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An Eclectic Approach to Estimating U.S. Potential GDP

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Eclectic: drawing upon the best theories from different systems, rather than building a new one.

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Abstract

The authors describe the principal results obtained from a new method applied to the estimation of potential U.S. GDP. This method derives from the work of Rennison (2002), which suggests that the joint use of extended multivariate filters and structural vector autoregression models is optimal for estimating potential output. The authors use this approach to estimate the two components of potential GDP: the full-employment labour input and trend labour productivity. This decomposition is particularly useful for identifying sources of fluctuations in potential output. It reveals, for example, that the vigorous growth rate of potential output recorded during the second half of the 1990s is attributable to a fall in the structural rate of unemployment and a marked upswing in trend productivity growth. This approach also reveals that the excess supply observed in the second quarter of 2002 is entirely attributable to the fact that the labour input was below its equilibrium level.

JEL classification: E23, C32, E32.
Bank classification: Potential Output, Econometric and Statistical Methods, Business Fluctuations and Cycles.

Résumé

Dans cette étude, les auteurs exposent les principaux résultats quant à l'application d'une nouvelle méthode d'estimation du PIB potentiel américain. Cette méthode est fondée sur les travaux de Rennison (2002), qui indiquent que l'utilisation conjointe de filtres multivariés étendus et de VAR structurels est optimale pour l'estimation de la production potentielle. Les auteurs utilisent cette approche afin d'estimer les deux composantes du potentiel, soit l'intrant travail de plein emploi ainsi que la tendance productivité de la main-d'oeuvre. Une telle décomposition fournit une bonne identification des sources de fluctuations du PIB potentiel. Elle permet par exemple de montrer que la vigueur du taux de croissance du PIB potentiel enregistrée au cours de la seconde moitié des années 1990 est imputable à une chute du taux de chômage structurel et à une accélération notable du rythme de croissance de la productivité tendancielle. Cette approche permet aussi de montrer que l'offre excédentaire observée au deuxième trimestre de 2002 est entièrement imputable au fait que l'intrant travail se trouve en-dessous de son équilibre.

Classification JEL: E23, C32, E32.
Classification de la Banque: Production potentielle, Méthodes économétriques et statistiques, Cycles et fluctuations économiques.

1. Introduction

Estimating the disequilibrium between aggregate supply and demand is vitally important in identifying the pressures on production capacities. This disequilibrium, usually referred to as the output gap, incorporates a considerable amount of information concerning the expected evolution of inflation. The output gap underlies the main forecasting models used by the Bank of Canada. It represents the difference between actual and potential output levels. Conceptually, potential output corresponds to the level of output that an economy can sustain without generating inflationary pressures. It cannot be directly observed. During the 1990s, a considerable amount of research at the Bank was devoted to estimating potential output. This research revealed that models built on extended multivariate filters and structural vector autoregressions (SVARs) possess an appropriate theoretical structure and yield relatively reliable estimates of potential output. These models have shortcomings, however. For example, filters tend to generate biased estimates of potential output at the end of the sample, while potential output identified by SVARs show undue volatility. Extended filters are used to estimate Canadian potential GDP in the Quarterly Projection Model (QPM), while an SVAR is used for estimating U.S. potential GDP in USM.

In a recent study, Rennison (2002) shows that an optimal approach consists of using filters and SVARs jointly. From a technical perspective, this method consists of using an expanded version of a multivariate HP-filter to which an equilibrium path generated by an SVAR is added as information conditioning the estimate. This approach is already used for estimating structural unemployment in QPM. Among other things, it generates an equilibrium that is smoother than that observed by an SVAR while attenuating end-of-sample problems inherent in filters. Moreover, this approach retains the strength of the filter for purposes of detecting structural breaks. Since it combines the best qualities of the two methods, it can be considered eclectic. Incorporating a broad set of information, the eclectic approach minimizes the risk of error inherent in estimating the output gap.

The goal of this paper is to apply this eclectic approach and estimate U.S. potential output—not to prove that it is the best. Another innovation relative to USM is the decomposition of aggregate potential output into labour input and trend productivity. In addition to facilitating comparisons between Canada and the United States, this decomposition allows for a clearer identification of the sources of fluctuation in potential output. For example, the disaggregated eclectic approach reveals that the rapid expansion of potential output recorded during the second half of the 1990s is attributable to a drop in structural unemployment and a notable acceleration in trend productivity

growth. It also shows that the current level of excess supply is entirely attributable to the fact that the labour input is below its equilibrium level.

The remainder of this document is divided into three parts. Section 2 describes the methodology, and section 3 presents the detailed estimation results. Finally, section 4 concludes and suggests directions for further research.

2. Methodology

Potential output is a variable that can only be known as an estimate. In this section, we briefly review the approaches used by the Bank to calculate it, and present the estimation method utilized in this paper.

Trend-stationary processes (linear or quadratic), the Beveridge and Nelson (1981) decomposition, and unobserved component models (Kuttner 1994; Kichian 1999) are methods for estimating potential output. However, the economic underpinnings of these models are quite poorly developed, complicating the explanation of fluctuations in potential output within a specific economic framework. With their more complete theoretical structure, extended filters and SVARs are the most frequently used methods for estimating potential output at the Bank. Filters are used to estimate Canadian potential output in QPM (Butler 1996), while SVARs are used to estimate U.S. potential output in USM (Lalonde 1998, 2000). Cayen and van Norden (2002) explain how these models work.

2.1 Methods used at the Bank

Hodrick and Prescott filters (1981) consist of estimating a variable, τ, that minimizes the square of the difference between τ and the observed variable, X, as well as variations in the growth rate of τ, using the following equation:

$$\tau = \min_{\tau} T = (\tau - X)' W_x (\tau - X) + \lambda \tau' D' D \tau \,, \qquad (1)$$

where W_x is a matrix of weights determined empirically (usually the identity matrix), λ is a smoothing parameter, and D contains the second difference of τ. The HP-filter is thus essentially mechanical, since it is based entirely on the information contained in the series X. The obtained series is a smooth variant of X. An extended version of the multivariate HP-filter, developed by Laxton and Tetlow (1992) has allowed it to be enriched with information of a structural nature. Simply, a theoretical framework can be developed by inserting a third term into equation (1):

$$\tau = \underset{\tau}{minT} = (\tau - X)'W_X(\tau - X) + (\tau - Y)'W_Y(\tau - Y) + \lambda\tau'D'D\tau. \quad (2)$$

In this case, the filter also assigns a weight, W_y, to the squared difference between τ and *Y*, where *Y* and *X* are linked in an assumed or estimated economic relationship (for example, cointegration). These filters capture structural breaks quite rapidly, and generate a path for potential output that is relatively smooth. However, their parameterization is often arbitrary and not based on estimates. Moreover, St-Amant and van Norden (1997), as well as Rennison (2002), show that filters generate a biased estimate of the output gap at the end of the sample. This is a serious problem, since fluctuations observed during the final quarters of the sample period have the greatest impact on monetary policy decisions.

