# The Labour Market in Macroeconomic Models of the Australian Economy*

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## Abstract

This paper examines the treatment of the labour market in three macroeconometric models of the Australian economy: the Australian Treasury Macroeconomic (TRYM) model, the Access Economics Macro (AEM) model, and the Murphy model. In each of these models, employment and unemployment are basically determined at the aggregate level (though in the Murphy model, labour demand is determined at the industry level). The unemployment rate converges in the long run to an equilibrium level at which the average rate of real-wage inflation across the economy is equal to the rate of productivity growth in the economy. This rate, the non-accelerating inflation rate of unemployment or NAIRU, is given by an expectations-augmented Phillips curve. In each of the models, the NAIRU is treated as exogenous and its value is estimated as a parameter of the model. In the short run, expected wage inflation depends on deviations of the unemployment rate from the NAIRU and on a number of other variables including, in all the models, the change in the unemployment rate (a "speed-limit" effect). This makes it possible to define a "short-run" or "flexible" NAIRU as the unemployment at which expected real-wage inflation equals the rate of productivity growth, and this short-run NAIRU depends on lagged unemployment.

# 1. Introduction

## *1.1 General introduction*

This paper examines the treatment of the labour market in three macroeconometric models of the Australian economy: the Treasury Macroeconomic (TRYM) model of the Australian economy, the Access Economics Macro (AEM) model, and the Murphy model.

There are strong similarities between the models, in part because they all descend (though often with substantial modifications) from the National Income Forecasting (NIF) models developed in the Commonwealth Treasury in the 1970s and 1980s. The similarity is especially strong with respect to the labour market, in particular in relation to unemployment. There are three key aspects to this:

- First, in each of the models employment and unemployment are basically determined at the aggregate level—that is, it is not built up from industry-specific, skill-specific, state-specific, age-specific or gender-specific levels. The TRYM model works entirely at the aggregate level. The AEM model includes industry and state detail for output and employment, but this is a decomposition of the corresponding aggregate variables. In the Murphy model, labour demand is determined at the industry level, but the unemployment rate is an aggregate variable.
- Second, in each of the models, the unemployment rate converges in the long run to an equilibrium level at which the average rate of wage equation across the economy is equal to the rate of productivity growth in the economy. This rate, the non-accelerating inflation rate of unemployment or NAIRU, is given by an expectations-augmented Phillips curve. In each of the models, the NAIRU is constant and is treated as exogenous—that is, its value is estimated as a parameter of the model an is not explicitly related to other aspects of the economy.
- Third, expected wage inflation in the short run depends on deviations of the unemployment rate from the NAIRU and also on several other variables. In particular, all models include the change in the unemployment rate as a determinant of expected wage inflation. This means that, in the short run, the unemployment rate at which expected wage inflation equals the rate of productivity growth is not equal

to the NAIRU unless the unemployment rate is already equal to the NAIRU. This makes it possible to define a "short-run" or "flexible" NAIRU as the unemployment at which expected wage inflation equals the rate of productivity growth, and this short-run NAIRU will depend on lagged inflation. The short-run NAIRU is discussed on page 28 in subsection 2.4.3 for the TRYM model, on page 46 in subsection 3.3.1 for the AEM model, and on page 51 in subsection 4.3.1 for the Murphy model.

The paper is divided into four sections: an introductory section (Section 1) and sections given details of the three models examined–Section 2 on the TRYM model, Section 3 on the AEM model, and Section 4 on the Murphy model. The remainder of this section discusses by way of background a number of elements that are common to all the models (subsection 1.2) and gives a broad overview of the way the labour market is handled in the models. Sections 2, 3 and 4 are each divided into three parts. First they give some brief background on the model being dealt with in the section; second they give an overview of the way labour market is treated in the relevant model; and third they describe in detail the main labour market equations in the model. The equations of the models as presented in the sections use more a textbook style notation than the documentation for the models, which use more computer-language styles. Appendixes D, E and F—for the TRYM model, the AEM model, and the Murphy model, respectively—give details of how the notation used here corresponds to that used in the documentation.

### *1.2 Common elements of macro models*

There are several elements in common to most of the macro models reviewed here. First, the TRYM, AEM and Murphy models all have equilibrium paths to which, in the absence of short-run shocks, the economy converges in the long run. Second, the long-run unemployment level is determined by a Phillips curve relation that links the growth rate of the expected real wage to deviations of the unemployment rate from a natural rate or NAIRU. Third, the TRYM model includes unfilled vacancies as part of its measure of labour demand and models the Beveridge curve—the relationship between the vacancy rate and the unemployment rate. And fourth, the models integrate the long-run equilibrium path of the economy with short-run dynamics in an error-correction framework. This section describes these four elements.

### *1.2.1 Long-run equilibrium*

The macro models all feature a long-run equilibrium growth path to which the economy is continually drawn. This is usually the path the economy would follow if there were no shocks, prices were perfectly flexible, and agents had either rational expectations or perfect foresight. Shocks push the economy away from this equilibrium path, but there are forces in the economy that draw the economy back. The speed at which the economy returns depends on the size of physical adjustment costs, such as those in installing new capital or matching workers with job vacancies, and the speed with which expectations adjust to changes in the economy.

The models assume a constant rate of labour-augmenting technological progress, $\lambda$ say. Along the equilibrium growth path, the real interest rate is constant and equal to the world interest rate, and the unemployment rate is also constant, and equal to the NAIRU. All output related variables grow with productivity and labour inputs. That is, the real hourly wage grows at rate $\lambda$; GDP and its components, measured per unit of labour input, grow at rate $\lambda$; and the capital-output ratio is constant.

This sort of long-run equilibrium is basically the one implied by the neo-classical growth model—though that model does not usually include explicit features that would give rise to unemployment. In most respects the macro models examined here are not constructed by adding short-run adjustment costs and sluggish expectations to the neoclassical growth model—rather they are constructed in a more ad hoc manner, incorporating features that will cause the economy to converge to a path with the same properties as the neoclassical growth model.

### *1.2.2 The Phillips curve and the NAIRU*

All the macro models considered here contain a wage-setting equation based on an expectations-augmented Phillips curve. The basic idea behind this goes back to Phillips (1958) who found an inverse relationship between annual changes in nominal wages and the unemployment rate in the U.K. over the period 1861–1957. Subsequent studies found similar negative relationships between nominal wage growth and unemployment, and between inflation and unemployment, for a large number of countries. These findings gave rise to the original Phillips curve theory—the idea that there is a negative relationship between inflation and unemployment and that there is a long-run trade off between the two.

Attempts to explain or put "micro foundations" under the Phillips curve, in particular by Friedman and Phelps, suggested however that true relationship is between expected real wage growth and the unemployment rate. When the labour market is tight (unemployment is low) workers seek, and firms are willing to give, wage rises considerably above the expected rate of inflation; when there is high unemployment, workers will accept a fall in the real wage. If we write the rate of growth of the nominal wage as the change in the log of wages in period $t$+1, $\Delta\ln(W_{t+1})$, the expected inflation rate in period t+1 as $\pi^e_{t+1}$, and the unemployment rate in period $t$ as $UR_t$, then there is a relationship of the form $\Delta \ln(W_{t+1}) - \pi^e_{t+1} = f(UR_t)$, where $f' < 0$.[1] There will be some unemployment rate at which expected real wage growth is equal to the long-run equilibrium rate of real wage growth, $\lambda$, given by the rate of technological progress. If we call this unemployment rate the natural rate and denote it by $UR^{nat}$, then the relationship between expected real wage inflation and the unemployment rate has the form $\Delta \ln(W_{t+1}) - \pi^e_{t+1} - \lambda = g(UR_t - UR^{nat})$, where $g' < 0$ and $g(0) = 0$.

The theory of the expectations-augmented Phillips curve has two additional elements. First, wage rises tend to feed into price rises. Second, expectations are backward looking so that the higher recent inflation has been, the higher future inflation is expected to be. With these additional assumptions, if unemployment is kept below the natural rate in any period then wage and price inflation will not just be relatively high, they will be accelerating. If the unemployment rate is low in any period, nominal wage growth will be high relative to the expected inflation rate and the past inflation rates on which expectations are based. This fast increase in nominal wages will produce high inflation and cause expectations of inflation to be revised upward. If the unemployment rate stays low in the next period, the gap between nominal wage growth and expected

[1] This assumes that wages for period $t$+1 are set in period $t$.

inflation must again be high, but the expected inflation rate is higher than before so nominal wage growth must be higher too. This then leads to higher inflation, a further upward revision of inflation expectations and even faster rates of wage and price inflation in the following period. That is, permanently low unemployment leads to accelerating inflation. Similarly, permanently high unemployment—an unemployment rate above the natural rate—will lead to a falling inflation rate. The only unemployment rate at which the inflation rate can be constant (or not accelerating) is the natural rate. Hence, this rate is often referred to as the non-accelerating-inflation rate of unemployment or NAIRU.

Under the theory of the expectations-augmented Phillips curve, expected inflation is equal to actual inflation along the equilibrium growth path of the economy, the unemployment rate is equal to the NAIRU, and real wages grow at the rate of technological progress, $\lambda$.

There are three additional points to be made about the expectations-augmented Phillips curve and the way it is incorporated into the models reviewed here:

- First, in the description above, the rate of growth of expected real wages depends only on the tightness of the labour market, which in turn depends only on the unemployment rate. The long-run equilibrium paths of the economy in the macro models considered here are consistent with these assumptions. In the short run, however, the models allow real wage growth to be affected by factors other than labour market tightness (such as changes in wage-setting arrangements) and do not measure labour market tightness just by the unemployment rate. In particular they include changes in the unemployment rate as well as the unemployment rate itself. For a given unemployment rate in period t, the labour market is tighter and expected real wage growth in period $t+1$ is higher if the unemployment rate had fallen between period $t-1$ and period t than if it had risen. Thus, the period-t unemployment rate at which period $t+1$ expected real wage growth is equal to the long-run equilibrium rate will always be between the unemployment rate in period $t-1$ and the NAIRU: it will be below the NAIRU if $UR_{t-1} < NAIRU$, it will be above the NAIRU if $UR_{t-1} > NAIRU$, and it will equal the NAIRU if $UR_{t-1} = NAIRU$.

- Second, the value of the NAIRU in principle depends on the structure of the economy; it might change as the economy changes and be treated as a function of variables related to the structure of the economy. None of the models looked at here takes that approach. They treat the NAIRU as constant and exogenous. Both the AEM and Murphy models treat the NAIRU as constant and are estimated over a period (from 1976 on) for which that is a plausible assumption. The TRYM model allows the value of the NAIRU to differ between the period before 1974 and period from 1974. It decomposes the change into search-efficiency and wage setting components, but the wage-setting component is basically a residual and the model effectively treats the value of the NAIRU as (constant and) exogenous in both periods. Note that, while the long-run value of the NAIRU is exogenous in the models, short-run factors can affect wage-setting for many periods and can give clues as to variables that might be included if the NAIRU were endogenised.
- Third, the value of the NAIRU might depend on past values of the unemployment rate. In the extreme version of this, "hysteresis", a period of high (or low) unemployment can permanently raise (or lower) the NAIRU. The path of the unemployment does not have permanent effects on the NAIRU in any of the models looked at here, but the inclusion of a change-in-unemployment term in the wage-setting equation could be interpreted as implying a flexible NAIRU. That is, the "long-run" NAIRU is fixed, but there is also a "short-run" NAIRU that in period t is the value of the unemployment rate URt for which the expected growth in the real wage in period $t+1$ is equal to the equilibrium growth rate, λ. This short-run NAIRU is an increasing function of $UR_{t-1}$ and equal to the long-run NAIRU only when $UR_{t-1} = NAIRU$.

*1.2.3 The Beveridge curve*

The AEM and Murphy models use actual employment to measure labour demand and the size of the labour force to measure labour supply (the sum of employment and unemployment). The TRYM model, however, equates labour demanded with the sum of employment and unfilled vacancies and labour supplied with the labour force. This helps with identification of the two curves and is use in the model to decompose changes in the NAIRU into those associated with search efficiency and those associated with wage setting. The introduction of the extra variable, vacancies, requires an extra equation and the TRYM model includes a negative relationship between the rate of unemployment and the vacancy rate (the ratio of unfilled vacancies to the sum of employment and vacancies). This relationship is known as the *Beveridge curve*.

The idea behind the Beveridge curve is that when the labour market it tight, unemployment is low and firms find it difficult to find workers to fill vacant positions. Thus the stock of vacancies is relatively high. On the other hand, when the unemployment rate is high, vacancies will fill quickly and the stock of unfilled vacancies at any time will be low. The position of the Beveridge curve in vacancy rate/unemployment rate space—that is, the level of the vacancy rate for any given unemployment rate—depends on how effectively the unemployed can be matched with vacant jobs. This in turn depends on:

- How efficient the labour market is at matching suitable workers with suitable jobs—matching unemployed factory workers with vacant factory jobs and unemployed IT workers with vacant IT positions.
- The degree of mismatch between workers and vacancies—matching will be slow if most of the unemployed are factory workers but most vacancies are for IT workers.
- The level of general work skills of the unemployed—for example, there may be a group of long-term unemployed that difficult to match with any vacancies.

In the TRYM model there is an outward shift in the Beveridge curve in 1973 and 1974, but the relationship is treated as stable in the periods before and after those years. There are more details in section on the TRYM model below.

