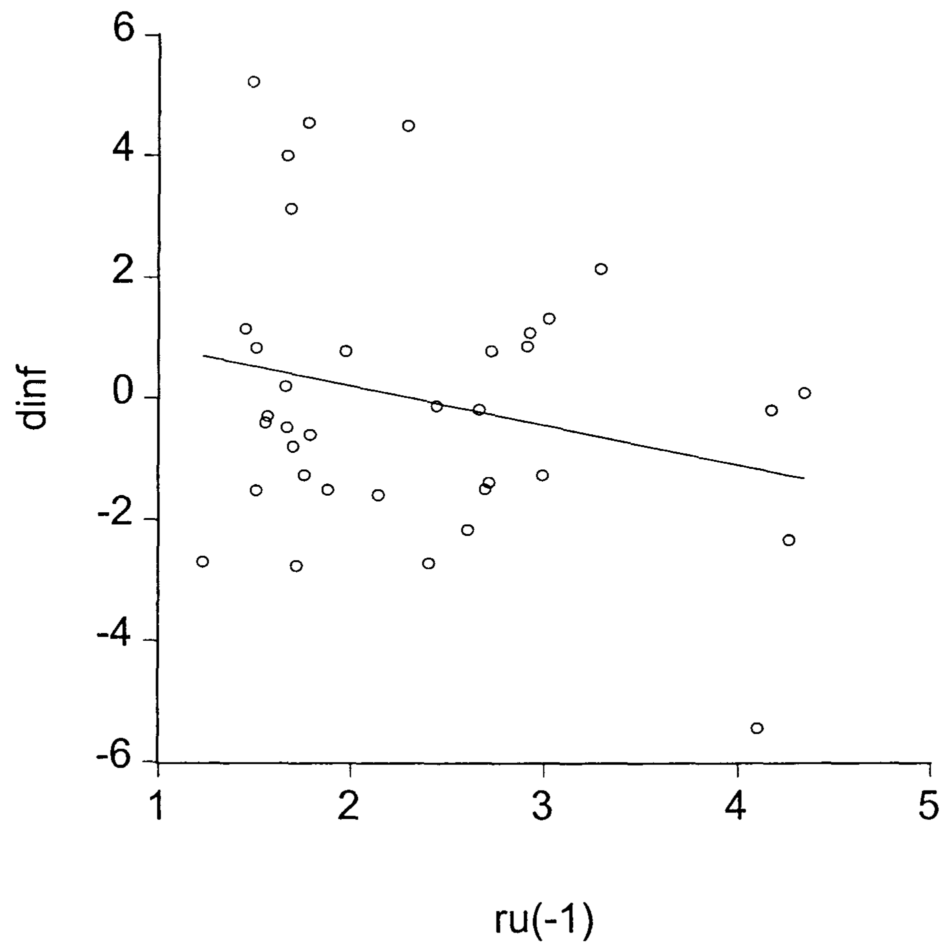

Figure 2.
The Monthly Unemployment Rate for Taiwan, 1978: m1-2002: m2.