The SVAR approach is based on the Blanchard and Quah (1989) decomposition. It identifies trends in variables using vector autoregressions with some restrictions on the long-term impacts of structural shocks.[1] Theoretically, all that is required is that the variable of interest be separable into a permanent and a temporary component, and that temporary shocks are orthogonal to permanent shocks. This method allows the extraction of information from variables whose long-term trend is potentially linked to that of the variable under study.

By construction, SVARs generate a potential output profile that is consistent with the behaviour of macroeconomic variables. Furthermore, these models are not very vulnerable to the end-of-sample problems inherent in filters (Rennison 2002). Conversely, they are sensitive to structural breaks and generate a volatile path for the evolution of potential output. This last feature is difficult to reconcile with standard economic assumptions and, as such, it results in estimates of the output gap that are problematic for monetary authorities.

Filters appear to provide good estimates when SVARs fail, and since the converse is also true, intuition dictates that a model combining these two approaches would yield the optimal approach.

2.2 The eclectic approach

A combination of the two approaches—the use of extended filters and SVARs—can be implemented rather easily. This method consists of using an expanded version of the multivariate HP-filter to which the equilibrium path generated by an SVAR, $\hat{X}_{svar}$, weighted with $W_{\hat{X}_{svar}}$, is added as information conditioning the estimation of the unobserved series τ:

1. For an explanation of the theoretical underpinnings of this approach, see Appendix A.

$$\tau = \underset{\tau}{minT} = (\tau - X)'W_X(\tau - X) + (\tau - \hat{X}_{svar})'W_{\hat{X}_{svar}}(\tau - \hat{X}_{svar}) + \lambda\tau'D'D\tau \ . \quad (3)$$

Using Monte-Carlo simulations, Rennison (2002) reveals that this approach effectively reproduces the output gap from the data-generation process, and does so for a wide variety of specifications of the process's parameters. Furthermore, this conclusion is as valid in the middle as at the end of the sample. This approach has many benefits: (i) combining the two methods yields estimates that are more reliable than those generated by each method used separately; (ii) using SVARs enhances the theoretical depth and reduces end-of-sample problems; (iii) using filters penalizes high-frequency fluctuations specific to SVAR-generated estimates; and (iv) using filters allows a faster identification of structural breaks.

Lalonde and Rennison (2002) use the combined approach to estimate the Canadian NAIRU in QPM.

2.3 Application to potential output and overview of the proposed approach

We estimate the following decomposition to compute potential output:

$$Y_t^e = L_t^e \times \left(\frac{Y_t}{L_t}\right)^e \ , \quad (4)$$

where L_t^e is the full-employment labour input and $(Y_t/L_t)^e$ is average labour productivity at equilibrium. The full-employment labour input is given by the following product:

$$L_t^e = POP_t \times PART_t^e \times (1 - UR_t^e) \times H_t^e \ , \quad (5)$$

where POP_t is the population, $PART_t^e$ is the equilibrium participation rate, UR_t^e is the equilibrium unemployment rate (NAIRU), and H_t^e is equilibrium hours worked.[2] Estimation of potential output thus requires computing four equilibria: $PART_t^e$, UR_t^e, H_t^e, and $(Y_t/L_t)^e$. Except for H_t^e, which is found using a univariate HP-filter, all of these are calculated with a filter using an equilibrium path generated by an SVAR.

Disaggregating potential output into several components helps us better identify its sources of fluctuation. Furthermore, this approach is more consistent with that used in QPM, facilitating comparisons between the two models. Diagram 1 clearly illustrates the scope of the eclectic

2. We use the observed population level, since it is unlikely that this variable will be affected by economic cycles.

approach. The filter generating trend labour productivity is conditioned by the results of two SVARs. The first identifies trend labour productivity in the non-farm sector. This SVAR is based on a cointegration relationship between real wages and average non-farm labour productivity. The second SVAR estimates the gap between the output level of the manufacturing sector and non-accelerating inflation capacity (i.e., the non-accelerating inflation capacity utilization rate, NAICUR). The presence of a NAICUR gap within the productivity filter improves our ability to capture the effect of the business cycle. The labour input depends on five SVARs—two to identify the NAIRU and three to identify the equilibrium participation rate. To account for demographic changes, we estimate an SVAR for the equilibrium unemployment rate of the labour force under 25 years of age and another for those aged 25 and over. The NAIRUs generated by these two SVARs are then combined to yield a NAIRU for the labour force as a whole. The NAIRU thus obtained conditions the filter applied to the unemployment rate. Similarly, we estimate an SVAR for the trend participation rate of those under 25, another for women 25 and over, and a third for men 25-plus. The results of these three SVARs are then combined to produce an equilibrium participation rate for the entire population. This participation rate conditions the filter generating the trend participation rate. Note that some determinants of the trend participation rate differ from one age group to the next.

2.4 Specification of the SVARs

This section describes the specification of the seven SVARs used in the eclectic approach. Subsection 2.4.1 presents the variables introduced into each SVAR, while subsection 2.4.2 discusses the hypotheses retained in terms of variable ordering, lag, and the order of integration of the variables.