### *1.2.4 Error-correction models*

A common way of integrating the short-run and long-run relationships between the variables in models is through an error-correction framework. For example, the equilibrium path of a variable, $y$, might depend on a vector of variables, $X$, through a relationship of the form, $y_t^{eq} = g(X_t)$. In the short run, however, changes in the value of $y$ might also depend on changes in variables in the vector, $Z$ (which might include variables also in $X$ and lagged values of $y$ and of variables in $X$), through a function of the form, $f(\Delta Z)$. An error-correction model for this variable would have the form $\Delta y_t = f(\Delta Z_t) - a[y_{t-1} - g(X_{t-1})]$, where the coefficient $a$ is positive. The first term on the right-hand side represents the purely short-run factors affecting $y$. The second term, the error-correction term, represents a force pulling $y$ toward its long-run equilibrium path. The expression in brackets is the difference between $y$ and its equilibrium value in period $t-1$. If $y_{t-1}$ is above its equilibrium value, then the term begin subtracted is positive. In the absence of short-run effects on $y$, this makes $\Delta y_t$ negative; that is, $y$ falls between period $t-1$ and period $t$. Similarly, if $y_{t-1}$ is below its equilibrium value, the error-correction term causes $y$ to increase. Usually the value of the coefficient $a$ is between 0 and 1, in which case the "correction" to $y$ in period $t$ is a fraction of the "error" in period $t-1$ and the error-correction term tends to cause $y$ to converge monotonically to its equilibrium path. If $a$ equalled one, however, then convergence would occur within one period and any difference between $y_t$ and its equilibrium value would be due to $\Delta Z_t$. If $a$ were between 1 and 2 then the error-correction term would produce dampened oscillations in $y$ about its equilibrium path. (A negative value of $a$, or a value above 2 would cause $y$ to diverge.)

### *1.3 General structure of the models*

The three models—the TRYM model, the AEM model and the Murphy model—each has an aggregate labour market, though the Murphy model builds up labour demand from sectoral demands. There is one unemployment rate in all models, however, and its long-run value is determined by an aggregate wage-setting equation.

There are four components of the labour market in the AEM model and the Murphy model; the TRYM model has these four components and two additional ones. The components are:

- Labour demand. In the AEM model and the Murphy model labour, demand is measured in persons and is identified with employment; in the TRYM model it is measured in hours and includes both the hours worked by those employed and the hours that would have been worked had all vacancies been filled. In all models labour demand is the sum of the basically exogenously determined labour demand by general government and government enterprises on the one hand, and of the endogenously determined labour demand by the private business sector on the other.

- Labour supply by households. In the AEM model and the Murphy model, labour supply is measured in persons and is identified with the size of the labour force; in the TRYM model it is measured in hours and includes both the hours worked by those employed and the hours that the unemployed would like to have worked
- In the TRYM model only, average hours worked by employees. This links labour demand and labour supply measured in hours to labour demand and labour supply in numbers of persons. Average hours are not required in the AEM model or the Murphy model, though allowance is made for the changing proportion of part-time work.
- Again in the TRYM model only, the relationship between unemployment and vacancies or Beveridge curve. This provides the link between labour demand and labour supply in persons on the one hand, and employment on the other hand.
- In all models, the relationship between expected real wage inflation and the unemployment rate—the Phillips curve. A "low" unemployment rate tends to produce a "large" increase in the real wage. This tends to reduce labour demand and pushes the unemployment rate up. Similarly, a "high" unemployment rate tends to produce a "small" increase or a fall in the real wage, which tends to push the unemployment rate down. This process gives a mechanism through which the unemployment rate is pushed toward an equilibrium level.
- Price setting by private sector firms. This ensures equilibrium in the goods market to match what is happening in the labour market.

Of course, the models are all general equilibrium models so that, in principle, events in the labour market cannot be looked at in isolation from those in the other parts of the economy. What happens in the labour market affects household consumption decisions, firms' price-setting and investment decisions, the exchange rate, etc. And changes to these variables feedback to the labour market, particularly through the effect of output on demand for labour. In the short-run, this interaction between the labour market and the rest of the economy is important for unemployment and employment levels. In the long run, however, employment and unemployment are determined entirely from the labour market relationships. The most important is that the long-run unemployment rate is equal to an exogenously determined NAIRU. This is common to all the models. The employment relationship differs across the models, however, and will be examined in the specific discussion for each model.

## 2. The Treasury Macroeconomic (TRYM) Model

This section examines the labour market in the Commonwealth Treasury's TRYM model. Subsection 2.1 gives some brief background on the TRYM model. Subsection 2.2 outlines the way the labour market is treated in the TRYM model, parallelling and expanding on the more general but briefer discussion in subsection 1.3 above. Subsection 2.3 examines the labour market in the long run in more detail, and subsection 2.4 discusses the long-run and short-run versions of each of the main labour-market equations in the TRYM model.

### *2.1 Background to model*

The Treasury macroeconomic (TRYM) model is a highly aggregated and relatively small quarterly model of the Australian economy. It has 29 estimated equations, 3 financial identities, 20 behavioural identities and 60 accounting identities. It follows on from the series of larger National Income Forecasting (NIF) models that were developed by the Commonwealth Treasury in the 1970s and 1980s, the last of which was NIF88. Work on the TRYM model began in 1990. It is used in Treasury for forecasting aggregate variables.

The main documentation for the TRYM model is: "The Macroeconomics of the TRYM Model of the Australian Economy" (Commonwealth Treasury, 1996), which gives an overview of the model and outlines the general macroeconomic framework underlying the model; "Documentation of the Treasury Macroeconomic (TRYM) Model of the Australian Economy" (Commonwealth Treasury, 1996,1999),[2] which gives details of the equations in the model; and "The User's Guide—How to Use the Treasury Macroeconomic (TRYM) Model of the Australian Economy with TSP Software"

[2] In the version of this paper currently on the Treasury web site, the reported estimation results for the labour market use data up to 1999(2); the reported results for other equations use data up to 1995(3), in line with the original version of the paper.

(Commonwealth Treasury, 1996), which explains the use of the commercially available software for running the TRYM model. In addition there are some 20 “TRYM related papers” dealing with various aspects of the TRYM model. Many of these papers have been presented at conferences on TRYM or aspects of the Australian economy. The ones of most relevance to the labour market are Johnson and Downes (1994), Stacey and Downes (1995), Downes and Stacey (1996), and Downes and Bernie (1999). All of this documentation is available from the Treasury web site—http://www.treasury.gov.au/). In addition, all data series used in the estimation the TRYM model, including series constructed especially for the model, are available at the ABS web site (http://www.abs.gov.au/). The discussion here is drawn mainly from “Documentation of the Treasury Macroeconomic (TRYM) Model of the Australian Economy,” which is referred to as *Documentation*, and Downes and Bernie (1999).

### *2.2 Outline of the labour market in the TRYM model*

The labour market in the TRYM model has the six components referred to in the general introduction (subsection 1.3). A more detailed, but still brief, description of the way the six components are treated in the TRYM model is as follows:

- Labour demand. Labour demand in the TRYM model is measured in hours and includes both employment (filled jobs) and unfilled vacancies. Labour is demanded by three sectors in the economy—the private business sector, the government enterprise sector and the general government sector. Employment in the general government sector was around 15 per cent of civilian employment at the end of the 1990s. It is treated as being exogenous in the TRYM model. Employment in the government enterprise sector as a proportion of civilian employment has declined steadily over time from around nine per cent in the middle of the 1960s to around six per cent at the end of the 1980s to two to three per cent of at the end of 1990s. In the TRYM model, labour demand by the government enterprise sector (in hours) depends on investment by (and the capital stock of) the sector, which is treated as exogenous. It does not depend on the real wage, even in the short run. Employment in the private business sector accounted for over 80 per cent of civilian employment at the end of the 1990s (its lowest fraction over the past 35 years occurred in the second half of the 1970s when it was about 75 per cent). In the long run, labour demand by the private business sector depends on output and the real producer wage—though as explained below, it depends ultimately in equilibrium on labour supply.

- Labour supply. Labour supply, like labour demand, is measured in hours. It includes both employment and unemployment. In the long run, labour supply in hours depends on three factors: population, the employment rate and an exogenous trend. First, labour supply is measured relative to the working-age population (persons aged between 15 and 64). This means that labour supply grows with population and allows for the effects of the aging of the adult population due to falling mortality rates. Second, the relationship to employment represents an encouraged/discouraged worker effect. It is allowed to vary with the proportion of males to females in the labour force. For a given population size and level of average hours, an increase in employment by ten persons is estimated to cause four additional persons to enter the labour force, and hence to reduce the number of persons unemployed by six. Third, the exogenous trend is decomposed into two components: one that reflects changes in the age composition of the population (due to the baby boom) and the changes this produces because of the differences in participation rates across age cohorts; and a second component that picks up all other trends in participation. In the short run, labour supply also reacts to fluctuations in labour demand, though more strongly to changes in private sector labour demand than to public sector labour demand.
- Average hours. In the long run, average hours follow an exogenous trend. This no doubt reflects factors such as the increase in part-time work and in female relative to male employment, but these are not modelled explicitly. In the short run, average hours worked also respond to labour demand.
- Beveridge curve. The model posits a long-run negative linear relationship between the log of the unemployment rate and the log of the vacancy rate. This relationship is allowed to shift out over time—each vacancy rate is associated with a higher unemployment rate. This shift is interpreted as a reduction in search effectiveness. The shift is modelled by a logistical growth function with the size, timing and speed of the shift being estimated. The shift is estimated to have occurred almost entirely between 1973(3) and 1975(4) and to have added around half a percentage point to the average unemployment rate (NAIRU). This reflects the change from the late

1960s and early 1970s, when the vacancy rate was around 1.5–2.5 per cent and the unemployment rate was rarely much above two per cent, to the period since the late 1970s, when the vacancy rate has mostly been below one per cent and the unemployment rate has mostly been between five and 11 per cent.

- Phillips curve. In the TRYM model, the Phillips curve relates changes in the expected real consumption wage to the unemployment rate, changes in the unemployment rate and changes in the degree of centralisation of wage determination.

Expectations are backward looking and the expected consumer-price inflation rate used in calculating expected real wage inflation is the average inflation rate over the previous four quarters. This means that changes in expected inflation lag behind changes in actual inflation. For example, when the inflation rate is increasing, expected inflation is less than actual inflation. Changes in the nominal wage are based on expected inflation, so the increases in the nominal wage and the actual real wage are relatively small. This causes an increase in labour demand and puts downward pressure on the unemployment rate. That is, in the short run before inflation expectations catch up with actual inflation, increases in the inflation rate tend to lead to low unemployment rates.

There is an unemployment rate, the NAIRU, at which there is no upward or downward pressure on wage inflation (given no change in other factors). The level of the NAIRU is modelled as the sum of two components—a search-effectiveness component and a wage-setting component. The search-effectiveness component comes from the Beveridge curve and the level of the unemployment rate at which the unemployment rate and the vacancy rate are equal. It thus increased as the Beveridge curve shifted out from the end of 1973 to the end of 1974, from around 2¼ per cent to around 2¾ per cent. The wage-setting component is modelled as a "constant" that jumped in value between 1973(4) and 1974(1). The reason for this increase is not modelled. The combined effect of the increases in the two components was for the estimated NAIRU to increase from around four per cent in the early 1970s to about 6½ per cent from the late 1970s onward. The NAIRU is effectively treated as exogenous in the TRYM model except during the brief period when Beveridge curve was shifting outward. The decomposition of the NAIRU into search-effectiveness and wage-setting components is endogenous, but the wage-setting component is, in effect, a residual.

In the short-run, the growth rate of the expected real wage also depends on the change in the unemployment rate. For a given unemployment rate, a decrease in the unemployment rate puts additional upward pressure on wage growth, and an increase in the unemployment rate tends to reduce wage growth. The size of these effects is not symmetric—the effect on wage growth of a fall in the unemployment rate is estimated to be almost twice as large as the effect of an increase in the unemployment rate of the same magnitude—and the strength of the effects is made to depend on the fraction of the work force that is unionised—the effects are stronger if a larger fraction of workers are union members. Changes in the degree of centralisation of wage determination also affect wage inflation. If in any quarter the degree of wage centralisation is greater than it was in the corresponding quarter of the previous year, the rate of wage increase in the quarter will be different from what it would otherwise have been—an increase in centralisation causes a temporary change in wage growth.[3] In addition to the centralisation variable, there is a dummy for the metal trades wage decision in 1974(3).

### *2.3 The labour market in the long run*

In the long run virtually all the labour-market quantity variables—the unemployment rate, the levels of employment and unemployment, average hours and vacancies—are exogenous in the TRYM model. Average hours are explicitly treated as exogenous. The long-run equilibrium unemployment rate is equal to the NAIRU, which is the sum of a constant (the wage-setting parameter) and the unemployment rate at which the unemployment rate and the vacancy rate are equal according to the Beveridge curve. Since the Beveridge curve is exogenous, both components of the NAIRU are

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[3] The direction is a not clear from the TRYM model documentation. In the wage-setting equation in Downes and Bernie (1999) and the main text of *Documentation*, the change in centralisation term is –$a_3(QCC_t, - QCC_{t-4})$ and the estimated value of $a_3$,is positive. This would imply that an increase in centralisation temporarily reduces wage inflation. In Appendix C to *Documentation*, however, there is no negative sign before the coefficient, $a_3$. If the value of $a_3$ is correctly reported in the text, this would that an increase in centralisation temporarily increases wage inflation. The comments on the estimation results in Downes and Bernie and *Documentation* do no help clarify the issue—they merely note that "[w]ages respond to changes in the institutional environment in the wage determination system."

exogenous, so the NAIRU itself and the long-run unemployment rate are exogenous. The estimate of the current NAIRU in the TRYM model is 6.45 per cent.