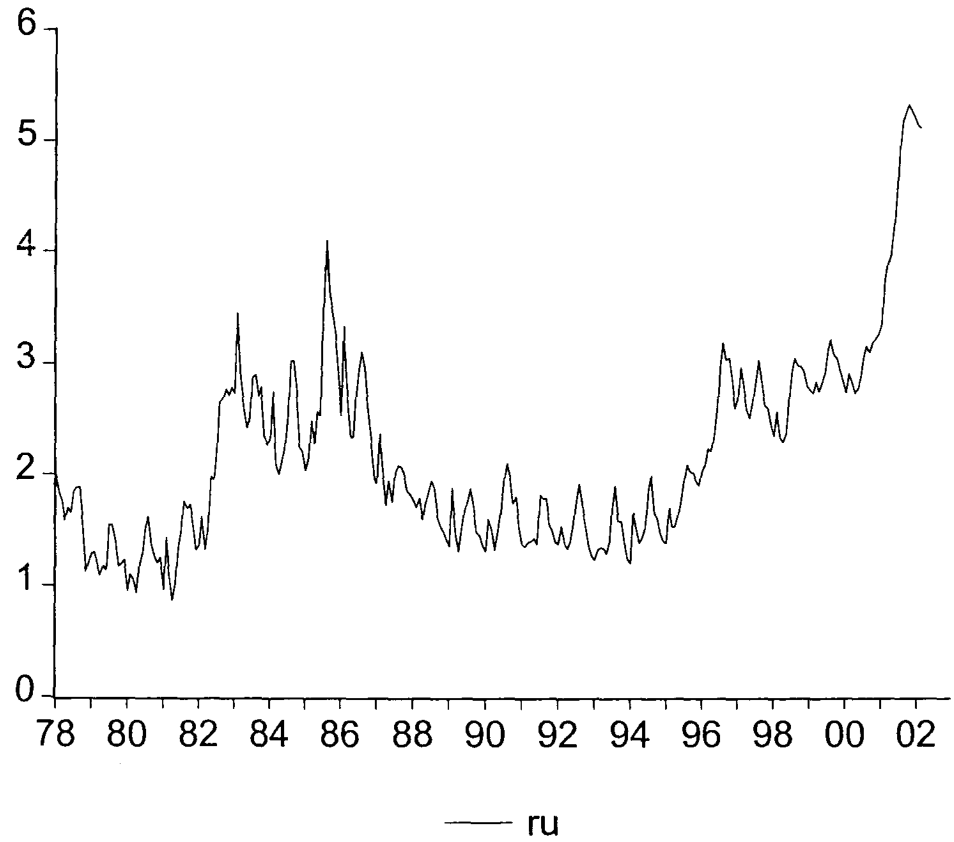

Figure 3.
The Estimates of the Constant and Time-Varying NAIRU with the Monthly Unemployment Rate.

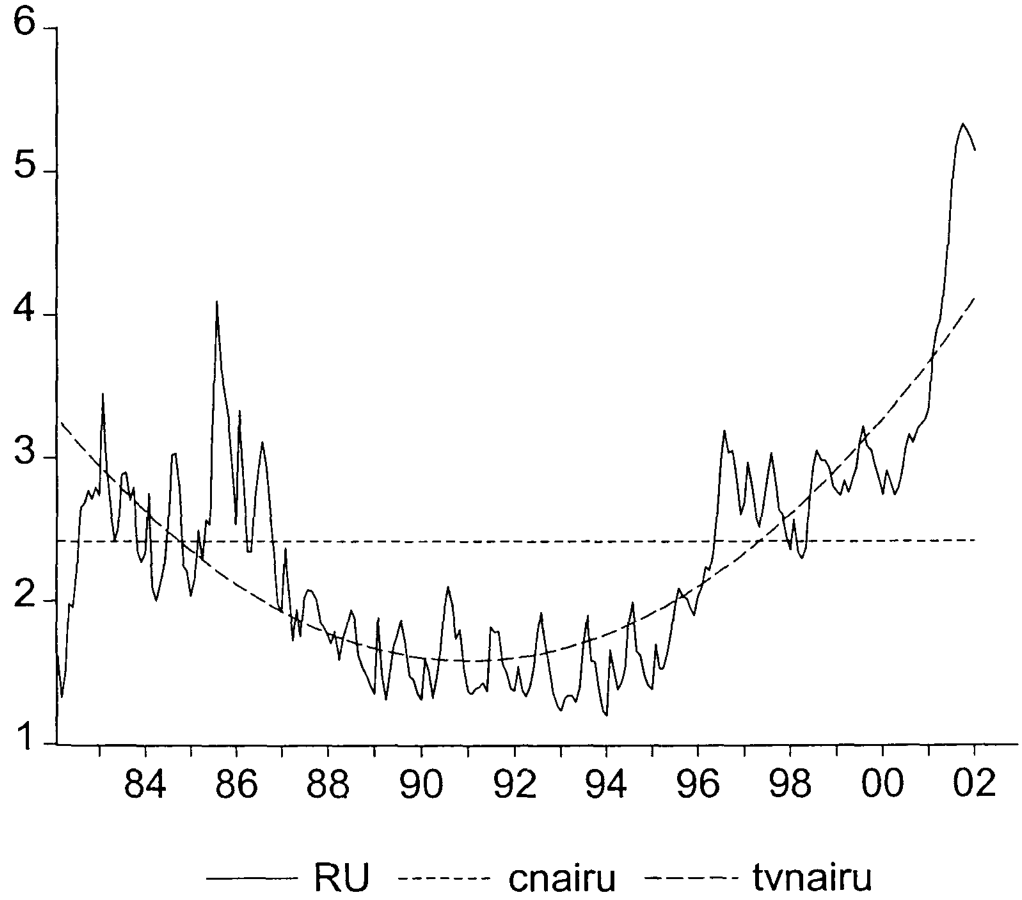

Figure 4.
The Estimates of the Time-Varying NAIRU Using Hermite Polynomial Series of Order One, Two, Three and Four.