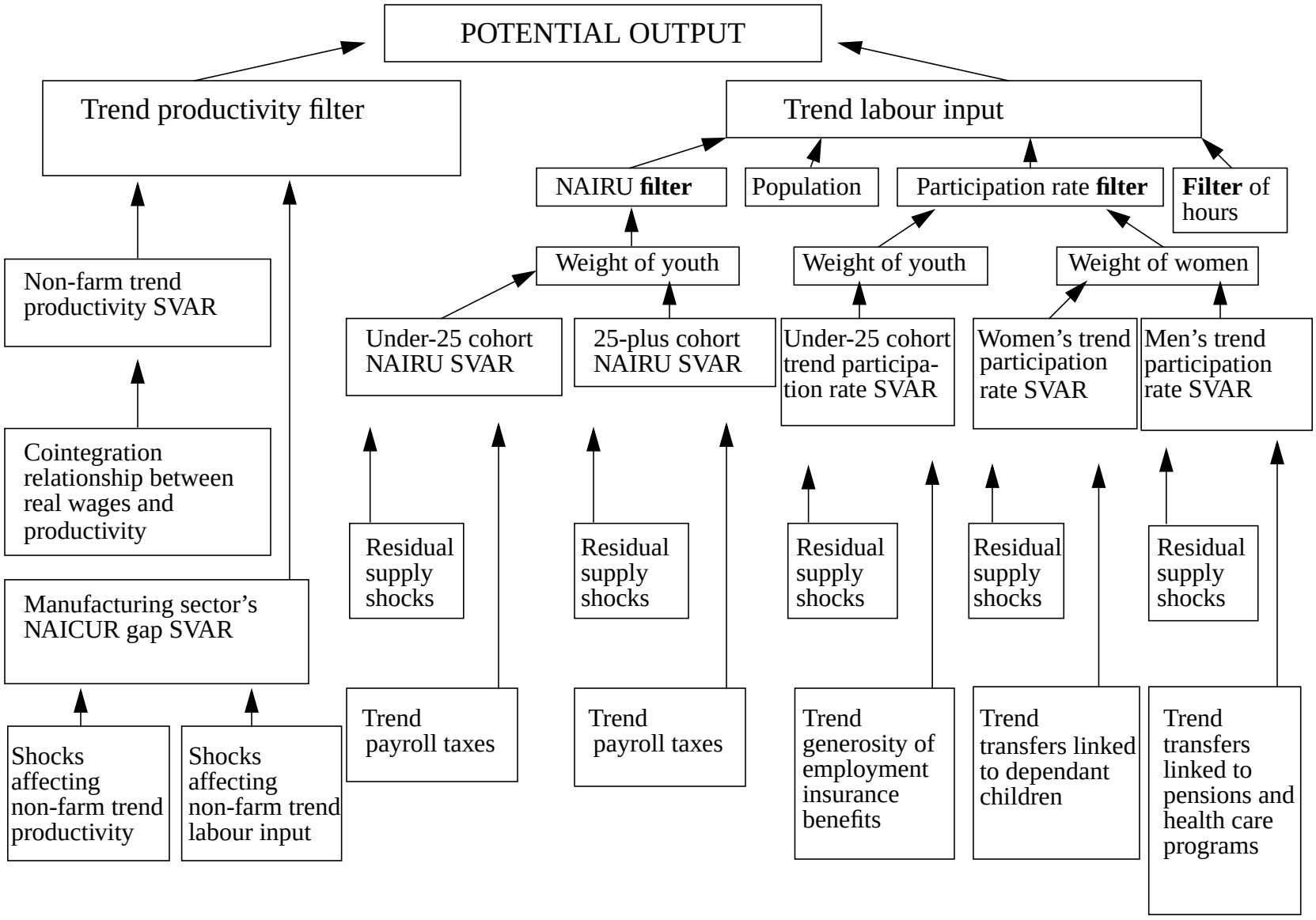
2.4.1 Variable selection

The SVAR approach allows the level of a non-stationary variable to be decomposed into temporary and permanent components. The model performs this decomposition on the basis of information contained in the SVAR's variables. Consequently, the results are often sensitive to the choice of variables, which is dictated both by the theory and by the empirical literature.

It is self-evident that the variable under study must be in the model. Furthermore, it is important to add a nominal variable (e.g., the inflation rate, the rate of growth of nominal wages) in order to allow the model to distinguish between nominal and real variations. This is essential in order to adequately identify temporary (demand-side) and permanent (supply-side) components.[3]

3. For example, in the theory, trend inflation is essentially a monetary phenomenon. Consequently, the presence of inflation in the model, and the resulting identification of its trend, allow the model to identify monetary shocks.

Diagram 1


POTENTIAL OUTPUT
Trend productivity filter
Trend labour input
NAIRU **filter**
Population
Participation rate **filter**
Filter of hours
Non-farm trend productivity SVAR
Weight of youth
Weight of youth
Weight of women
Under-25 cohort NAIRU SVAR
25-plus cohort NAIRU SVAR
Under-25 cohort trend participa-tion rate SVAR
Women's trend participation rate SVAR
Men's trend participation rate SVAR
Cointegration relationship between real wages and productivity
Residual supply shocks
Residual supply shocks
Residual supply shocks
Residual supply shocks
Residual supply shocks
Manufacturing sector's NAICUR gap SVAR
Trend payroll taxes
Trend payroll taxes
Trend generosity of employment insurance benefits
Trend transfers linked to dependant children
Trend transfers linked to pensions and health care programs
Shocks affecting non-farm trend productivity
Shocks affecting non-farm trend labour input

Since the participation rate and the unemployment rate are variables from the labour sector, the nominal variable used is the growth rate of nominal wages. Moreover, because of the close link between real wages and labour productivity, the growth rate of nominal wages is also used in the SVARs generating trend labour productivity and the NAICUR. The SVAR used to estimate trend productivity also accounts for a cointegrating relationship between real wages and productivity.

Real interest rates also help to identify the temporary components of macroeconomic variables. To account for the impact of monetary policy, we introduce the real federal funds rate. The real yield on 10-year government bonds is also added to capture other types of demand shocks (e.g., shocks affecting business investment, fiscal policy shocks).

Finally, variables associated with supply shocks are introduced. These shocks vary with the component of GDP to be estimated. The supply variables were chosen according to the following criteria.

- Do shocks affecting the trend in the supply variable explain an appreciable and statistically significant proportion of the fluctuation in the variable under study (e.g., the unemployment rate) in the long run? If not, this variable is not a determinant of the trend in the variable under examination.
- Does the reaction of the variable of interest to a shock affecting supply include a temporary component? If so, the decomposition into permanent and cyclical components may no longer be valid because the trend could be contaminated by a cyclical element. One way to evaluate the importance of this issue is to observe the sign of the correlation between the reactions of the variable of interest and the growth rate of wages to a given shock.
- Does the introduction of the supply-side variable into the model affect the results? If not, the presence of this variable adds only unnecessary parameters, increasing the uncertainty surrounding the estimates.
- Do shocks affecting the trend in the variable linked to supply explain a significant share of the fluctuations in nominal wages in the long run? In this event, some shocks affecting the trend in the variable of interest will have a permanent effect on inflation. The trend in the variable could then be contaminated by monetary shocks.

In summary, all SVARs incorporate the following variables: the growth rate of nominal wages, the real federal funds rate, and the real long-term interest rate.

Empirical research on the determinants of the equilibrium U.S. unemployment rate (the NAIRU) is extensive. Among the major contributions, Blanchard and Katz (1997), Gordon (1998), Staiger, Stock, and Watson (2001), Katz and Krueger (1999), and, finally, Cohen, Dickens, and Posen (2001) are particularly noteworthy. According to these studies, factors affecting the NAIRU

include government policy (the minimum wage, the generosity of social programs, etc.), the composition of the labour force (the relative proportions of youth, men, and women, for example), the rate of employee unionization, and the incarceration rate.[4]

More recently, Ball and Mankiw (2002), as well as Hatton (2002) (for the United Kingdom) have maintained that productivity growth may be a determinant of the NAIRU. These authors found that a measure of the gap between the current growth of productivity and a long moving average of its past growth is strongly correlated with movements in the NAIRU.

Table 1 presents supply-related variables that we considered for the SVAR used to generate the NAIRU. After applying the previously described criteria, however, we ultimately retained a single determinant, payroll taxes. Nonetheless, to account for the possible impact of changes in labour force composition on the NAIRU, we estimated two SVARs with the same explanatory variables. The first generates a NAIRU for the labour force aged 16 to 24, and the second for a cohort of 25 and over. Consequently, as we saw in Diagram 1, the projected aggregate NAIRU depends on the following factors:

- the projected evolution of the relative share of youth in the overall population;
- all government policies affecting the payroll tax;
- the presence of residual supply shocks of unknown provenance.