It requires only a small amount of algebraic manipulation to see that the levels of employment, unemployment and vacancies are also exogenous. Since the unemployment rate is the ratio of the number of unemployed to the labour force, and the labour force is the sum of the number of persons employed and the number of persons unemployed, we can write the condition that the long-run unemployment rate equals the NAIRU as

$$\frac{U_t^{LR}}{E_t^{LR} + U_t^{LR}} = NAIRU,$$

where $E_t^{LR}$ is the long-run equilibrium number of persons employed in quarter $t$ and $U_t^{LR}$ is the equilibrium number of persons unemployed. This implies that the employment rate (as a fraction of the labour force) is:

$$\frac{E_t^{LR}}{E_t^{LR} + U_t^{LR}} = 1 - NAIRU.$$

Taking logs gives:

$$\ln\left(E_t^{LR} + U_t^{LR}\right) = \ln\left(E_t^{LR}\right) - \ln\left(1 - NAIRU\right) \approx \ln\left(E_t^{LR}\right) + NAIRU.$$

The log of the labour force is approximately equal to the sum of the log of unemployment and the NAIRU.[4]

The long-run labour supply equation has the form:

$$\ln\left(\frac{\left[E_t^{LR} + U_t^{LR}\right] \times H_t^{LR}}{POP_t}\right) = a_{0,t}^{LS} + a_1^{LS} \times \ln\left(\frac{E_t^{LR} \times H_t^{LR}}{POP_t}\right),$$

where $H_t^{LR}$ is desired average hours in period $t$ and $POP_t$ is the working-age population in quarter $t$. The numerator in the expression on the left-hand side of the equation is labour supply in hours—the product of the number of persons wanting to work (the sum

[4] This result uses the fact that for small $x$, $\ln(1+x) \approx x$, or $\ln(1-x)$ ) $\approx -x$.

of numbers employed and unemployed) and average hours. Thus the left-hand side of the expression is the log of labour supply in hours relative to the working population. Similarly, the second term on the right-hand side is the log of employment in hours relative to the working-age population. This term reflects the encouraged/discouraged worker effect. The estimated value of the coefficient on the employment term is 0.400. The other coefficient, $a_{0,t}^{LS}$, reflects participation rates and demographic factors and can change over time (hence the time subscript), but its value is exogenous.

If we expand the fractions in the labour-supply equation and collect terms, we get:

$$\ln\left(E_t^{LR}+U_t^{LR}\right)=a_{0,t}^{LS}+a_1^{LS}\times\ln\left(E_t^{LR}\right)-\left(1-a_1^{LS}\right)\times\ln\left(H_t^{LR}\right)+\left(1-a_1^{LS}\right)\times\ln\left(POP_t\right).$$

Then substituting in the approximate expression for the log of labour force and solving for the log of employment gives:

$$\ln\left(E_t^{LR}\right)\approx\frac{a_{0,t}^{LS}}{1-a_1^{LS}}-\ln\left(H_t^{LR}\right)+\ln\left(POP_t\right)-\frac{NAIRU}{1-a_1^{LS}}.$$

Since all the terms on the right-hand side of this expression are exogenous in the TRYM model, the level of employment is also exogenous. The expression tells us that, for given population and average hours, a one percentage point fall in the NAIRU is associated with a $1/(1-a_1^{LS})$ per cent increase in employment, or a one per cent increase in employment is associated with a $1-a_1^{LS}$ percentage point fall in the long-run unemployment rate. Since the estimated value of $a_1^{LS}$ is 0.400, this means that a one percentage point fall in the NAIRU is associated with a 1.7 per cent increase in employment, or a one per cent increase in employment is associated with a 0.6 percentage point fall in the long-run unemployment rate.

Finally, the long-run Beveridge curve has the form:

$$\ln\left(\frac{U_t^{LR}}{E_t^{LR}+U_t^{LR}}\right)=a_0^{BC}+a_1^{BC}\times\ln\left(\frac{V_t^{LR}}{E_t^{LR}+U_t^{LR}}\right),$$

where $V_t^{LR}$ is the long-run level of vacancies and $a_0^{BC}$ and $a_1^{BC}$ are parameters. The left-hand side of the expression is the log of the unemployment rate and the final term on the right-hand side is the log of the vacancy rate. Since the long-run unemployment rate is exogenously determined, so is the vacancy rate. If we substitute for the log of the unemployment rate and the log of the labour force and rearrange, we get:

$$\ln\left(V_t^{LR}\right) \approx -\frac{a_0^{BC}}{a_1^{BC}} + \frac{1}{a_1^{BC}} \times \ln\left(NAIRU\right) + \ln\left(E_t^{LR}\right) + NAIRU.$$

Substituting for the log of employment gives:

$$\ln\left(V_t^{LR}\right) \approx \frac{a_{0,t}^{LS}}{1-a_1^{LS}} - \frac{a_0^{BC}}{a_1^{BC}} - \ln\left(H_t^{LR}\right) + \ln\left(POP_t\right) + \frac{1}{a_1^{BC}} \times \ln\left(NAIRU\right) - \frac{a_1^{LS}}{1-a_1^{LS}} NAIRU.$$

All the terms on the right-hand side of the expression are exogenous, so the level of vacancies is also exogenous.

### *2.4 Details of equations in the TRYM model*

This section provides further details of the main labour-market equations in the TRYM model. For each equation, the long run and the short run are examined separately. The notation used in the equations in this section differs somewhat from the notation in the TRYM documentation. The relationship between the notation here and that in the TRYM model documentation is given in Appendix A.[5]

#### *2.4.1 Unemployment in the long run*

The wage-setting equation, or Phillips curve, in the TRYM model makes the rate of growth of real wages depend, among other things, on the deviation of the unemployment rate from the NAIRU and on changes in the unemployment rate. In the long run, the rate of growth of real wages is constant and equal to the rate of productivity growth, and the unemployment rate is equal to the NAIRU. The NAIRU, however, depends in part on the Beveridge curve relationship. Specifically, the NAIRU is given by:

$$NAIRU_t = \begin{Bmatrix} UR_t^{ADJ} + WSo & \text{until } 1973(4) \\ UR_t^{ADJ} + WS & \text{from } 1974(1) \end{Bmatrix}.$$

The NAIRU in the TRYM model is not treated as constant. Reasons for changes in the NAIRU are not modelled explicitly but they are separated into two types:

[5] Appendices A,B and C to this working paper can be downloaded as a pdf file from the Melbourne Institute website – www.melbourneinstitute.com.

- Those that relate to changes in search efficiency as reflected in shifts in the Beveridge curve. These are reflected in the variable $UR_t^{ADJ}$.
- Those that relate to changes in wages setting. These are captured by the terms *WSo* and *WS*.

The variable $UR_t^{ADJ}$ is the unemployment rate adjusted for search effectiveness—that is the unemployment rate at which unemployment and vacancies are equal in the Beveridge-curve relationship. It also includes the residuals from the Beveridge curve equation. If the residuals were not included then, as explained below, $UR_t^{ADJ}$ would have been essentially constant and equal to 2.09 per cent until 1973(3), constant and equal to 2.64 per cent from 1975(4), and increasing between the two levels between 1973(4) and 1975(3). The initial and final values of $UR_t^{ADJ}$, the timing of the change and the rate of change are all estimated. Note that the Beveridge curve was estimated using data for the period 1967(3) to 1999(2) so that the 2.09 per cent value of $UR_t^{ADJ}$ can be taken as extending back into the 1960s.

The second term in the expression for the NAIRU is a "constant" that takes the value *WSo* up to 1973(4) and the value *WS* from 1974(1). The wage equation is estimated for the period 1971(1) to 1999(2). Had the sample period extended back into the 1960s, there would have been at least one additional change in the value of the "constant". The timing of the break as 1974(1) is imposed but the values of *WSo* and *WS* are estimated. The estimates reported in Downes and Bernie (1999) are $WSo = 1.83$ and $WS = 3.70$. Downes and Bernie give the corresponding values of the NAIRU, after excluding the effects of the residuals from the Beveridge curve, as 4.05 per cent in the early 1970s and 6.45 per cent from the mid-1970s.[6] (They note that the NAIRU was probably around two per cent in the 1960s.)

[6] The estimates for the NAIRU reported by Downes and Bernie (1999) do not quite match the estimates they report for *WSo* and *Ws* and the values of $UR_t^{ADJ}$, their variable $RNUST_t$, implied by their estimated Beveridge curve and confirmed by the series for *RNUST* given in the ABS's TRYM model database. These imply values of the NAIRU of 3.92 per cent and 6.34 per cent, rather than 4.05 per cent and 6.45 per cent.

The TRYM model thus implies that the NAIRU increased from around 2 per cent in the 1960s to around 4 per cent in the early 1970s, all the increase being due to wage-setting factors. The NAIRU increase by a further 2½ per cent between the early 1970s and the late 1970s; around one-half of a percentage point of this increase was due to a decrease in search efficiency and the remainder was due to wage-setting factors. Note that, apart from the fact that the timing of the change in the wage-setting parameter (from *WSo* to *WS*) is imposed independently of the Beveridge curve, the wage-setting component of the change in the NAIRU is effectively a residual—the part of the total change not explained by the change in $UR_t^{ADJ}$.

The time path of the NAIRU in the TRYM model from 1971(1) to 1999(2) is shown in Figure 1.[7] The thinner line gives the value of the NAIRU including the effects of the residuals from the Beveridge curve on $UR_t^{ADJ}$; the thicker, smoother line gives the NAIRU corresponding to zero values for the residuals. The NAIRU increases between 1973(4) and 1975(3) with a big jump between 1973(4) and 1974(1) due mainly to the switch in the value of the wage-setting parameter from *WSo* to *WS*.

Figure 2 shows the path of the unemployment rate for the period 1959(3) to 1999(2) and the TRYM model NAIRU, excluding the residuals from the Beveridge curve equation, for the period 1971(1) to 1999(2).[8] Two features stand out:

- The unemployment rate is below the NAIRU throughout the 1970s and the increase in the NAIRU (mainly in 1974) precedes the main increase in the unemployment rate (which occurs in the second half of 1975 and 1976).
- In the 1980s and 1990s the NAIRU is considerably below the average unemployment rate.

Understanding these results requires knowledge of the short run wage-setting equation, so we'll examine this and then return to possible explanations for these results. We'll

[7] The NAIRU is calculated as the sum of $RNUST_t$ and the parameters, *WSo* and *WS*. The time series for $RNUST_t$ including residuals is taken from the ABS TRYM model database. The underlying series for $RNUST_t$ is calculated from the estimated Beveridge curve.

[8] The NAIRU is the same as in Figure 1. The unemployment rate is taken from the ABS TRYM database.

also discuss some the reasons suggested by Downes and Bernie (1999) for the increase in the NAIRU.

*Figure 1. TRYM NAIRU 1971(1) to 1999(2)*

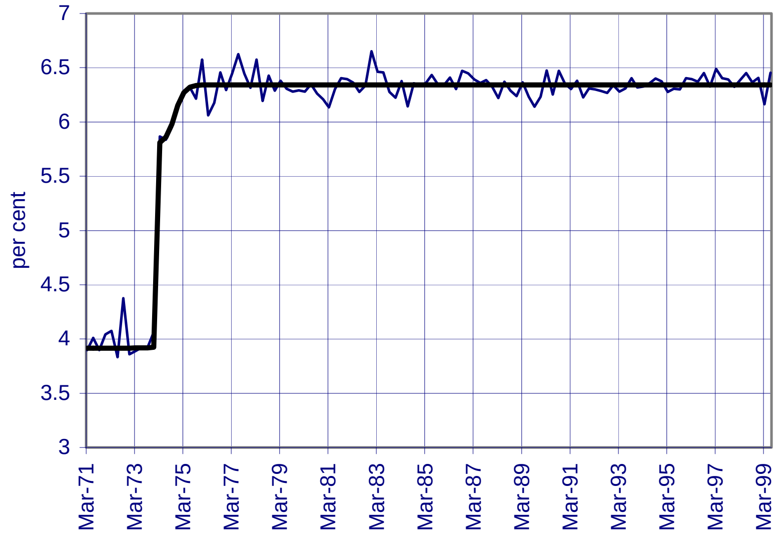
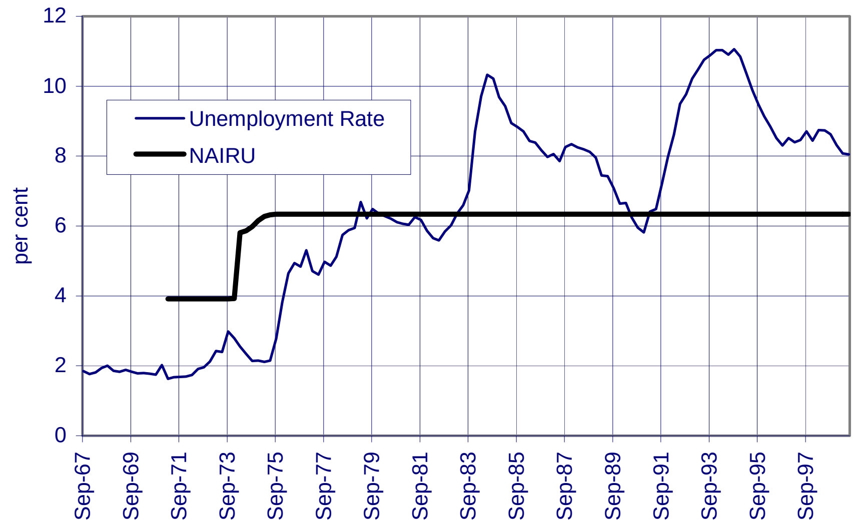



*Figure 2. Australian Unemployment Rate and TRYM model NAIRU*




### *2.4.2 The wage equation in the short run*

In the short run in the TRYM model, the expected rate of real-wage inflation relative to the trend rate of productivity growth is modelled as depending on:

- The change in the degree of centralised wage fixing.

- Union membership as a proportion of total employment.
- The lagged change in the unemployment rate.
- The lagged deviation of the unemployment rate from the NAIRU as a fraction of the unemployment rate.