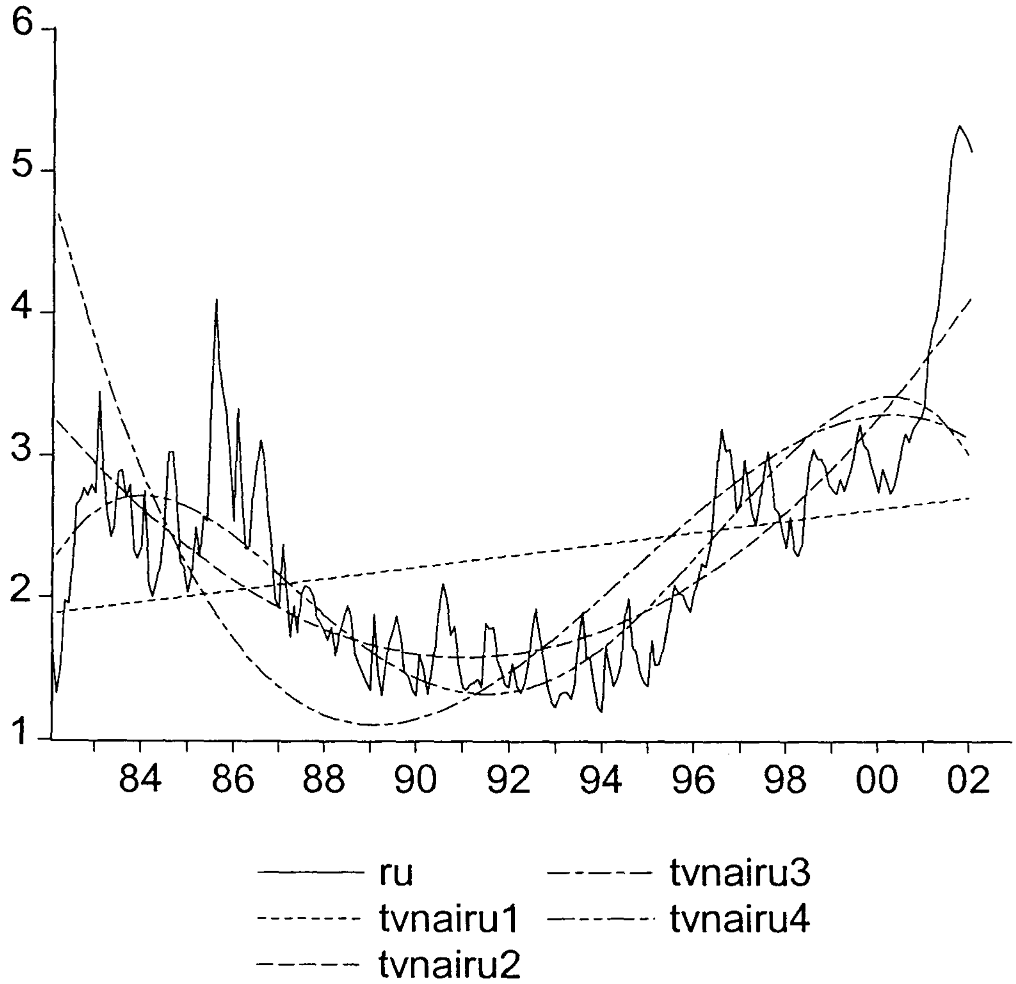

Table 1.
The Omitted Annual Observations in Figure 1

Year	The Unemployment Rate (%)	The Inflation Gap (%)
1961	3.98	-10.69
1974	1.26	39.28
1975	1.53	-42.25
1980	1.28	9.26
1982	1.36	-13.36

Table 2.