4. Human resource practices and the globalization of markets have also been mentioned as potential determinants of the NAIRU in the United States.

Table 1: Variables whose trend is potentially linked to that of the unemployment rate

1. Government policy	Relative generosity of unemployment insurance benefits[a]
	Rate of transfer payments to individuals[b]
	Total transfer payment[c]
	Government size
	Payroll taxes
	Minimum / nominal wage
	Proportion of unemployed receiving unemployment insurance
2. Unionization rate	
3. Productivity gap (Ball and Mankiw measure)	
4. Incarceration rate	

a. Total benefits divided by the number of unemployed / nominal GDP divided by the number of jobs. We also tested total benefits divided by the number of unemployed / total wages divided by the number of jobs. These latter variables are affected by the effective rate of unemployment insurance benefits and by the ease of access to unemployment insurance. Indeed, these variables are affected by the ratio of the number of beneficiaries to the number of unemployed.

b. (Transfers to individuals—unemployment insurance benefits) / nominal GDP.

c. Transfers to individuals / nominal GDP.

The participation rate displays little cyclicality. The last 25 years have been characterized by a massive influx of women into the labour market and a decline in the male participation rate.[5] Previously, variables such as the relative importance of labour income compared to other income sources (government transfers, investment income) were used to explain variations in the participation rate (Andersen 1978). Recent research has shown that demographic factors predominate. Shimer (2001) demonstrates that the participation rate is significantly affected by the relative weight of youths in the labour force, while Michael (1985) and Shank (1998) study the impact of greater female participation. Most of the increase in the total participation rate is explained by increased labour-force activity of women, which, in turn, springs from social currents difficult to quantify into a variable. For instance, Johnson and Skinner (1986), as well as Parkman (1992), analyze the link between divorce and the participation rate of women.

Despite limited variability of the participation rate, we seek to isolate its cyclical component. To account for demographic changes, we estimate three SVARs for the equilibrium participation rate.

5. The drop in the male participation rate is directly connected to the rise in female participation. This may be explained by the fact that women's entry into the labour market has increased household income, allowing some men to cut back on their labour supply.

The first generates a trend for the participation rate of men and women aged 16 to 24. The two other SVARs identify trend participation rates for men and women aged 25 and over. We explored introducing variables that could permanently affect the reservation wage of each of these groups. Table 2 enumerates these variables.

Table 2: Variables whose trend is potentially linked to that of the participation rate

1. Government policy	Relative generosity of unemployment insurance benefits[a] (youth)
	Rate of transfer payments to individuals[b]
	Total transfer payments[c]
	Government size
	Minimum / nominal wage (youth)
	Non-labour income / labour income (men)
	Transfer payments linked to pensions and health care (men)
	Transfer rate for dependent children (women)
2. Divorce rate (women)	
3. Relative price of education: education CPI / overall CPI (youth)	

a. Total benefits divided by the number of unemployed / nominal GDP divided by the number of jobs. We also tested total benefits divided by the number of unemployed / total wages divided by the number of jobs. These latter variables are affected by the effective rate of unemployment insurance benefits and by the ease of access to unemployment insurance. Indeed, these variables are affected by the ratio of the number of beneficiaries to the number of unemployed.

b. (Transfers to individuals—unemployment insurance benefits) / nominal GDP.

c. Transfers to individuals / nominal GDP.

The SVAR identifying the trend youth participation rate incorporates the generosity of unemployment insurance benefits, while those used to estimate these trends for women and men include transfers for dependent children and transfers linked to pensions and health care, respectively. Consequently, the projected trend in the aggregate participation rate is a function of the following factors:

- the projected evolution of the relative weight of women in the population;
- the projected evolution of the relative weight of youth in the population;
- all government policies affecting transfers linked to dependent children (women's participation rate) and health care and pensions (men's participation rate);
- all government policies having an impact on the relative generosity of unemployment insurance benefits (youth participation rate);
- residual supply shocks of unknown origins.

To exploit the long-term relationship between labour productivity (non-farm GDP per hour worked) and real wages, we estimate a wage gap and add it to the SVAR identifying the trend average labour productivity.[6]

Finally, the SVAR estimating the NAICUR includes average productivity in the manufacturing sector. Table 3 presents the variables introduced into the seven SVARs. All the SVARs comprise five variables and are estimated over the longest possible sample period (depending on data availability). In the case of the NAIRU and NAICUR SVARs, the sample begins in the second quarter of 1960 and ends in the second quarter of 2002. As to the SVARs for the participation rates and productivity, the sample begins in the second quarter of 1967 and ends in the second quarter of 2002.[7]

Table 3: Variables introduced into the study's seven SVARs

Variables[a]	SVAR						
	NAIRU		Trend participation rate			Trend productivity	NAICUR
	Youth	Others	Youth	Women	Men		
Payroll taxes	X	X					
Generosity of unemployment insurance benefits			X				
Generosity of transfers for dependent children				X			
Generosity of transfers linked to pensions and health care					X		
Average productivity in manufacturing sector							X
Growth rate of nominal wages	X	X	X	X	X	X	X
Real short-term interest rate	X	X	X	X	X	X	X
Real long-term interest rate	X	X	X	X	X	X	X
Wage gap						X	

a. The variable under examination must be added to this list. For example, the SVAR generating the youth NAIRU includes the youth unemployment rate as well as the variables selected in the second column of Table 3.

6. In log, the wage gap = real wages – 0.62 * (average labour productivity).
7. The sample period for the productivity SVAR was chosen to yield statistically significant results in terms of the cointegration between productivity and real wages.

2.4.2 Ordering, number of lags, and order of integration of the variables

The SVAR approach permits identification of the structural model underlying the estimated reduced-form model (i.e., the VAR) using a minimum of restrictions imposed on the long-term impacts of structural shocks. The ordering of variables within the model springs from decisions about what restrictions to impose. If theory predicts that shocks affecting the trend of some variable have an impact on the trend of the variable of interest, the former will be inserted before the latter. For example, the payroll tax is introduced before the unemployment rate in the ordering of the variables in the SVAR used to identify the NAIRU. Only assumptions about the placement of the variable of interest within the ordering of variables affect its decomposition into transitory and permanent elements. The ordering of the other variables with regard to each other has no impact on this decomposition.

The number of lags introduced into the VAR was selected using likelihood-ratio tests, the strategy being to move from the general to the specific starting from eight lags. In all cases, this method led to the selection of eight lags. We tested the sensitivity of the results by estimating models based on six and ten lags, and the results were essentially the same for all the VARs.