In addition there is a dummy for the metal trades wage decision in 1974(3). The estimated equation has the form:

$$\pi_{W\,t} - \pi_{C\,t}^{e} - \lambda = -a_2 \times Union_t \times \left[c_1 \times \Delta UR_{t-1}^{+} + (1 - c_1) \times \Delta UR_{t-1}^{-}\right] - a_3 \times \Delta^4 Central_t$$
$$+ a_4 \times \frac{NAIRU_{t-1} - UR_{t-1}}{UR_{t-1}} + a_5 \times Q743_t .$$

On the left-hand side of the equation, $\pi_{W\,t}$ is the rate of nominal wage inflation in quarter *t* (the change in the log of the hourly wage rate between quarter $t-1$ and quarter *t*), $\pi_{C\,t}^{e}$ is the expected rate of inflation of consumption good prices in period *t*, and $\lambda$ is the trend rate of labour-augmenting technical progress. Thus the left-hand side is the expected rate of increase of the real wage rate in excess of productivity growth (its trend rate of growth). Expected consumer price inflation is a weighted average of the change in the log of the deflator of private consumption over the previous four quarters, with the weights declining geometrically. That is:

$$\pi_{C\,t}^{e} = \frac{\pi_{C\,t-1} + a_1 \pi_{C\,t-2} + a_1^{\,2} \pi_{C\,t-3} + a_1^{\,3} \pi_{C\,t-4}}{1 + a_1 + a_1^{\,2} + a_1^{\,3}},$$

where $\pi_{C\,t}$ is the actual rate of inflation of consumption good prices in period *t* (the change in the log of the deflator of private consumption between quarter $t-1$ and quarter *t*). The estimated value of $a_1$ is 0.798 so the weights on the four lags of inflation in the expression for expected inflation are 0.340, 0.271, 0.216 and 0.173.

On the right-hand side of the wage equation, $Union_t$ is union membership as a proportion of total employees in quarter *t*, $Central_t$ is a variable for the degree of centralisation of wage fixing, $Q743_t$ is a dummy variable that equals one in 1974(3) and zero in all other quarters, and $UR_t$ is the unemployment rate in percentage points. $\Delta UR_t$ is the change in the unemployment rate between quarter $t-1$ and quarter *t*. $\Delta UR_t^{+}$ is the positive part of the change in the unemployment rate—it equals $\Delta UR_t$ when $\Delta UR_t$ is positive and equals zero when $\Delta UR_t$ is negative. Similarly, $\Delta UR_t^{-}$ is the negative part of the change in the unemployment rate—it equals $\Delta UR_t$ when $\Delta UR_t$ is negative and equals zero when $\Delta UR_t$ is positive. Thus, $\Delta UR_t = \Delta UR_t^+ + \Delta UR_t^-$. $NAIRU_t$ is the value of the NAIRU in period $t$, expressed in percentage points, as explained in the previous subsection.

The first term on the right-hand side of the wage equation, $-a_2 \times Union_t \times \left[c_1 \times \Delta UR_{t-1}^+ + (1-c_1) \times \Delta UR_{t-1}^-\right]$, gives the effect of changes in the unemployment rate on real-wage inflation—an increase in the unemployment rate reduces the rate of wage growth. The strength of this effect depends on the degree of unionisation—the greater the proportion of workers who are union members, the greater is the upward pressure on wages of a reduction in unemployment. The degree of union membership rose from around 50 per cent at the start of the 1970s to around 55 per cent in the second half of the 1970s through to the middle of the 1980s. Since then it has fallen steadily, down to 35 per cent at the end of the 1990s. The effects of positive and negative changes in the unemployment rate are asymmetric. The estimated value of $c_1$ is 0.367, so $1-c_1$ is 0.633 and the upward effect on wage growth of a decrease in the unemployment rate is 0.633/0.367 = 1.725 times as great as the downward effect on wage growth of an increase in the unemployment rate. The estimated value of the coefficient $a_2$ is 0.0004.

The second term on the right-hand side of the wage equation, $-a_3 \times \Delta^4 Central_t$, represents the change in the degree of centralisation of wage setting in quarter $t$ compared to the corresponding quarter in the previous year. $Central_t$ is a constructed variable. It took the value 0.20 up to 1975(1), the 0.80 from 1975(2) to 1981(1), 0.20 again from 1981(2) to 1982(4), and 0.80 from 1983(1) to 1985(3). Since then it has been declining linearly, from 0.70 in 1985(4) to 0.16 in 1999(2). The estimated value of the coefficient $a_3$ is 0.018.

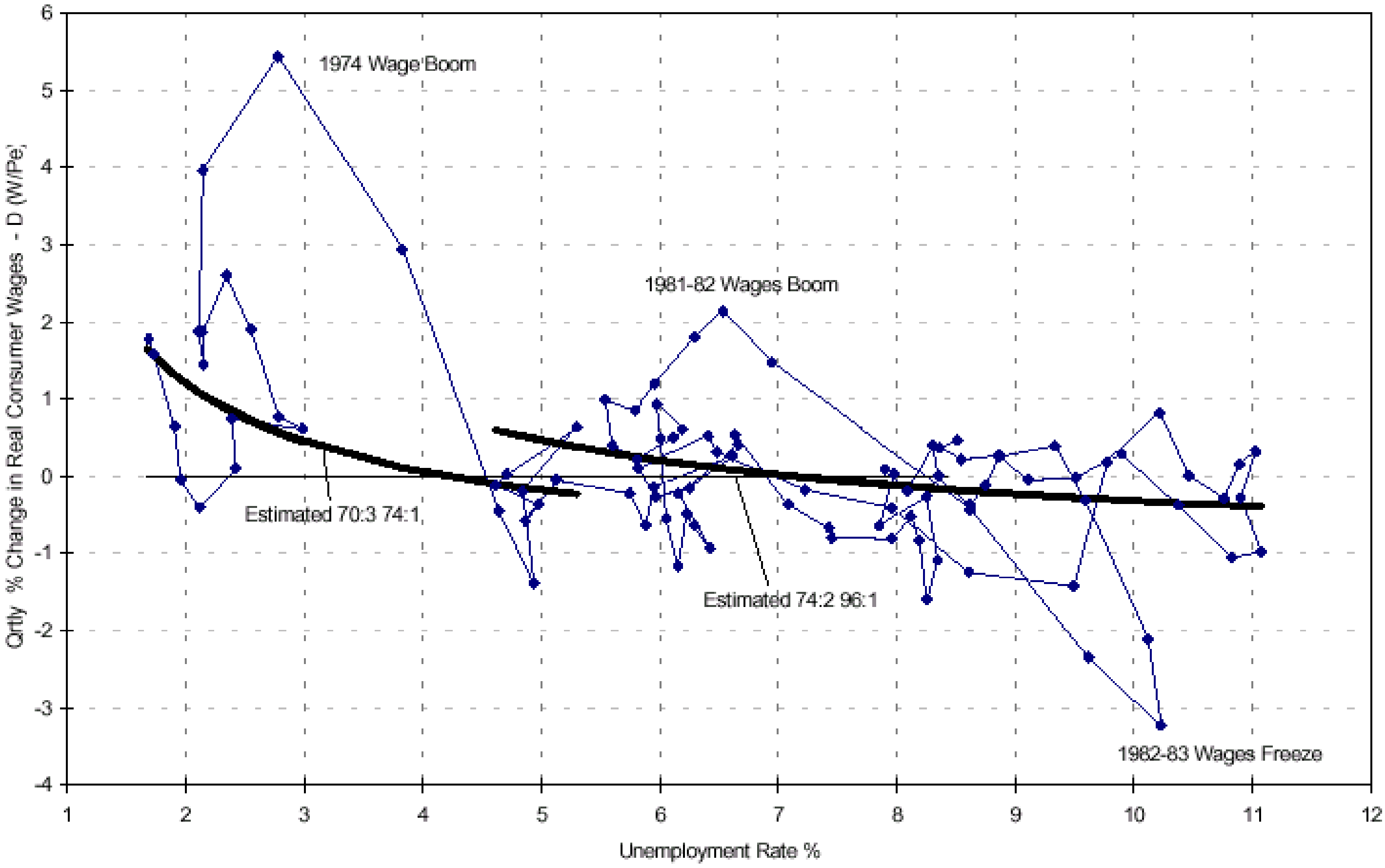
The third term on the right-hand side of the wage equation, $a_4 \times \dfrac{NAIRU_{t-1} - UR_{t-1}}{UR_{t-1}}$, is the negative of the deviation of the lagged unemployment rate from the NAIRU as a fraction of the unemployment rate. Low unemployment rates are associated with fast wage growth, and high unemployment rates are associated with slow wage growth. The estimated value of the coefficient $a_4$ is 0.11. If the NAIRU is 6.45 per cent, then a constant unemployment rate of 5.45 per cent in quarter $t-1$ (one percentage point below the NAIRU) would add about 0.20 per cent to the quarterly rate of wage inflation in quarter *t*, relative to the scenario in which the unemployment rate equalled the NAIRU; a constant unemployment rate of 7.45 per cent in quarter $t-1$ (one percentage point above the NAIRU) would subtract about 0.15 per cent from the quarterly rate of wage inflation in quarter *t*.

The final term on the right-hand side of the wage equation, $a_5 \times Q743_t$, is a dummy for the metal trades wage decision in the September quarter of 1974. The estimated value of $a_5$ is 0.075. That is, wages were 7.5 per cent higher in 1974(3) than they would have been without the wage decision.

Figure 3—reproduced from Downes and Bernie (1999), Figure 6 on page 32—shows the relationship between expected real wage growth and the unemployment rate from 1970(3) to 1996(1). Also shown in the figure are the estimated expectations-augmented Phillips curves for the early 1970s and for the period from the second half of the 1970s estimated using data up to 1996(1). These earlier estimates gave higher NAIRUs than the latest ones—around 4½ per cent in the early 1970s and around 7 per cent in the later period. Downes and Bernie make the point that the Phillips curve for this later period is extremely flat so that the NAIRU cannot be accurately estimated. Visual inspection of the date suggests that the negative slope of the curve is due almost entirely to the observations for 1974(2) and 1974(3),[9] the 1981–82 wages boom and the 1982–83 wages freeze. Without these observations, expected wage inflation seems essentially unrelated to the unemployment rate.

[9] The curve is estimated for the period starting 1974(2). The observation for 1974(3) corresponds to the metal trades wage decision and is dummied out.

*Figure 3: Estimated Expectations – Augmented Phillip's Curves in TRYM*




### *2.4.3 Further comments on the NAIRU in the TRYM model*

It was noted above that in the 1970s the NAIRU was above the unemployment rate; the trend increase in the NAIRU preceded the main increase in the unemployment rate in the mid-1970s; and in the 1980s and 1990s the NAIRU was less than the average unemployment rate. Let us consider each of these in turn:

- The wage equation predicts that expected real wage growth will be high when the unemployment rate is below the NAIRU. That is, the estimated parameters in the wage equation will tend to be such that any sub-period with relatively high expected real wage growth will tend to be interpreted as a boom—a period with an unemployment that is low relative to the NAIRU. This means giving an estimate of the NAIRU that is high relative to observed unemployment rates for the sub-period. This may provide a reason for the comparatively high NAIRU for the early 1970s. Figure 6 in Downes and Bernie (1999) (reproduced here as Figure 3) is consistent with this interpretation. There are three queries that might be made in relation to the observed rate of expected real wage inflation and its relationship to the NAIRU:

- First, the dependent variable is strictly the excess of real wage inflation relative to productivity growth. In the wage equation in the TRYM model the rate of productivity growth is treated as being constant over the sample period. There is considerable evidence however that productivity growth was higher in the early 1970s that in later parts of the sample period (except perhaps the second half of the 1990s). Thus expected real wage growth relative to productivity may be overstated.
- Second, expected price inflation is a weighted average of past price inflation. If agents are more forward-looking than the model assumes then, in a period of rising price inflation such as the early 1970s, the measure of expected price inflation will understate expected price inflation and measured expected real wage inflation will overstate actual expected real wage inflation.
- Third, if there is a long-lasting increase in labour's share in output, as there was in the early seventies, this will be associated with high real-wage growth. It is not clear that this would have the same effect on unemployment as a faster than trend real-wage growth that was expected to be reversed in subsequent periods.

- On the timing of the increase in the NAIRU, the major part of the increase is due to the increase in the wage-setting parameter and the timing of this increase is imposed. It would be interesting to know whether the imposed quarter—1974(1)—would have been the one chosen if the timing of the break had been estimated.
- On the low NAIRU in the 1980s and 1990s relative to average unemployment rates in those decades, Downes and Bernie (1999) explain this phenomenon in terms the asymmetric response of wages to unemployment rate increases and decreases—the upward effect on wage inflation of a fall in the unemployment rate is 70 per cent larger than the downward effect of an equal-size increase in the unemployment rate. In addition to this, the "low" NAIRU must represent the flip side of some of the factors discussed above in relation "high" NAIRU of the early 1970s—real wage growth has been lower than in the early 1970s, the inflation rate, the inflation rate

has fallen, and labour's share has declined. Since these trends in the 1980s and 1990s have been spread out over a longer period (a period of two decades is longer than a period of one decade), there effects are likely to be smaller than in the 1970s.