Unit Root Test (Augmented Dickey-Fuller test)

Variable	*t*-stat.	1% critical value	5% critical value
RU	-0.619291	-3.4557	-2.8721
DRU	-2.444860	-2.5731	-1.9407
INFCP	-2.047144	-3.4557	-2.8721
DINFCPI	-8.848383	-2.5731	-1.9407
INFCPIEEF	-1.961995	-3.4591	-2.8737
DINFCPIEEF	-12.05487	-3.4592	-2.8737
INFMPI	-4.020209	-2.5730	-1.9407
DINFMPI	-11.83654	-3.9939	-3.4271
INFCPIEF	-9.663261	-3.9983	-3.4292
DINFCPIEF	-13.36418	-3.4584	-2.8733

Table 3.

Unit Root Test (Phillips-Perron Test)

Variable	*t*-stat.	1% critical value	5% critical value
RU	-1.556279	-3.9934	-3.4268
DRU	-15.86094	-3.9935	-3.4269
INFCP	-16.14111	-3.9934	-3.4268
DINFCPI	-43.69200	-3.9935	-3.4269
INFCPIEEF	-21.05019	-3.9977	-3.4289
DINFCPIEEF	-61.36084	-3.9978	-3.4290
INFMPI	-11.69395	-3.9934	-3.4268
DINFMPI	-34.44252	-3.9935	-3.4269
INFCPIEF	-16.37849	-3.9977	-3.4289
DINFCPIEF	-37.80244	-3.9978	-3.4290

Table 4.

The Regression Output of the Estimation of the Constant NAIRU

Dependent Variable: DINFCPI
Method: Least Squares
Date: 07/10/02 Time: 19:55
Sample(adjusted): 1981:09 2002:02
Included observations: 246 after adjusting endpoints

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
C	-0.219753	0.198094	-1.109335	0.2685
RU (-1)	-0.030865	0.280750	-0.109936	0.9126
RU (-2)	0.618560	0.402176	1.538035	0.1255
RU (-3)	-0.059712	0.407963	-0.146365	0.8838
RU (-4)	-0.587487	0.409168	-1.435807	0.1525
RU (-5)	-0.766084	0.403754	-1.897402	0.0591
RU (-6)	0.437358	0.401892	1.088247	0.2777
RU (-7)	0.833601	0.397742	2.095833	0.0373
RU (-8)	-0.732898	0.387845	-1.889668	0.0601
RU (-9)	-0.302504	0.389418	-0.776811	0.4381
RU (-10)	0.540109	0.381848	1.414459	0.1587
RU (-11)	0.161163	0.385156	0.418434	0.6760
RU (-12)	-0.020215	0.287837	-0.070232	0.9441
DINFCPI (-1)	-1.508238	0.110533	-13.64513	0.0000
DINFCPI (-2)	-1.711758	0.175469	-9.755321	0.0000
DINFCPI (-3)	-1.731012	0.206465	-8.384055	0.0000
DINFCPI (-4)	-1.567694	0.212690	-7.370805	0.0000
DINFCPI (-5)	-1.344469	0.200332	-6.711202	0.0000
DINFCPI (-6)	-0.989182	0.172148	-5.746115	0.0000
DINFCPI (-7)	-0.603339	0.154194	-3.912849	0.0001
DINFCPI (-8)	-0.479044	0.149536	-3.203528	0.0016
DINFCPI (-9)	-0.403038	0.138078	-2.918908	0.0039
DINFCPI (-10)	-0.305924	0.119780	-2.554050	0.0113
DINFCPI (-11)	-0.141372	0.093783	-1.507441	0.1332
DINFCPI (-12)	-0.018061	0.063551	-0.284197	0.7765
DINFCPIEF (-1)	0.461901	0.121417	3.804259	0.0002
DINFCPIEF (-2)	0.594177	0.183643	3.235500	0.0014
DINFCPIEF (-3)	0.619863	0.209765	2.955029	0.0035
DINFCPIEF (-4)	0.627969	0.208179	3.016483	0.0029
DINFCPIEF (-5)	0.594730	0.180960	3.286519	0.0012

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
DINFCPIEF (-6)	0.395392	0.121794	3.246413	0.0014
R-squared	***0.669749***	***Mean dependent var.***		***0.000982***
Adjusted R-squared	***0.623668***	***S.D. dependent var.***		***1.411726***
S.E. of regression	***0.866036***	***Akaike info criterion***		***2.667558***
Sum squared resid	***161.2539***	***Schwarz criterion***		***3.109287***
Log likelihood	***-297.1096***	***F-statistic***		***14.53403***
Durbin-Watson stat	***1.986216***	***Prob. (F-statistic)***		***0.000000***

Table 5.