A unit-root test covering the period 1960–2002 reveals that all the variables, except the level of short- and long-term real interest rates, are first difference stationary. Consequently, we introduce the variables into the model in first differences (or growth rates). In the non-farm sector, Johansen and Engle-Granger tests reveal that average productivity and real wages are cointegrated. The share of the labour input implicit in the cointegration vector is 62 per cent.

3. Results

This section is divided into four parts. The first sets forth the results of the model identifying the NAIRU. The second presents the results of the model generating the equilibrium participation rate, while the third contains results from the model estimating trend productivity. In the last section, an analysis of the results for potential GDP generated by the eclectic approach is discussed.

3.1 NAIRU

This section comprises three subsections, respectively dealing with estimation of the NAIRU for the labour force aged 25 years and under, the NAIRU for 25 and over, and the NAIRU for the entire labour force. In all cases, the supply variable retained is the payroll tax. In theory, an

increase in trend payroll taxes should motivate firms to reduce staff, which should in turn cause an increase in structural unemployment. The filter generating the structural unemployment rate derives from information contained in these three NAIRUs.

3.1.1 SVAR model of the NAIRU for the under-25 labour force

The cyclical component of the NAIRU for youth is quite significant. As Table 4 indicates, on impact, 71 per cent of the variance in the unemployment rate for this group is explained by demand factors. The variance of the transitory component of the under-25 unemployment rate is about three times greater than for the 25-and-above group, indicating that youth unemployment rates are more sensitive to cyclical conditions.

In the long run, 40 per cent of the variance of the youth NAIRU is explained by shocks affecting trend payroll taxes, while the rest is attributable to residual supply shocks. A shock resulting in a permanent increase in payroll taxes causes a permanent rise in the youth unemployment rate. As we would expect, over any time horizon, shocks affecting the unemployment rate trend do not have a statistically significant impact on growth in nominal wages. On average, 85 per cent of the trend in nominal wages is attributable to demand.

Table 4: Variance decomposition of the level of the youth unemployment rate

Horizon (quarters)	Supply	Demand
1	29	71
4	43	57
8	47	53
16	50	50
32	77	23
∞	100	0

Figure B.1 (in Appendix B) shows the level and trend of the youth unemployment rate, while Figure B.3 presents the transitory component of that group's unemployment rate. The youth equilibrium unemployment rate is currently estimated at about 10.5 per cent. These graphs clearly reveal that there is considerable excess supply in the youth labour market in the United States. According to our results, the gap between the actual and equilibrium unemployment rate was about 1.3 percentage points in the second quarter of 2002. The recession in the early 1980s was very difficult for this group—their unemployment rate gap rose to nearly 4.5 percentage points.

3.1.2 SVAR model of the NAIRU for the 25-and-above labour force

The cyclical component of the unemployment rate of the 25 population is of the same order of magnitude as that of youth. As Table 5 reveals, on impact, an 83 per cent share of the variance in this group's unemployment rate is explained by demand factors. In the long run, 55 per cent of the variation in the NAIRU of the 25-and-above group is attributable to shocks affecting trend payroll taxes, while the remainder is attributable to residual supply shocks. This may appear rather large, but this share represents *all* shocks affecting trend payroll taxes. For example, it is possible that an increase in the generosity of some social programs implies an associated rise in the payroll tax to finance them. In this context, the payroll tax may simultaneously capture the impact on unemployment of employers' responses to this tax and of changes in the generosity of social programs.

Table 5: Variance decomposition of the level of the unemployment rate of the labour force 25 and above

Horizon (quarters)	Supply	Demand
1	17	83
4	30	70
8	40	60
16	48	52
32	72	28
∞	100	0

As predicted, a shock resulting in a permanent rise in the payroll tax causes a permanent increase in the unemployment rate of those aged 25 and over. As in the case of youths, regardless of the time horizon, shocks affecting the trend unemployment rate of the 25-and-above group have no statistically significant impact on the pace of growth of nominal wages. On average, 85 per cent of the trend of nominal wages is attributable to demand.

Figure B.2 illustrates the level and the trend of the unemployment rate for the 25-and-above group, while Figure B.3 presents the transitory element of this group's unemployment rate. The equilibrium unemployment rate of the population aged 25 and over is estimated at about 3.5 per cent in the second quarter of 2002, substantially lower than that of youth. These figures reveal that excess supply in the 25-and-above labour market resembles that of youth. Indeed, the disequilibrium is found to be about 1.0 percentage point at the end of the sample. The magnitude of the variation of the transitory component is significantly lower for the 25-and-above cohort

than for youth. This graph clearly shows the extent to which youth employment is more sensitive to the business cycle.

3.1.3 Aggregate NAIRU

Figure B.4 presents two measures of the NAIRU. The first, a dotted line, illustrates the NAIRU obtained as a weighted sum of the youth and 25-and-above NAIRUs given by the SVAR (with the weights representing their share in the labour force). At the end of the sample, the under-25 cohort represents about 16 per cent of the labour force, yielding an aggregate NAIRU of 4.8 per cent. The second measure, the solid line, is given by the eclectic approach, using an extended filter integrating the first NAIRU as conditional information. As predicted, this measure is considerably smoother than the first. It also yields a NAIRU of 4.8 per cent at the end of the sample. In both cases, we observe a rise in structural unemployment during the 1970s (reaching nearly 8.0 per cent), followed by a gradual decline in the 1980s and 1990s. This characterizes the NAIRUs of both youth and those 25 and over. Overall, our results are consistent with those of Laubach (2001) and Ball and Mankiw (2002).

Figure B.5 reveals the aggregate unemployment rate gaps given by these two measures. We note that the estimates obtained are very similar: the correlation between them being 0.91. The gap generated by the SVAR shows recessions that are often deeper than those of the eclectic approach. Currently, excess supply is as present among youth as it is in the 25-and-above group.

3.2 Trend participation rate

This section is divided into four subsections. The first three present the results from the three SVARs used to calculate the aggregate equilibrium participation rate, while the final examines the results of the eclectic approach applied to the participation rate. Keep in mind that the supply variable for the youth participation rate is the generosity of unemployment insurance benefits. In theory, an increase in the trend of this variable should motivate youth to enter the labour force. The supply variable retained for women 25 and over is the generosity of transfers for dependent children. In this case, we expect that an increase in the trend of this variable will induce a decline in women’s participation rate. Finally, the supply-side variable used for estimating the participation rate of men 25 years and over is the generosity of transfers relating to pensions and health care. In theory, an increase in the trend of this variable should cause a drop in the labour force. The filter generating the trend in the participation rate is based on a combination of these three SVARs.

3.2.1 SVAR model of the trend youth participation rate

In examining Table 6, we observe that the cyclical component of the youth participation rate is relatively minor. On impact, only 23 per cent of the variation in their participation rate is attributable to demand factors. A similar phenomenon is observed in the case of women and men aged 25 and over. The variance of the transitory component of the participation rate of youth is, however, six times greater than that of both men and women 25 years and over. This result probably reflects the weaker attachment of youth to the labour market.