If we define the short-run NAIRU in quarter *t* as the unemployment rate in quarter *t* that produces expected wage inflation equal to the long-run trend between quarters *t* and $t+1$, then this depends on the unemployment rate in quarter $t-1$. If we set the left-hand side of the wage-setting equation, the change in the degree of centralisation of wage setting and the dummy for the metal trades industry wage decision in 1974(3) all equal to zero, step one quarter ahead, and identify the unemployment rate in quarter *t* with the short-run NAIRU, $NAIRU_t^{SR}$, then the wage-setting equation becomes:

$$0 = -a_2 \times Union_{t+1} \times \left[c_1 \times \Delta UR_t^{+} + (1-c_1) \times \Delta UR_t^{-}\right] + a_4 \times \frac{NAIRU - NAIRU_t^{SR}}{NAIRU_t^{SR}}.$$

Rewrite this as:

$$0 = -d_2 \times \left(NAIRU_t^{SR} - UR_{t-1}\right) + \frac{NAIRU - NAIRU_t^{SR}}{NAIRU_t^{SR}},$$

where the coefficient $d_2$ depends on the unionisation variable, $Union_t$, and on the sign of the change in the unemployment rate between quarter $t-1$ and quarter *t*, as well as on $a_2$ and $a_4$. Solving this equation gives the short-run NAIRU as a function of the previous quarter's unemployment rate:

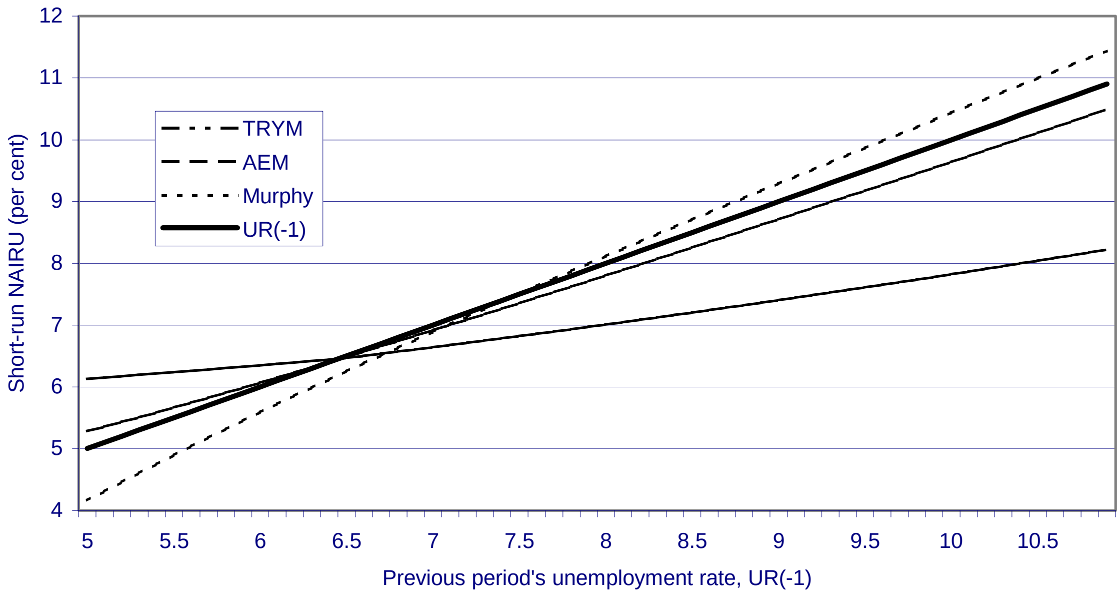
$$NAIRU_t^{SR} = \frac{1}{2} \times \left[UR_{t-1} - \frac{1}{d_2} + \sqrt{\left(UR_{t-1} - \frac{1}{d_2}\right)^2 + \frac{4 \times NAIRU}{d_2}}\right].$$

When the value of $Union_t$ is 0.35, its value at the end of the 1990s, the value of $d_2$ is 0.00051 for $UR_{t-1} < NAIRU$, and 0.00089 for $UR_{t-1} > NAIRU$. The equation is plotted in Figure 4. (Figure 4 also contains plots of the "short-run" NAIRUs for the AEM and Murphy models. The TRYM model line is the flattest dashed line. The thick unbroken line is a 45-degree line.) If $UR_{t-1}$ equals the NAIRU (6.45 per cent) then the short-run NAIRU is equal to the NAIRU. If $UR_{t-1}$ equals 7.45 per cent, one percentage point higher than the NAIRU, then the short-run NAIRU is equal to 6.80 per cent, 0.35 percentage points above the NAIRU and 0.65 percentage points below $UR_{t-1}$. If $UR_{t-1}$

equals 5.45 per cent, one percentage point lower than the NAIRU, then the short-run NAIRU is equal to 6.22 per cent, 0.23 percentage points below the NAIRU and 0.77 percentage points above $UR_{t-1}$. There are two points to note:

- First, the short-run NAIRU is closer to the long-run NAIRU if the unemployment rate is below the NAIRU than if the unemployment rate is an equal number of percentage points above the NAIRU.
- Second, the actual unemployment rate will generally not move by as much as the short-run NAIRU might suggest because expected wage growth at the long-run equilibrium rate will not in general lead to the change in unemployment that would required to get that rate of wage growth.

*Figure 4. "Short-Run" NAIRUs in Australian Macro Models*




### *2.4.4 The Beveridge curve in the long run*

On the long-run equilibrium growth path, the relationship between the unemployment rate and the vacancy rate—the Beveridge curve—has the form $UR_t = C_{0,t}(VR_t)^{c_1}$, where $UR_t$ is the unemployment rate in quarter $t$, $VR_t$ is the vacancy rate (the ratio of vacancies to the labour force), and $c_1$ is the elasticity of the unemployment rate with respect to the vacancy rate. The coefficient $C_{0,t}$ is not a constant, but follows a logistical growth function. More specifically,

$$\ln(UR_t) = c_0 + LGF_t + c_1 \times \ln(VR_t),$$

where the logistical growth function term, $LGF_t$, has the form,

$$LGF_t = \frac{c_2}{1+\exp\left(\frac{c_3 - t}{c_4}\right)}, \quad c_4 > 0.$$

For large negative values of t, $LGF_t$ is close to zero, and for large positive values of t, $LGF_t$ is close to $c_2$. The transition between these two values is centred on quarter $c_3$, and the speed of the transition depends on the value of $c_4$—a large value of $c_4$ implies a slow transition. The estimated value of $c_2$ is 0.419, the estimated value of $c_4$ is 0.198, and the estimated value of $c_3$ corresponds to a point approximately midway between the September and December quarters of 1974. Thus, $LGF_t$ ranges between zero and 0.419 with the transition centred on the second half of 1974.

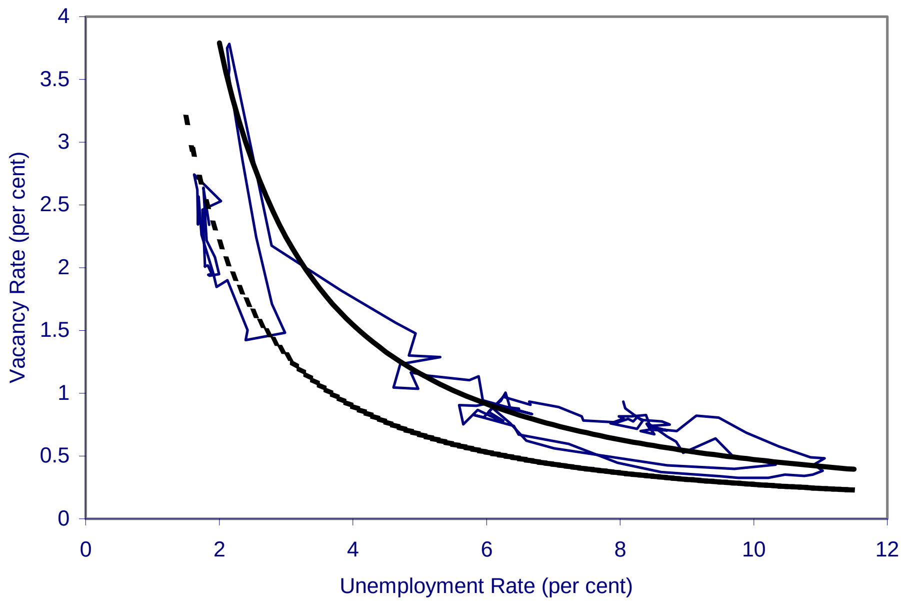
The unemployment rate adjusted for search effectiveness used in the wage-setting equation, $UR_t^{ADJ}$, is found by setting the unemployment rate equal to the vacancy rate in the long-run Beveridge curve. Solving the resulting equation gives

$$\ln\left(UR_t^{ADJ}\right) = \frac{c_0 + LGF_t}{1 - c_1}.$$

The estimated values of $c_0$ and $c_1$ are 1.304 and –0.773, respectively. (The negative value of $c_1$ implies that the Beveridge curve slopes downward.) Thus the log of the unemployment rate adjusted for search effectiveness ranges between 1.304/(1+0.773) = 0.735 and (1.304 + 0.419)/1.773 = 0.971, and $UR_t^{ADJ}$ itself ranges from 2.086 to 2.641.

The unemployment rate in Australia is plotted against the vacancy rate in Figure 5. The figure also shows the long-run Beveridge curve in the early 1970s as a broken line and the long-run Beveridge curve from the second half of the 1970s on as an unbroken line.

*Figure 5. Australian Beveridge Curve 67(3)-99(2)*




### *2.4.5 The Beveridge curve in the short run*

In the TRYM model the short-run Beveridge curve is given by:[10]

$$\Delta \ln(UR_t) = a_1 \times \Delta \ln(VR_t) + a_2 \times \Delta LGF_t \\ - a_0 \times \{\ln(UR_{t-1}) - [c_0 + LGF_{t-1} + c_1 \times \ln(VR_{t-1})]\},$$

where as before $UR_t$ and $VR_t$ are the unemployment and vacancy rates in quarter $t$ and $LGF_t$ is a logistical growth function. As noted above the value of $LGF_t$ grows over the sample period from zero to 0.419 with the growth centred on the second half of 1974. Almost all of the change (more than 99 per cent) occurs between the September quarter of 1973, when the value of the function is 0.0016, and the December quarter of 1975, when the value of the function is 0.418. The estimated values of the new coefficients are $a_0 = 0.157$, $a_1 = -0.206$ and $a_2 = 2.271$.

---

[10] Downes and Bernie (1999) show a plus sign before the error-correction coefficient, $a_0$, but give an estimated value that is positive. This would imply that a "high" value of the unemployment rate causes the unemployment rate to increase further. They also show a minus sign before the coefficient, $c_1$, but give an estimated value that is negative. This would imply a positive relationship between the unemployment rate and the unemployment rate and the vacancy rate—an upward-sloping Beveridge curve. In both cases I treat the sign before the coefficient as the typo.

This relationship has an error-correction form. The term in braces at the end of the right-hand side is the long-run Beveridge curve. If the log of the unemployment rate exceeds the level implied by the long-run Beveridge curve in period $t-1$, then the log of the unemployment rate falls in period $t$ by a fraction $a_0 = 0.157$ of the discrepancy in period $t-1$. Since $a_1 = -0.206$, the first term on the right-hand side of the short-run Beveridge curve relationship implies that an increase in the vacancy rate in period $t$ tends to be associated with a decrease in the unemployment rate of about one-fifth the size in proportionate terms. In the late 1960s and early 1970s the unemployment and vacancy rates were quite similar in magnitude, so an increase in the vacancy rate tended to be associated with a decrease in the unemployment rate of about one-fifth the size in absolute terms. In the 1980s and 1990s, however, the vacancy rate has typically been between one-half and one per cent whereas the unemployment rate has been between about five and 11 per cent. Thus the implied percentage point fall in the unemployment rate has often been considerably larger than the associated percentage point rise in the vacancy rate.

With respect to the remaining term on the right-hand side of the short-run Beveridge curve, the one involving change in the logistical growth function, except between 1973(4) and 1975(3) this term is effectively zero. During the transition period when the long-run Beveridge curve is shifting outward however, the short-run increase in the log of the unemployment rate is about twice as large ($a_2 = 2.271$) as the increase in the logistical growth function. The change in the logistical growth function is the long-run change in the log of the log of the unemployment rate for a given vacancy rate. However, the average vacancy rate is lower after the transition than before so that there is both an outward shift of the Beveridge curve and a movement along the curve. The coefficient $a_2$ is greater than one because it picks up these two effects, both of which lead to increases in the unemployment rate.

### *2.4.6 Labour supply in the long run*

There is some discrepancy between the long-run and short-run labour supply equations in the main text of Downes and Bernie (1999) and *Documentation*, and between these equations and the short-run equation shown in Appendix C of *Documentation*. These differences are described in more detail in the Appendix A below. The form shown here follows Appendix C of *Documentation*.

In the TRYM model, labour supplied is the product of the civilian labour force and the number of hours worked per employee. That is, it is the sum of the hours worked by those employed and the hours the unemployed would have worked had they worked the same hours on average as those currently employed. There are separate equations for the labour supply (in hours) and average hours worked.

In the long run, labour supply is affected by employment (an encouraged-worker effect), changes in participation rates of age cohorts, and changes in the age composition of the labour force. The TRYM model documentation expresses long-run labour supply as the product of the long-run participation rate and desired long-run average hours worked per employee (which is exogenous). Average hours can be cancelled out in both the long-run and short-run labour supply equations, however.[11] When this cancellation is made, the long-run participation rate is given by an expression of the form:

$$\ln(PR_t) = c_7 \times Female_t \times \ln\left(ER_t^{POP}\right) + Trend_t + \ln(Dem_t),$$

where $PR_t$ is the participation rate in quarter $t$ as a fraction of the number of persons of working age and $ER_t^{POP}$ is the employment rate, also measured as a fraction of the number of persons of working age. More specifically, the participation rate and the employment rate are measured as

$$PR_t = \frac{LF_t}{POP_t^{15-64}} \text{ and } ER_t^{POP} = \frac{E_t}{POP_t^{15-64}},$$

where $LF_t$ is the civilian labour force in quarter $t$, $E_t$ is the number of persons employed, and $POP_t^{15\text{–}64}$ is the number of persons aged between 15 and 64.

The strength of the short-run encouraged-worker effect depends on the proportion of females in the labour force, captured by the variable $Female_t$.[12] A higher proportion of

[11] Strictly, this is true in the form in the equations as presented is Appendix C of *Documentation*—the form used here—but not in the form of the equation in the main text of *Documentation* and Downes and Bernie (1999).