The Regression Output of the Estimation of the Time-Varying NAIRU.

Dependent Variable: DINFCPI
Method: Least Squares
Date: 07/10/02 Time: 20:07
Sample(adjusted): 1982:03 2002:02
Included observations: 240 after adjusting endpoints

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
H0	-0.383369	0.440069	-0.871156	0.3847
H1	0.001841	0.002455	0.749717	0.4543
H2	-4.28E-06	5.42E-06	-0.790139	0.4304
RU (-1)	-0.017418	0.296491	-0.058746	0.9532
RU (-2)	0.720527	0.404554	1.781043	0.0764
RU (-3)	0.005852	0.409926	0.014276	0.9886
RU (-4)	-0.488662	0.411027	-1.188878	0.2358
RU (-5)	-0.887671	0.403322	-2.200901	0.0288
RU (-6)	0.319023	0.403329	0.790976	0.4299
RU (-7)	0.815220	0.402778	2.023994	0.0443
RU (-8)	-0.685152	0.395013	-1.734504	0.0843
RU (-9)	-0.336884	0.397192	-0.848165	0.3973
RU (-10)	0.513005	0.390979	1.312105	0.1909
RU (-11)	0.096168	0.392698	0.244891	0.8068
RU (-12)	0.063150	0.292605	0.215821	0.8293
DINFCPI (-1)	-1.516970	0.110016	-13.78864	0.0000
DINFCPI (-2)	-1.737473	0.175265	-9.913391	0.0000
DINFCPI (-3)	-1.787490	0.207276	-8.623734	0.0000
DINFCPI (-4)	-1.687636	0.216526	-7.794147	0.0000
DINFCPI (-5)	-1.557338	0.211137	-7.375970	0.0000
DINFCPI (-6)	-1.277440	0.193110	-6.615095	0.0000
DINFCPI (-7)	-0.934037	0.183197	-5.098540	0.0000
DINFCPI (-8)	-0.790502	0.176621	-4.475701	0.0000
DINFCPI (-9)	-0.680558	0.162266	-4.194077	0.0000
DINFCPI (-10)	-0.530900	0.139448	-3.807154	0.0002
DINFCPI (-11)	-0.288740	0.107368	-2.689252	0.0077
DINFCPI (-12)	-0.090895	0.069374	-1.310222	0.1916
DINFCPIEF (-1)	0.399035	0.122217	3.264964	0.0013
DINFCPIEF (-2)	0.475583	0.186716	2.547091	0.0116
DINFCPIEF (-3)	0.475369	0.214087	2.220450	0.0275

Variable	Coefficient	Std. Error	*t*-Statistic	Prob.
DINFCPIEF (-4)	0.490003	0.212035	2.310954	0.0218
DINFCPIEF (-5)	0.507479	0.182633	2.778687	0.0060
DINFCPIEF (-6)	0.359471	0.122065	2.944915	0.0036
R-squared	***0.683831***	***Mean dependent var.***		***0.006432***
Adjusted R-squared	***0.634954***	***S.D. dependent var.***		***1.421736***
S.E. of regression	***0.858999***	***Akaike info criterion***		***2.660982***
Sum squared resid	***152.7411***	***Schwarz criterion***		***3.139570***
Log likelihood	***-286.3179***	***F-statistic***		***13.99101***
Durbin-Watson stat	***1.992762***	***Prob. (F-statistic)***		***0.000000***

Table 6.
Specification and Diagnostic Tests (the Likelihood Ratio Test)

	p-value
Redundant variables	
RU (-1 to -12)	0.001
RU (-1 to -6)	0.002
RU (-7 to -12)	0.041
DINFCPI (-1 to -12)	<0.001
DINFCPIEF (-1 to -6)	0.001
Omitted variables	
DINFMPI (-1 to -12)	0.969
DINFMPI (-1 to –6)	0.897
DINFMPI (-7 to -12)	0.918

References:

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