In the long run, 10 per cent of the variance of the youth participation rate is explained by shocks affecting the trend unemployment insurance generosity, while the remainder is attributable to residual supply shocks. As expected, a shock causing a permanent increase in the generosity of unemployment insurance benefits generates a permanent increase in the youth participation rate. Furthermore, shocks affecting the trend participation rate have no statistically significant effect on the growth rate of nominal wages, in either the short or long run.

Figure C.1 (in Appendix C) presents the level and trend of the participation rate of the population under 25 years of age, and Figure C.2 presents the cyclical component of the participation rate for this group. While the transitory component is generally quite small, that is not the case at present. During the second quarter of 2002, the youth participation rate was about 1.5 percentage points below its equilibrium level. A similar situation occurred during the recession of 1990–91. The impact of the recessions in 1980 and 1982 on the transitory component of the youth participation rate was considerably weaker than that of the subsequent recessions.[8]

Table 6: Variance decomposition of the level of the youth participation rate

Horizon (quarters)	Supply	Demand
1	77	23
4	73	27
8	84	16
16	93	7
32	97	3
∞	100	0

8. This may indicate that an increasing number of young people return to school during economic slumps.

3.2.2 SVAR model of the trend participation rate for women 25 and above

In many respects, the results of the SVAR identifying the equilibrium participation rate of women aged 25 and over resemble those for the under-25 cohort. On impact, a little less than one quarter of the fluctuation in their participation rate is attributable to demand factors. This result reflects the very smooth path of the participation rate of women 25 and older. Furthermore, the massive entry of women into the labour force observed during the 1970s and 1980s is manifestly attributable to structural and social causes.

It is very difficult to explicitly capture these factors in a variable. This explains why residual supply shocks account for 87 per cent of the variance in the women's trend participation rate, while shocks affecting the trend benefits for dependent children explain the remainder. A shock that permanently increases this rate results in a decline in the women's participation rate and also has a weak positive fallout on wages. In the long run, about 75 per cent of the variance in the growth rate of nominal wages is attributable to demand factors.

Figure C.3 presents the level and trend of the participation rate of women aged 25 and over, and Figure C.4 the cyclical component of the participation rate of this same group. The women's participation rate, like that of youth of both sexes, is currently well below the equilibrium level. A similar situation was observed during the recession in 1990–91.

Table 7: Variance decomposition of the level of the participation rate of women 25-plus

Horizon (quarters)	Supply	Demand
1	77	23
4	80	20
8	87	13
16	95	5
32	97	2
∞	100	0

3.2.3 SVAR model of the trend participation rate of men 25 and above

Unlike that of women, the men's participation rate has shown a clear decline (see Figure C.5). Since 1995, however, we observe a certain degree of stabilization. According to the SVAR results, a large share of the decline in the participation rate that occurred during the 1970s was attributable to a sustained rise in the rate of transfers associated with pensions and health care. This trend

reversed during the 1980s and the second half of the 1990s. During these two periods, shocks that undercut the trend in transfer rates (perhaps linked to government decisions) lifted men's participation rate. On average, the SVAR attributes half of the variance in the trend in this rate to shocks affecting trends in pension and health-care-related transfers. The impact of residual supply shocks on the trend men's participation rate was substantial during the 1970s and 1980s. Nonetheless, since 1990, the relative impact of these shocks has dampened considerably.

Table 8: Variance decomposition of the level of the participation rate of men 25 and over

Horizon (quarters)	Supply	Demand
1	77	23
4	79	21
8	85	15
16	91	9
32	96	4
∞	100	0

The SVAR attributes only a small share of the variance in the men's participation rate to demand factors (only 23 per cent on impact). Conversely, demand shocks explain 91 per cent of the trend in the growth rate of nominal wages. The various shocks having a permanent effect on men's participation rate have only a negligible and statistically insignificant impact on the rate of growth of nominal wages, in both the short and long run. According to the results presented in Figure C.6, the recessions of 1980–82 and 1990–91 drove the participation rate for men below the equilibrium level. The current recession has not, however, caused a repeat of this phenomenon. In 2002Q2, the men's participation rate was 0.1 percentage points above the equilibrium level.

3.2.4 Aggregate trend participation rate

Figure C.7 presents the level and trend of the aggregate participation rate obtained by combining the equilibrium participation rates given by the three SVARs. Figures C.8 and C.9 compare the evolution of the cyclical and equilibrium components generated by the SVAR with those from the eclectic approach.

According to the results of the SVAR approach, during the current recession the aggregate participation rate is below the equilibrium level. That was also the case during the 1990–91 recession. Excess supply at present is solely attributable to the participation rate of women aged 25 and over and the under-25 cohort. According to the results of the SVAR and the eclectic

approach, the aggregate equilibrium participation rate increased by 0.5 percentage points between 1992 and 1997. This rise is almost exclusively attributable to an increase in women's participation rate. Since 1997, the equilibrium participation rate generated by the SVAR has been almost constant at 67.0 per cent (+/–0.1), while that from the eclectic approach remained stable at 67.0 per cent. As expected, the aggregate participation rate yielded by the eclectic approach is smoother than that from the SVAR.

The cyclical component of the aggregate participation rate generated by the eclectic approach is strongly correlated with that produced by the SVAR (0.71). The cyclical components generated by the two approaches also have similar standard errors (0.20 for the eclectic approach and 0.18 for the SVAR).

3.3 Trend labour productivity

The filter generating trend labour productivity draws on information contained in two SVARs. The first identifies trend labour productivity in the non-farm sector, while the second estimates an output gap in the manufacturing sector. Subsections 3.3.1 and 3.3.2 describe the results from these two SVARs, while subsection 3.3.3 presents the eclectic approach applied to labour productivity.

3.3.1 SVAR for labour productivity in the non-farm sector

As previously mentioned, the SVAR generating trend labour productivity is based on a cointegrating relationship between real wages and marginal labour productivity. In the short term, two-thirds of productivity fluctuations are attributable to demand factors (Table 9). The model's results correspond to our expectations. A shock that positively affects the trend productivity induces a very gradual adjustment in real wages, such that the wage gap diminishes on impact. In the long run, the impact on real wages equals that on the marginal product of labour. Finally, without imposing this on the model, shocks affecting trend productivity have no permanent effect on the growth rate of nominal wages or the inflation rate. Consequently, in this model trend inflation is determined by demand factors alone.

A positive demand shock causes a temporary rise in labour productivity. The shock reduces the wage gap by increasing productivity, but also because it drives down real wages (because of an increase in price levels). In the long run, the impact on real wages is neutral, because the shock does not have a permanent effect on labour productivity. The effect of the shock on nominal wages is proportionally identical to that on prices.