[12] The effect of female participation is included only in the form of the labour-supply equation shown in Appendix C of *Documentation*.

females implies a stronger encouraged-worker effect. The value of this variable has grown steadily over the sample period from 0.8 at the start of the 1970s to about 1.01 at the end of the 1990s.

Since the size of the working-age population is treated as exogenous, $c_7$ is the long-run elasticity of the participation rate with respect to the employment rate, holding demographic variables constant. As is shown in Appendix A.6, this means that an increase in employment equal to one per cent of population leads to an increase in the labour force approximately equal to $c_7 / ER^{LF}$ per cent of population, where $ER^{LF}$ is the employment rate as a fraction of the labour force. It also leads to a fall in the unemployment rate, $UR \equiv 1 - E/LF$, of approximately $(1 - c_7)/PR$ percentage points.

The estimated value of the coefficient $c_7$ is 0.400. Thus when the long-run unemployment rate is seven per cent, so that $EF^{LF}$ equals 0.93, the TRYM model predicts that a long-run increase in employment equal to one per cent of the working-age population will cause a long-run increase in the labour force equal to about 0.43 per cent of the working-age population. The corresponding decrease in the unemployment rate depends on the participation rate, *PR*. This has varied from about 67 per cent in the middle of the 1960s to around 75 per cent in the second half of the 1990s.[13] For the earlier, smaller value of the participation rate, the unemployment rate would fall by about 0.9 percentage points; for the more recent value the unemployment rate would fall by about 0.8 percentage points.

The remaining terms in the expression for the participation rate are $Trend_t$ and $\ln(Dem_t)$. $Dem_t$ is an index reflecting changes in the average participation rate due to changes in the age composition of the labour force, holding constant participation rates by age cohort. It largely reflects the effects on participation rates of the baby boom. The other major demographic trend—the aging of the population due to falling mortality rates—is allowed for by calculating participation and employment rates relative to the population of working age (persons aged between 15 and 64) rather than relative to the total adult

[13] Recall that these figures relate to the labour force as a fraction of the population aged 15–64. The participation rate expressed as a fraction of the adult population aged 15 and above (the standard ABS definition) has varied from about 59 per cent to about 64 per cent.

population (all persons aged 15 or over). $Trend_t$ captures trend changes in participation rates, such as those associated with the increase in part-time employment and the increase in female participation, after adjusting for changes in the age composition of the population. It has the form:

$$Trend_t = c_0 + \frac{c_1}{1+\exp(c_2 \times [t+c_3])} + c_4 \times \left\{ t - \mathrm{pos}[t+c_5] + c_6 \times \left[ \frac{4}{1+\exp\left(\frac{-\mathrm{pos}[t+c_5]}{c_6}\right)} - 2 \right] \right\}.$$

The function pos[$t$+$c_3$] takes the value $t$+$c_3$ when $t$+$c_3$ > 0, and the value zero when $t$+$c_3$ < 0.

*2.4.7 Labour supply in the short run*

Short-run labour supply, as measured by the participation rate, is modelled by a partial adjustment equation of the form:

$$\ln(PR_t) = a_0 \times \left\{ \begin{aligned} &\ln(PR_{t-1}) \\ &+ a_1 \times Female_t \times \left[ \Delta \ln\left( \frac{LD_t^{PRIV}}{POP_t^{15-64}} \right) - a_6^{ld} \times Priv_t - \frac{u_t^{nebd}}{4} \right] \\ &+ a_2 \times Female_t \times \left[ \Delta \ln\left( \frac{E_t^{GOV} + E_t^{PUB}}{POP_t^{15-64}} \right) + a_6^{ld} \times Priv_t \right] \\ &+ \Delta Trend_t + \Delta \ln(Dem_t) \end{aligned} \right\} + (1-a_0) \times \left\{ Trend_t + \ln(Dem_t) + c_7 \times Female_t \times \left[ \ln(ER_t^{POP}) - \frac{u_t^{nebd}}{5} \right] \right\}.$$

The second term in braces on the right-hand side—the one multiplied by $(1-a_0)$—is the log of the long-run participation rate. The first term in braces on the right-hand side—the one multiplied by $a_0$—is the log of previous quarter's participation rate, $\ln(PR_{t-1})$, adjusted for demographic changes between quarter $t-1$ and quarter $t$ (the term $[\Delta Trend_t + \Delta \ln(Dem_t)]$) and an encouraged worker effect related to the change in labour demand (the second and third terms in the braces). The short-run encouraged worker effect is more complicated than the long-run encouraged worker effect in several ways:

- The short-run encouraged-worker effect is related to labour demand (employment plus vacancies) rather than just employment.
- The strength of the encouraged worker effect is allowed to vary between private sector labour demand and public sector employment. The first of the "encouraged-worker" terms involves private sector labour demand—private business sector employment plus vacancies, $LD_t^{PRIV}$—as a fraction of the working-age population, $POP_t^{15-64}$; and the second encouraged-worker term involves public sector employment—general government employment, $E_t^{GOV}$, plus public enterprise employment, $E_t^{PUB}$— as a fraction of the working-age population.
- Changes in private and public sector labour demand/employment are adjusted for the effects of privatisation of government assets through the term $a_6^{ld} \times Priv_t$, where $Priv_t$ is a measure of the amount of privatisation occurring in quarter *t* and the coefficient $a_{6\ t}^{ld}$, which comes from the labour-demand equation, is a measure of the strength of the privatisation effect.
- A fraction of the residual from the labour demand equation, $u_t^{nebd}$, is subtracted from the private-sector labour demand term to correct for possible bias arising from the fact that the employment and the labour force measures are drawn from the same survey. (A similar correction is made in the long-run encouraged-worker effect.)
- The strength of the short-run encouraged-worker effect, like that of the long-run encouraged-worker effect, depends on the proportion of females in the labour force, through the variable $Female_t$.[14]

[14] In the main text of Downes and Bernie (1999) and *Documentation* the adjustment for female participation is applied to short-run encouraged-worker effect only.

The estimated short-run labour supply equation for the period 1971(2) to 1999(2) is:

$$
\begin{aligned}
&\ln(PR_t) \\
&= 0.611 \times \left\{ \begin{aligned} &\ln(PR_{t-1}) \\ &+ 0.341 \times Female_t \times \left[ \Delta \ln\left( \frac{LD_t^{PRIV}}{POP_t^{15-64}} \right) - 0.000001 \times Priv_t - \frac{u_t^{nebd}}{4} \right] \\ &+ 0.145 \times Female_t \times \left[ \Delta \ln\left( \frac{E_t^{GOV} + E_t^{PUB}}{POP_t^{15-64}} \right) + 0.000001 \times Priv_t \right] \\ &+ \Delta Trend_t + \Delta \ln(Dem_t) \end{aligned} \right\} \\
&+ 0.389 \times \left\{ Trend_t + \ln(Dem_t) + 0.400 \times \left[ \ln\left(ER_t^{POP}\right) - \frac{u_t^{nebd}}{5} \right] \right\}.
\end{aligned}
$$

The short-run encouraged-worker effect is more than twice as strong with respect to private-sector labour demand as it is with respect to public-sector employment.

### *2.4.8 Average hours worked*

Long-run hours worked, $H_t^{LR}$, is given by a logistical growth function of the form:[15]

$$
H_t^{LR} = c_0 + \frac{c_1}{1 + \exp[c_2 \times (t + c_3)]}.
$$

In the short run labour, average hours worked per employee, $H_t$, is modelled by a partial-adjustment equation of the form: [16]

$$
\begin{aligned}
\ln(H_t) = a_0 \times &\left\{ \begin{aligned} &\ln(H_{t-1}) + a_1 \times \left[ \Delta \ln\left(Y_t^{PRIV}\right) - Growth_t \right] + a_2 \times \left[ \Delta \ln\left(Y_{t-1}^{PRIV}\right) - Growth_{t-1} \right] \\ &+ a_3 \times \left[ \frac{\ln\left(I_t^{DWELL} / I_{t-10}^{DWELL}\right)}{10} - \frac{Growth_t - Growth_{t-10}}{2} \right] \\ &+ a_4 \times \left[ \ln(VR_t) - \ln\left(VR_t^{EXP}\right) \right] + \Delta \ln\left(H_t^{LR}\right) \end{aligned} \right\} \\
&+ (1 - a_0) \times \ln\left(H_t^{LR}\right).
\end{aligned}
$$

The second term in braces on the right-hand side—the one multiplied by $(1 - a_0)$—is the log of desired long-run average hours. The first term in braces on the right-hand side

[15] The form used here is the one in Appendix C of *Documentation*; it differs from the one shown in Downes and Bernie (1999) and the main text of *Documentation*.

[16] Again the equation shown here follows the one in Appendix C of *Documentation*, which differs from the one shown in Downes and Bernie (1999) and the main text of *Documentation*.

is the log of previous period's participation rate average hours adjusted for trend changes in desired hours—the term $\Delta \ln\left(H_t^{LR}\right)$—and labour demand factors. The inclusion of labour demand factors reflects the fact that short-run adjustments in labour inputs will occur through changes in average hours worked (for example, increased overtime) as well as through changes in the number of employees. The particular demand factors included are:

- The current rate of growth of private business sector output relative to the underlying growth rate of the economy, $\left[\Delta \ln\left(Y_t^{PRIV}\right) - Growth_t\right]$, and the first lag of this relative growth rate, $\left[\Delta \ln\left(Y_{t-1}^{PRIV}\right) - Growth_{t-1}\right]$. The increase in labour input required for a high rate of growth of output in the private business sector will be partly met in the short run by an increase in hours. An increase in public sector output leads to an increase in the number employed.
- The ten-quarter rate of growth in dwelling investment relative to the underlying growth rate of the economy, $0.1 \times \ln\left(I_t^{DWELL} / I_{t-10}^{DWELL}\right) - 0.5 \times \left(Growth_t - Growth_{t-10}\right)$. The inclusion of dwelling investment in addition to private-sector output reflects the high levels of overtime per worker in the construction industry.
- The difference between the actual vacancy rate, $VR_t$, and the vacancy rate implied by the long-run Beveridge curve for the current unemployment rate.

The estimated short-run hours-worked equation for the period 1971(2) to 1999(2) is:

$$\ln\left(H_t\right) = 0.474 \times \left\{ \begin{array}{l} \ln\left(H_{t-1}\right) + 0.076 \times \left[\Delta \ln\left(Y_t^{PRIV}\right) - Growth_t\right] \\ + 0.163 \times \left[\Delta \ln\left(Y_{t-1}^{PRIV}\right) - Growth_{t-1}\right] \\ + 0.112 \times \left[ \dfrac{\ln\left(I_t^{DWELL} / I_{t-10}^{DWELL}\right)}{10} - \dfrac{Growth_t - Growth_{t-10}}{2} \right] \\ + 0.010 \times \left[\ln\left(VR_t\right) - \ln\left(VR_t^{EXP}\right)\right] + \Delta \ln\left(H_t^{LR}\right) \end{array} \right\}$$
$$+ 0.526 \times \ln\left(H_t^{LR}\right).$$

*2.4.9 Labour demand in the long run*

In the TRYM model, labour is demanded by the private business sector, by government enterprises and by the general government sector. As note above, the private business sector currently accounts for over 80 per cent of total employment, government enterprises account for about three per cent, and the general government sector accounts for around 15 per cent. The quantity of labour demanded is modelled in terms of total hours. In the long run, average hours worked is treated as exogenous and the number of workers is treated as endogenous (in the short run, average hours also has an endogenous component). The total number of workers demanded in the economy is measured as the sum of employment and vacancies.

The labour demand of the three labour-demanding sectors is modelled in different ways. In both the general government and government enterprise sectors, labour demand is measured as the product of employment in the sector and average hours in the economy. In the private business sector, labour demand is measured as the product of the average hours in the economy and the sum of vacancies and private business sector employment. The average hours part of labour demand is common to all three sectors and is modelled as described above. It is demand for bodies that differs across sectors. The simplest sector is general government for which employment is entirely exogenous in both the short run and the long run.

Labour demand by government enterprises is more complicated. Labour demand in hours is effectively exogenous in the long run but has an endogenous component in the short-run. Since long-run average hours are exogenous, long-run employment in the government enterprise sector is also exogenous. It is assumed that in the long run the capital-output ratio of the government enterprise sector is constant. This means that the rate of growth of labour demand is the rate of growth of output less the rate of labour-augmenting productivity growth in the government enterprise sector. That is,

$$\ln\left(E_t^{GE} \times H_t\right) = \ln\left(K_{t-1}^{GE}\right) + c_0 - \left(\lambda_L + c_1\right)t.$$

The left-hand side of this expression is the log of labour demand by the government enterprise sector—employment, $E_t^{GE}$, multiplied by average hours. The first term on the right-hand side is the log of the capital stock of the government enterprise sector at the end of quarter $t-1$, the capital stock available for use in quarter $t$. The second term is a constant. The third term represents technological progress; $\lambda_{GE} \equiv \lambda_L + c_1$ is the rate of labour-augmenting technological progress in the government enterprise sector decomposed into the rate of technological progress in the private business sector and the difference between the rates of technological progress in the two sectors. The government-enterprise capital stock is modelled as the accumulation of investment, $I_t^{GE}$, less depreciation at rate $\delta^{GE}$. That is, $K_t^{GE} = \left(1-\delta^{GE}\right)\times K_{t-1}^{GE} + I_t^{GE}$. Since investment is treated as exogenous, the capital stock and labour demand of the government enterprise sector are also exogenous in the long run.

For the sample period 1970(1) to 1995(3), the estimated value of $c_1$ implies an average productivity growth rate in the government enterprise sector of 4.4 per cent per annum compared with a growth rate of 0.8 per cent in the private business sector.