A positive shock to nominal wages is associated with a positive demand shock. In this case, the shock originates from pressures in the labour market. Upon impact, it drives up real and nominal wages. It also leads to a positive and cyclical reaction in labour productivity. In the short run, since the shock arises from nominal wages, the impact on the latter dominates and the wage gap is increased. In the long run, the shock is neutral on all real variables, and the effect is proportionally the same on nominal wage growth as on inflation.

Table 9: Variance decomposition of the level of labour productivity

Horizon (quarters)	Supply	Demand
1	37	63
4	35	65
8	30	70
16	51	49
32	71	29
∞	100	0

Figure D.1 (in Appendix D) compares the evolution of the level of labour productivity in the non-farm sector and its trend (generated by the SVAR). Figure D.2 presents the year-over-year trend and level of productivity. Finally, Figure D.3 shows the difference between the level and the trend of productivity measured with the SVAR.

As expected, labour productivity is strongly pro-cyclical. Indeed, between 1971 and 1979, the productivity level was above trend, and during the 1980–82 and 1990–91 recessions it was substantially below trend. Between 1996Q1 and 2001Q4, labour productivity was systematically lower than trend, despite the vigorous rate of economic growth. This result reflects a strong and sustained pace of growth in trend labour productivity, averaging 2.25 per cent over this period. According to the model, the very pronounced jump in productivity (an average increase of about 7.5 per cent) in 2001Q4 and 2002Q1 is largely attributable to temporary factors driving the productivity level above trend.

3.3.2 SVAR for the NAICUR

As mentioned above, we use the gap between actual production and capacity in the manufacturing sector in the eclectic approach generating trend labour productivity. Incorporating the NAICUR gap facilitates identifying cycles affecting labour productivity and exploiting the quality of data on industrial production. It should be noted that, in the long run, the model attributes 85 per cent

of the variance of the growth rate of nominal wages to demand factors.[9] Therefore, the production capacity identified by this model may, for all intents and purposes, be deemed the non-accelerating level of output. Furthermore, on impact, two-thirds of the variance in manufacturing output is explained by demand shocks.

Figure D.4 shows the historical evolution of the NAICUR gap. Since productivity in the manufacturing sector is introduced into the SVAR, this latter is able to break down the output gap into a productivity gap and a labour-input gap. This decomposition is presented in Figure D.5. Finally, Figure D.6 compares the evolution of the gap between the level and trend labour productivity identified by the SVAR presented in subsection 3.3.1 with that yielded by the SVAR generating the NAICUR.

The NAICUR SVAR effectively captures the major episodes of recession and excess demand in the 1970s. Furthermore, the model generates considerable excess demand in the manufacturing sector at the end of the 1990s, which then becomes excess supply comparable to that seen in the 1990–91 recession. The model imputes the bulk of this recent cycle to labour input disequilibria. Between 1995 and 1999, the level of labour productivity in the manufacturing sector was essentially consistent with its trend. After a negative episode, vigorous growth in productivity between 2001Q4 and 2002Q1 raised labour productivity to a level slightly above trend.

Figure D.6 reveals that the gap between the level of productivity in the manufacturing sector and the trend identified by the NAICUR SVAR is highly consistent with that generated by the SVAR of non-farm labour productivity.

3.3.3 Trend labour productivity given by the eclectic approach

Trend labour productivity generated by the eclectic approach is based on the following three sources of information:

- the productivity trend generated by the SVAR of the non-farm sector;
- the NAICUR gap;
- a filter.

Figure D.7 presents the year-over-year productivity level and trend generated by the eclectic approach. According to these results, the average growth rate of trend productivity (measured as real GDP divided by total hours) has been 2.25 per cent since 1996. This value is consistent with most estimates from other researchers, particularly Oliner and Sichel (2002) and Jorgenson, Ho,

9. The nominal variable in the model is nominal wages. The results are practically identical if we replace this variable by the inflation rate measure using the CPI excluding food and energy.

and Stiroh (2002). This result is identical to that obtained by the SVAR. Nonetheless, as we expected, the eclectic approach generates a much less volatile expansion path for trend productivity. However, Figure D.8 shows that the two methods produce paths that are generally comparable in terms of the cyclical component of labour productivity. The correlation between the cyclical components generated by these approaches is 0.74.

3.4 Potential output

Potential output is obtained from a direct application of equations (4) and (5). Figure E.1 (in Appendix E) presents the profile for potential output obtained using the eclectic approach, while Figure E.2 shows the year-over-year growth of potential and real GDP. Figure E.3 compares the output gap generated by the eclectic approach with that from the SVAR currently used in USM.

As expected, the year-over-year profile of potential output obtained by the eclectic approach is very smooth. It shows an acceleration in the pace of potential output growth during the period 1995–99, peaking at 4.0 per cent in 1997. Currently, it hovers slightly above 3.0 per cent. The vigour observed over the course of the second half of the 1990s is attributable to a fall in the NAIRU and a notable acceleration in the pace of growth of trend productivity. The decline in the NAIRU during this period is due largely to permanent cuts in payroll taxes. Nonetheless, since 2000, both the NAIRU and payroll taxes have stopped falling and, consequently, the year-over-year growth of potential output has abated. A slight deceleration of trend productivity has also contributed to the slowing of potential output.

The profile of the output gap generated by the eclectic approach is generally comparable with that in the SVAR used in USM. However, the episodes of excess supply for 1975 and 1981–82 are somewhat deeper in the eclectic approach, while that associated with the recession of 1990–92 is slightly more shallow. Moreover, unlike the SVAR currently used in USM, the eclectic approach generates very little excess supply for the period between 1985 and 1988.

It is worth noting that, since 2001Q3, the two approaches yield scenarios that are diametrically opposed. According to the eclectic approach, excess supply has remained relatively stable at 1.8 per cent, while the SVAR used in USM indicates that it has almost completely disappeared (excess supply of –0.3 per cent). This result is linked to the fact that, according to the results of the SVAR used in USM, year-over-year potential output growth fell since the second half of 2001, from 3.5 per cent to 1.2 per cent. These contrasting results are attributable to the fact that the eclectic approach draws on a much broader information base as well as to divergent interpretations to recent revisions to national accounts data (July 2002). Indeed, real and nominal

wages were revised downward by 3.1 per cent, while productivity was adjusted by only 0.8 per cent. The labour input was also reduced.

The SVAR does not account for any of the revisions to productivity and real GDP data. It also completely ignores revisions to nominal and real wage data. Consequently, it attributes variations entirely to negative supply shocks, since revisions to inflation are nil.

The eclectic approach interprets the revisions differently. As mentioned above, this approach is partially based on an SVAR incorporating a cointegrating relationship between real wages and labour productivity. Historical revisions are compatible with a downward revision of trend productivity, since real wages and productivity were revised downward. Nonetheless, according to the model, these results cannot be entirely explained by a negative supply shock, because revisions to wages were three times greater than those to productivity data.[10]

Furthermore, the revision to real wages is entirely attributable to revisions in nominal wages. The model imputes part of the downward revision of nominal (and real) wages to a negative demand shock causing a decline in pressures from the labour market. This observation is consistent with the negative revision to the labour input and with the results of the eclectic approach indicating that it is now clearly below its equilibrium level. In the productivity SVAR, on impact, this type of negative demand shock adversely affects nominal and real wages. It also engenders a negative and cyclical reaction of labour productivity. In the short term, since the shock originates from nominal wages, the effect on the latter dominates and the wage gap is reduced. Under these circumstances, price adjustments follow that of nominal wages after a certain delay.