Firms in the private business sector decide labour demand, prices and investment jointly. Technology is represented by a constant returns-to-scale, CES production function of the form:

$$Y_t^{BUS} = \left\{\alpha\left[\exp(\lambda_L t)L_t^{BUS}\right]^{\frac{\sigma-1}{\sigma}} + \beta\left[\exp(\lambda_K t)K_{t-1}^{BUS}\right]^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{\sigma-1}},$$

where $Y_t^{BUS}$ is the output of the private business sector in period $t$, $L_t^{BUS}$ is labour input in period $t$ hours, $K_{t-1}^{BUS}$ is the capital stock at the end of period $t-1$ and available for use in period $t$, $\lambda_L$ is the rate of labour-augmenting technological progress, $\lambda_K$ is the rate of capital- augmenting technological progress, and $\sigma$ is the elasticity of substitution between labour and capital. In the long run firms maximise profits. This means that they choose labour input to equate the marginal product of labour with the real producer wage. As is shown in Appendix A.7, this means for the CES production function that they set:

$$\ln\left(L_t^{BUS}\right) = \sigma\times\ln(\alpha) + (\sigma-1)\times\lambda_L t + \ln\left(Y_t^{BUS}\right) - \sigma\times\ln\left(\frac{W_t^{BUS}}{P_t^{BUS}}\right).$$

Desired labour input, on the left-hand side is the product of desired employment and average hours per employee, $H_t$; and desired employment is the sum of employment in the private business sector, $E_t^{BUS}$, and unfilled vacancies, $V_t$. Thus we can write the long-run labour demand equation for the private business sector as:

$$\ln\left(E_t^{BUS} + V_t\right) = \ln\left(Y_t^{BUS}\right) - \ln\left(H_t\right) - \lambda_L t + \sigma\times\ln(\alpha) - \sigma\times\left[\ln\left(\frac{W_t^{BUS}}{P_t^{BUS}}\right) - \lambda_L t\right].$$

For the sample period 1970(4) to 1999(2), the estimated value of the elasticity of substitution, $\sigma$, is 0.817. This is considerable below one. The estimated value for the rate of labour-augmenting technological progress, given by $\lambda_L$, is 1.2 per cent per year. The estimated value of the coefficient on labour in the production function, $\alpha$, is 0.404.

*2.4.10 Labour demand in the short run*

Labour demand is modelled differently across the three sectors—the private business sector, the government enterprise sector and the general government sectors—in the short run, just as it is in the long run.

In the short run, like the long run, general government labour demand is exogenous.

Government enterprises adjust their labour demand only gradually to changes in the capital stock. To capture this, short-run labour demand has an error-correction form with an additional lagged variable. The equation is written in terms of the labour-capital ratio as:

$$\Delta \ln\left(\frac{E_t^{GE} \times H_t}{K_{t-1}^{GE}}\right) = -\lambda_{GE} + a_1 \times \left[\Delta \ln\left(\frac{E_{t-1}^{GE} \times H_{t-1}}{K_{t-2}^{GE}}\right) + \lambda_{GE}\right]$$
$$a_0 \times \left[c_0 - \lambda_{GE} t - \ln\left(\frac{E_{t-1}^{GE} \times H_{t-1}}{K_{t-2}^{GE}}\right)\right].$$

For the sample period 1970(1) to 1995(3), the estimated value of $a_1$ is 0.108 and the estimated value of $a_0$ is 0.036. These estimates imply only slow adjustment of employment to changes in labour demand in hours. Note that government enterprise employment was not found to be sensitive to labour costs even in the short run.

The short-run labour demand curve for the private business sector has an error-correction form and is adjusted for population growth to ensure that steady-state bias is not introduced. It also contains a dummy to allow for the effects of privatisation:

$$
\begin{aligned}
\Delta\ln\left(E_t^{BUS}+V_t\right) = {} & n_t^8 - a_1\times\sigma\times\left[\Delta\ln\left(\frac{W_t^{BUS}}{P_t^{BUS}}\right)-\lambda_L\right]-(1-a_2)\times\Delta\ln(H_t) \\
& + a_3\times\left[\Delta\ln\left(Y_t^{BUS}\right)-n_t^4-\lambda_L\right]+a_4\times\left[\Delta\ln\left(Y_{t-1}^{BUS}\right)-n_{t-1}^4-\lambda_L\right] \\
& + a_5\times\left[\Delta\ln\left(Y_{t-2}^{BUS}\right)-n_{t-2}^4-\lambda_L\right]+a_6\times Priv_t \\
& - a_0\left\{\begin{array}{l} \ln\left(\dfrac{E_t^{BUS}+V_{t-1}}{Y_{-1t}^{BUS}}\right)+\ln(H_{t-1})+\lambda_L\times(t-1)-\sigma\times\ln(\alpha) \\ +\sigma\times\left[\ln\left(\dfrac{W_{t-1}^{BUS}}{P_{t-1}^{BUS}}\right)-\lambda_{L1}\times(t-1)\right]\end{array}\right\},
\end{aligned}
$$

where $E_t^{BUS}+V_t$ is labour demand in persons for the private business sector (the sum of employment and vacancies), $H_t$ is average hours per employee, $Y_t^{BUS}$ is the output of the private business sector, $W_t^{BUS}/P_t^{BUS}$ is the real producer wage, $Priv_t$ is a measure of privatisation, $n_t^8$ and $n^4$ are the average growth rates of the adult population over the past 8 and 4 quarters, $\sigma$ is the elasticity of substitution between capital and labour, $\alpha$ is the coefficient on labour in the production function, and $\lambda_L$ is the rate of labour-augmenting technological progress.

For the sample period 1970(4) to 1999(2), the estimated value of the error-correction coefficient, $a_0$, is 0.198 and the estimated value of the coefficient on the privatisation dummy is 0.000001. The estimated values of the other coefficients in the short-run part of the equation are: $a_1$ = 0.150; $a_2$ = 0.713; $a_3$ = 0.240; $a_4$ = 0.106; $a_5$ = 0.085.

## 3. Access Economics Macro (AEM) Model

This section examines the labour market in the Access Economics Macro model. Subsection 3.1 gives some background on the AEM model. Subsection 3.2 outlines very briefly the main labour market equations in the model. Section 3.3 discusses these equations in more detail. The material here is based on the documentation for Version 5.0 of the model. The Theory and Econometrics section of the documentation is dated September 1998; the Equation Listing section is dated June 1999.

### *3.1 Background to the AEM model*

The AEM model is a macroeconometric model of the Australian economy. It has two main functions: (1) forecasting—the production of quarter-by-quarter nine-year ahead forecasts of the Australian economy; (2) scenario analysis—the analysis of the quarter-by-quarter effects of different assumptions for the international environment and domestic macroeconomic policies. It is estimated from quarterly data beginning in most cases from 1976(1).

The model has over 300 equations including state and industry equations. Most of the long-term properties and behavioural structure of the model, however, are concentrated on around 100 “core” equations of which 19 are estimated behavioural equations. Like the TRYM model and the Murphy model, the AEM is an open economy model. It has five sectors:

I. A household sector, which consumes rental services and other consumption and supplies labour. Associated with this are an unemployment rate (labour supply) equation and a wage-setting equation (or Phillips curve).
II. A dwelling sector, which produces dwelling services from the stock of dwellings and materials for dwelling maintenance and undertakes dwelling investment
III. A business sector. The business sector uses three inputs—labour, business fixed capital, and imports—to produce three outputs—commodity exports, other exports and the domestic good. It undertakes investment, which adds to its capital stock. Long-run choices of levels of inputs and outputs are based on neoclassical first-order conditions
IV. A general government sector. Its expenditures on goods and services are exogenous to the model
V. A foreign sector, which demands commodity exports and other exports and supplies imports.

In the long run, all prices are flexible and the business sector maximises profits given prices and a constant returns-to-scale production function. This production function has a nested CES form. Total output, $Y_t$, is a CES function of imports, $M_t$, and “domestic factor” inputs, $DF_t$, given by:

$$Y_t = \left[\left(A_t^M M_t\right)^\delta + \left(A_t^{DF} DF_t\right)^\delta\right]^{\frac{1}{\delta}}.$$

The domestic factors are labour, $L_t$, and capital, $K_t$, and the $DF_t$ variable is a CES function of these two factors of the form:

$$DF_t = \left[ \left(A_t^L L_t\right)^{\rho} + \left(A_t^K K_t\right)^{\rho} \right]^{\frac{1}{\rho}}.$$

The estimated values of the parameters in these equations for the sample period 1980(1) to 1997(1) are: $\delta = -0.304$, which implies an elasticity of substitution between imports and domestic factors of $1/(1-\delta) = 0.7$; and $\rho = -0.299$, which implies an elasticity of substitution between capital and labour of $1/(1-\rho) = 0.77$. Rather than using these estimates, the values $\delta = \rho = -1/3$ are imposed; these imply elasticities of substitution of 0.75.

Households make three choices in the model:

(1.) They allocate consumption between rental services and other consumption. This choice is based on utility maximisation subject to a budget constraint.

(2.) The consumption/saving choice. This is based on an Ando-Modigliani consumption function

(3.) The work/leisure choice or labour force participation rate decision. This has heuristic foundations in the model.

### *3.2 Outline of the labour market in the AEM model*

The labour market in the AEM model has three main components. These are described in detail in section 3.3, but a brief description is as follows:

- **Labour demand**. Labour demand in the AEM model is measured in persons rather than in hours, and the quantity demanded in any quarter is measured by employment. Labour demand by government is treated as exogenous; labour demand by the private sector is endogenous.
- **Labour supply**. Labour supply is also measured in persons, and is the sum of employment and unemployment. In both the short run and long run it is driven by short-run changes in the unemployment rate. Subsection 3.3.2 below gives more details.
- **Phillips curve**. As in the TRYM model, the equilibrium unemployment rate is given by the NAIRU and, as in the TRYM model again, the confidence intervals about the coefficients used in calculating the NAIRU are quite broad so that the NAIRU is not very precisely estimated. In the short run, expected real wage

inflation, relative to trend, depends on the reciprocal of the unemployment rate in the corresponding quarter of the previous year, and on the change in the unemployment rate in the last quarter. Apart from an adjustment to wage inflation for changes in the superannuation guarantee, no other variables appear in the wage-setting equation in the AEM model.

### *3.3 Detail of labour market equations in the AEM model*

This section contains details of the main labour-market equations in the AEM model: the wage-setting equation or Phillips curve; the short-run unemployment rate equation or labour-supply equation; and the labour demand equation for the private sector. The relationship between the notation used here and the notation in the AEM model documentation, and some further details on estimation, are given in Appendix B.

#### *3.3.1 The wage-setting equation*

The wage-setting equation (Phillips curve) in the AEM model has the form:

$$\frac{\Delta \ln(W_t)}{1+SG_t} - \pi_t^e - \lambda_t = a_0 + a_1 \times \frac{\Delta E_{t-1}}{LF_{t-1}} + a_2 \times \frac{1}{UR_{t-4}} + u_t^{WE} - u_{t-1}^{WE},$$

where $W_t$ is average weekly earnings in quarter $t$, $SG_t$ is an exogenous adjustment for the superannuation guarantee, $\pi_t^e$ is expected inflation, $\lambda_t$ is the growth in the labour efficiency index, $E_t$ is total employment including defence personnel, $LF_t$ is labour supply or the labour force including defence personnel $UR_t$ is the unemployment rate in quarter $t$, and $u_t^{WE}$ is a residual.[17] The expected inflation term reflects both expected inflation in the near future and recent consumer price inflation (see Appendix B for more details).

The left-hand side of the equation is expected wage inflation between quarter $t-1$ and quarter $t$ relative to trend (and adjusted for changes in the superannuation guarantee). This depends inversely on the unemployment rate in quarter $t-4$, but also on the change in employment between quarter $t-2$ and quarter $t-1$ as a fraction of the labour

[17] Strictly it is the ratio of unemployment to the total labour force including defence personnel. The unemployment rate does not appear explicitly in the wage-setting equation in the AEM model. Defence personnel currently represent 0.6 per cent of the labour force and have not been more than 1.2 per cent since the middle of the 1970s.

force in period $t-1$. This change is approximately the negative of the change in the unemployment rate between quarter $t-2$ and quarter $t-1$. On the long-run equilibrium growth path, expected real wage inflation is equal to its trend value (the left-hand side of the wage-setting equation is zero), the unemployment rate is constant, and the residual is zero. Thus the equilibrium unemployment rate, the NAIRU, is

$$NAIRU = \frac{-a_2}{a_0}.$$

In the TRYM and Murphy models, expected wage inflation between quarter *t* and quarter $t+1$ depends on the change in the unemployment rate between quarter $t-1$ and quarter *t* and on the unemployment rate in quarter $t-1$. This allows us to define a short-run NAIRU in quarter *t* as the unemployment rate in quarter *t* that produces expected wage inflation equal to the long-run trend between quarters *t* and $t+1$, and to relate this to the unemployment rate in quarter $t-1$. This is not possible in the AEM model since expected wage inflation in quarter $t+1$ depends on the unemployment rate in quarter $t-3$ (and because an approximation to the change in the unemployment rate rather than the actual change appears in the wage-setting equation). The relationship between wage inflation and the unemployment rate is thus more complicated. We can, however, define a pseudo short-run NAIRU that would apply if the unemployment rate had not changed between quarter $t-3$ and quarter $t-1$. We get an expression for this pseudo NAIRU by setting the left-hand side of the wage-setting equation and the residuals equal to zero, stepping one quarter ahead, assuming that $UR_{t-1}$ is equal to $UR_{t-3}$, and solving for the unemployment rate in quarter *t*. This gives the pseudo short-run NAIRU as:

$$NAIRU_t^{SR} \approx UR_{t-1} + \frac{a_0}{a_1} + \frac{a_2}{a_1} \times \frac{1}{UR_{t-1}} = UR_{t-1} + \frac{a_0}{a_1} \times \left(1 - \frac{NAIRU}{UR_{t-1}}\right).$$

The documentation for the AEM model gives two different sets of estimated values for the coefficients in this equation. In the listing of the estimated equations on pages 87–88 of the documentation, the estimated values of the coefficients in the wage-setting equation for the period 1976(1) to 1997(1) are shown as: $a_0 = -0.0125$, $a_1 = 1.2549$, and $a_2 = 0.0008$. In the discussion of the wage-setting equation on pages 30–31 of the documentation, however, the estimated value of $a_0$ is given as –0.02157 and the estimated value of $a_2$ as 0.00165 (no estimates are given for other coefficients). These estimates give a NAIRU of 0.00165/0.02157 or 7.65 per cent. The values of the coefficients shown in the listing of equations give a NAIRU equal to 0.0008/0.0125 or 6.4 per cent,[18] and the equation for the pseudo short-run NAIRU is:

$$NAIRU_t^{SR} = UR_{t-1} - 0.00996 + 0.000638 \times \frac{1}{UR_{t-1}}.$$

This equation is plotted in Figure 4. (Figure 4 also contains plots of the "short-run" NAIRUs for the TRYM and Murphy models. The AEM model line is the dashed line which for most of its length is just below the thick, unbroken line, which is a 45-degree line.) If $UR_{t-1}$ equals the NAIRU (0.064 or 6.4 per cent) then the short-run NAIRU is equal to the NAIRU. If $UR_{t-1}$ equals 7.4 per cent, one percentage point higher than the NAIRU, then the short-run NAIRU is equal to 7.27 per cent, 0.87 percentage points above the NAIRU and 0.13 percentage points below $UR_{t-1}$. If $UR_{t-1}$ equals 5.4 per cent, one percentage point lower than the NAIRU, then the short-run NAIRU is equal to 5.58 per cent, 0.82 percentage points below the NAIRU and 0.18 percentage points above $UR_{t-1}$.

### *3.3.2 Labour Supply*

Labour supply in the AEM model in both the short run and long run is driven by short-run changes in the unemployment rate. Given an initial size of the labour force, subsequent sizes of the labour force can be calculated from employment and the unemployment rates given by the short-run unemployment rate equation. This equation is:

$$\begin{aligned} UR_t = {} & a_0 \times UR_{t-1} + a_1 \times NAIRU + a_2 \times \left[\gamma\left(D_t^{LR}\right) - \lambda_t - \gamma\left(E_t\right)\right] + a_3 \times \Delta Replace_t \\ & + u_t^{UR} - a_0 \times u_{t-1}^{UR}, \end{aligned}$$

where $UR_t$ is the unemployment rate in period $t$, $\gamma(D_t^{LR})$ is the growth rate of trend domestic final demand, $\lambda_t$ is the growth rate of the labour efficiency index, $\gamma(E_t)$ is the

[18] Strictly this is unemployment as a fraction of the total labour force including defence personnel. With defence personnel currently representing 0.6 per cent of the labour force, it corresponds to an unemployment rate under the conventional definition of 6.44 per cent.

growth rate of employment, $Replace_t$ is the replacement ratio, the ratio of the unemployment benefit to the after-tax wage, and $u_t^{UR}$ is a the residual in the unemployment rate equation. The values of the coefficients in the unemployment equation are imposed. The equation is:

$$UR_t = 0.9 \times UR_{t-1} + 0.1 \times NAIRU + 0.3 \times \left[\gamma\left(D_t^{LR}\right) - \lambda_t - \gamma\left(E_t\right)\right] + 0.1 \times \Delta Replace_t \\ + u_t^{UR} - 0.9 \times u_{t-1}^{UR}.$$

The first two terms on the right-hand side represent a weighted average of the previous period's unemployment rate and the NAIRU, with a weight of 90 per cent on lagged unemployment. Thus the unemployment rate will converge to the NAIRU in the long run. The term in square brackets is the difference between the trend growth in demand for labour (the trend growth in output less the increase in labour productivity) and the growth in unemployment. This is a measure of the amount by which employment growth is below trend. A positive value leads to an increase in the unemployment rate, though the fact that the coefficient on the term is less than the participation rate implies that there is an encouraged/discouraged worker effect. The equation also implies that an increase in the replacement rate will cause a temporary increase in the unemployment rate through an increase in the participation rate.

### *3.3.3 Labour Demand*

Labour demand in the AEM model is the sum of private sector employment and government employment. Government employment is treated as exogenous. In the short run, private sector labour demand is given by:

$$\ln\left(E_t - E_t^{GOV}\right) - \ln\left[\left(1 + n_t\right) \times \left(E_{t-1} - E_{t-1}^{GOV}\right)\right] \\ = a_0 - a_1 \times \ln\left(\frac{P_t^{EW} \times Micro_t}{P_t}\right) + a_3 \times \Delta YoverK_t + a_4 \times \Delta YoverK_{t-1} - a_5 \times t \\ - a_2 \times \ln\left[\left(1 + n_t\right) \times \left(E_{t-1} - E_{t-1}^{GOV} - E_{t-1}^{P,EQ}\right)\right] + u_t^{LD},$$

where $E_t$ is total employment in quarter $t$, $E_t^{GOV}$ is exogenously given general government employment, $n_t$ is the rate of growth of the working-age population, $P_t$ and $P_t^{EQ}$ are the actual and short-run equilibrium price indexes for domestic production, $Micro_t$ is an exogenous index of microeconomic reform, $YoverK_t$ is the output-capital ratio, $E_t^{P,EQ}$ is the short-run equilibrium private-sector employment, and $u_t^{LD}$ is the residual in the labour demand equation.

The left-hand side of the equation is the change in the log of private-sector employment between quarter $t-1$ and quarter *t*, allowing for population growth between the quarters. This depends negatively on microeconomic reform in the sense that, for given output, microeconomic reform reduces the amount of labour required for a given output. An increase in the capital-output ratio is associated with an increase in the demand for labour. The term in square brackets on the right-hand side is an error-correction term. It is the difference between quarter $t-1$ private sector employment and its equilibrium value, adjusted for population growth. If actual private-sector employment is above its short-run equilibrium value in quarter $t-1$, private sector employment tends to fall relative to trend in quarter *t*.

## 4. The Murphy Model

This section examines the labour market in the Murphy Model. Subsection 4.1 gives some background on the Murphy Model. Subsection 4.2 outlines very briefly the main labour market equations in the model. Section 4.3 discusses these equations in more detail. The material here is based on Powell and Murphy (1997) and the 1999 documentation for the MM2 version of the Murphy model, which also draws heavily on Powell and Murphy.

### *4.1 Background to the Murphy Model*

The Murphy Model shares much of the same history as the AEM model. The most recent MM2 version of the Murphy Model, however, incorporates a large amount of sectoral detail in a manner that makes it and integrated macro-CGE model. There are strong similarities between the macro aspects of the two models and while the demand side of the labour market in the Murphy model is handled at the sectoral level, wage setting and labour supply are modelled at the aggregate level.

### *4.2 Outline of the labour market in the Murphy Model*

The labour market in the Murphy model has three main components. These are described in detail in section 4.3, but a brief description is as follows:

- **Labour demand**. Labour demand in the Murphy Model, as in the AEM model, is measured in persons rather than in hours, and the quantity demanded in any quarter is measured by employment. Labour demand by government is treated as exogenous; labour demand by the private sector is endogenous and is build up from the individual labour demands of the industries in the economy.
- **Labour supply**. Labour supply is also measured in persons, and is the sum of employment and unemployment. It is modelled at the aggregate level rather than the industry level. In the long run it is basically exogenous though the model incorporates a demographic module. In the short run it is also affected by employment (an encouraged/discouraged worker effect).
- **Phillips curve**. As in the TRYM and AEM models, the equilibrium unemployment rate is given by the NAIRU. In the short run, expected real wage inflation, relative to trend, depends on the reciprocal of the unemployment rate and on the change in the unemployment rate in the previous quarter. No other variables appear in the wage-setting equation in the Murphy Model. In particular, wage inflation does not depend directly on any industry-specific variables.

### *4.3 Detail of labour market equations in the Murphy Model*

This section contains details of the wage-setting equation or Phillips curve and the short-run labour supply equation in the Murphy Model. The relationship between the notation used here and the notation in the Murphy Model documentation, and some further details on estimation, are given in Appendix C.

#### *4.3.1 The wage-setting equation*

The wage-setting equation (Phillips curve) in the Murphy Model has the form:

$$\Delta \ln(W_t) - \pi_t^e - \lambda_t = c_0 + c_1 \times \Delta UR_{t-1} + c_2 \times \frac{1}{UR_{t-2}} + z_t^W ,$$

where $W_t$ is average earnings in quarter $t$, $\pi_t^e$ is expected inflation, $\lambda_t$ is the growth in labour efficiency, $UR_t$ is the unemployment rate in quarter $t$, and $z_t^W$ is a residual (or user-supplied shock).[19] Expected inflation is measured as the average of (1) a rational-expectations forecast of inflation in quarter $t-2$ and (2) the actual change in prices of consumption goods in the year to quarter $t-1$. The growth in labour efficiency is a weighted average across industries.

The left-hand side of the equation is expected wage inflation between quarter $t-1$ and quarter $t$ relative to trend. This depends inversely on the unemployment rate in quarter $t-2$, but also on the change in the unemployment rate between quarter $t-2$ and quarter $t-1$. On the long-run equilibrium growth path, expected real wage inflation is equal to its trend value (the left-hand side of the wage-setting equation is zero), the unemployment rate is constant, and the residual is zero. Thus the equilibrium unemployment rate, the NAIRU, is

$$NAIRU = \frac{-c_2}{c_0}.$$

If we define the short-run NAIRU in quarter *t* as the unemployment rate in quarter *t* that produces expected wage inflation equal to the long-run trend between quarters *t* and $t+1$, then this depends on the unemployment rate in quarter $t-1$. Setting the left-hand side of the wage-setting equation and the residual equal to zero, stepping one quarter ahead, and solving for the unemployment rate in quarter *t* gives the short-run NAIRU as:

$$NAIRU_t^{SR} = UR_{t-1} - \frac{c_0}{c_1} - \frac{c_2}{c_1} \times \frac{1}{UR_{t-1}} = UR_{t-1} - \frac{c_0}{c_1} \times \left(1 - \frac{NAIRU}{UR_{t-1}}\right).$$

[19] In the Murphy Model, the unemployment rate is given its usual definition: the ratio of unemployment to the civilian labour force (the sum of civilian employment and unemployment). What actually appears in the wage-setting equation, however, is the ratio of unemployment to the total labour force including defence personnel. Defence personnel currently represent 0.6 per cent of the labour force and have not been more than 1.2 per cent since the middle of the 1970s.

The estimated values of the coefficients in the wage-setting equation are: $c_0 = -0.02144295$, $c_1 = -1.261288$, and $c_2 = 0.0016$. Thus the NAIRU is equal to $0.0016/0.02144295$ or 7.46 per cent,[20] and the equation for the short-run NAIRU is:

$$NAIRU_t^{SR} = UR_{t-1} - 0.017001 + 0.00127 \times \frac{1}{UR_{t-1}}.$$

This equation is plotted in Figure 4. (Figure 4 also contains plots of the "short-run" NAIRUs for the TRYM and AEM models. The Murphy model line is the dotted line, which for most of its length is just above the thick, unbroken line, which is a 45-degree line.) If $UR_{t-1}$ equals the NAIRU (0.0746 or 7.46 per cent) then the short-run NAIRU is equal to the NAIRU. If $UR_{t-1}$ equals 8.46 per cent, one percentage point higher than the NAIRU, then the short-run NAIRU is equal to 8.26 per cent, 0.80 percentage points above the NAIRU and 0.20 percentage points below $UR_{t-1}$. If $UR_{t-1}$ equals 6.46 per cent, one percentage point lower than the NAIRU, then the short-run NAIRU is equal to 6.72 per cent, 0.74 percentage points below the NAIRU and 0.26 percentage points above $UR_{t-1}$.

### *4.3.2 Labour supply*

In the Murphy model, the labour supply is equal to the labour force—the sum of total employment (including defence personnel) and unemployment. It is determined by the participation rate (which is defined to exclude defence personnel), the adult population, and the number of defence personnel. In the long run, each of these three factors is treated as exogenous—as an input to the model—and so labour supply is exogenous.

In the short run, labour supply also depends on contemporaneous and lagged employment. Further dynamics are introduced through a lagged labour supply term. The short-run labour supply equation is:

[20] Strictly this is unemployment as a fraction of the total labour force including defence personnel. With defence personnel currently representing 0.6 per cent of the labour force, it corresponds to an unemployment rate under the conventional definition of 7.50 per cent.

$$\ln(LF_t) - \ln(LF_t^{LR}) = c_0 + c_1 \times t + c_2 \times \ln\left(\frac{LF_{t-1}}{LF_{t-1}^{LR}}\right) + c_3 \times \ln\left(\frac{E_t}{LF_t^{LR}}\right)$$
$$+ c_4 \times \ln\left(\frac{E_{t-1}}{LF_{t-1}^{LR}}\right) + c_5 \times \ln\left(\frac{E_{t-2}}{LF_{t-2}^{LR}}\right) + z_t^N,$$

where $LF_t$ is labour supply or the total labour force including defence personnel in period *t*, $LF_t^{LR}$ is trend labour force, $E_t$ is total employment, and $z_t^N$ is a residual (or user-supplied shock). The trend labour force is the product of the trend participation rate, $PR_t^{LR}$, and the adult population, $POP_t^{15+}$. That is, $LF_t^{LR} = PR_t^{LR} \times POP_t^{15+}$. Note that the left-hand side of the equation is the log of the ratio of actual labour supply to trend labour supply.

The estimated values of the coefficients are: $c_0 = -0.4501$, $c_1 = 0.0002$, $c_2 = 0.7875$, $c_3 = 0.5024$, $c_4 = -0.5794$ and $c_5 = 0.1896$.

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