Overall, according to the eclectic approach, a combination of negative supply shocks and negative demand shocks from the labour market fully explain the nature of recent revisions to the national accounts. Consequently, according to the eclectic approach, the historical revisions translate into a reduction of potential output and the output gap, while the SVAR used in USM indicates that only potential output is revised downward.

According to the results of the eclectic approach, the current excess supply situation is entirely attributable to the fact that the labour input is below its equilibrium level. This situation is largely the result of a gap in the participation rate (i.e., –0.3 per cent) and to the fact that the unemployment rate exceeds the NAIRU by 1.2 percentage points.

10. Within the productivity SVAR, a shock affecting the labour-productivity trend engenders a homogeneous impact on the productivity level at all times.

4. Conclusion and Directions for Further Research

The purpose of this paper has been to apply the eclectic approach to determining U.S. potential output. The disaggregated approach has allowed us to better identify the sources of fluctuations in potential output. The estimate of U.S. potential output generated by the eclectic approach also has the benefit of being compatible with that from QPM. These are two major improvements with respect to the SVAR currently used in USM.

The output gap yielded by the eclectic approach will serve as an explanatory variable within the Phillips curve used in the new forecasting model for the U.S. economy; the new model is to be finalized in the upcoming months. Recall that the use of filters requires establishing weights to assign to the squares of the differences between the series to be estimated and the observed series, as well as to the squared differences between the series to be estimated and the SVAR equilibrium path. In this study, we used unit weights for all terms in each filter.

The next step in this research will consist of finding the optimal weight to assign to each of these gaps. These weights will be specified on the basis of empirical criteria with respect to the quality of the inflation forecasts given by the Phillips curve. More precisely, we intend to estimate these weights recursively. We will vary them in order to determine which values provide an output gap minimizing the mean squared error of the out-of-sample forecasts of the Phillips curve.

References

Andersen, L.C. 1978. ‘‘An Explanation of Movements in the Labour Force Participation Rate, 1957–76.’’ *Federal Reserve Bank of St. Louis Review* (August).

Ball, L. and N.G. Mankiw. 2002. ‘‘The Nairu in Theory and Practice.’’ NBER Working Paper No. 8940.

Beveridge, S. and C.R. Nelson. 1981. ‘‘A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the Business Cycle.’’ *Journal of Monetary Economics* 7(2): 151–74.

Blanchard, O.J. and L.F. Katz. 1997. ‘‘What We Know and Do Not Know About the Natural Rate of Unemployment.’’ *Journal of Economic Perspectives* 11(1): 51–72.

Blanchard, O.J. and D. Quah. 1989. ‘‘The Dynamic Effects of Aggregate Demand and Supply Disturbances.’’ *American Economic Review* 79(4): 655–73.

Butler, L. 1996. *A Semi-Structural Method to Estimate Potential Output: Combining Economic Theory with a Time-Series Filter.* Technical Report No. 77. Ottawa: Bank of Canada.

Cayen, J.-P. and S. van Norden. 2002. ‘‘La fiabilité des estimations de l’écart de production au Canada.’’ Bank of Canada Working Paper No. 2002–10.

Cohen, J., W.T. Dickens, and A. Posen. 2001. ‘‘Have the New Human-Resources Practices Lowered the Sustainable Unemployment Rate?’’ In *The Roaring Nineties: Can Full Employment Be Sustained?,* edited by A.B. Krueger and R. Solow. New York.

Gordon, R.J. 1998. ‘‘Foundations of the Goldilocks Economy: Supply Shocks and the Time-Varying NAIRU.’’ *Brookings Papers on Economic Activity* (2): 297–333.

Hatton, T. 2002. ‘‘Can Productivity Growth Explain NAIRU? Long-run Evidence from Britain, 1871–1999.’’ Centre for Economic Policy Research Discussion Paper No. 3424.

Hodrick, R.J. and E.C. Prescott. 1981. ‘‘Post-War U.S. Business Cycle: An Empirical Investigation.’’ Center for Mathematical Studies in Economics and Management Science. Northwestern University Discussion Paper No. 451.

Johnson, W.R. and J. Skinner. 1986. ‘‘Labour Supply and Marital Separation.’’ *American Economic Review* 76(3): 455–69.

Jorgenson, D.W., M.S. Ho, and K.J. Stiroh. 2002. ‘‘Projecting Productivity Growth: Lessons from the U.S. Growth Resurgence.’’ *Federal Reserve Bank of Atlanta Economic Review* 87(3).

Katz, L.F. and A.B. Krueger. 1999. ‘‘The High-Pressure U.S. Labour Market of the 1990s.’’ *Brookings Papers on Economic Activity* (1): 1–65.

Kichian, M. 1999. ‘‘Measuring Potential Output within a State-Space Framework.’’ Bank of Canada Working Paper No. 99–9.

Kuttner, K.N. 1994. ‘‘Estimating Potential Output as a Latent Variable.’’ *Journal of Business and Economic Statistics* 12(3): 361–68.

Lalonde, R. 1998. ‘‘Le PIB potentiel des États-Unis et ses déterminants : la productivité de la main-d’œuvre et le taux d’activité.’’ Bank of Canada Working Paper No. 1998–13.

Lalonde, R. 2000. ‘‘Le modèle USM d’analyse et de projection de l’économie américaine.’’ Bank of Canada Working Paper No. 2000–19.

Lalonde, R. and A. Rennison. 2002. ‘‘Le TCNA canadien estimé à l’aide d’un VAR structurel.’’ Bank of Canada. Photocopy.

Laubach, T. 2001. ‘‘Measuring the NAIRU: Evidence from Seven Economies.’’ *The Review of Economics and Statistics* 83(2): 218–31.

Laxton, D. and R. Tetlow. 1992. *A Simple Multivariate Filter for the Measurement of Potential Output*. Technical Report No. 59. Ottawa: Bank of Canada.

Michael, R.T. 1985. ‘‘Consequences of the Rise in Female Labor Force Participation Rates: Questions and Probes.’’ *Journal of Labor Economics* 3(1) Part 2: 117–46.

Oliner, S.D. and D.E. Sichel. 2002. ‘‘Information Technology and Productivity: Where Are We Now and Where Are We Going?’’Federal Reserve Board. Photocopy.

Parkman, A.M. 1992. ‘‘Unilateral Divorce and the Labour-Force Participation Rate of Married Women, Revisited.’’ *American Economic Review* 82(3): 671–78.

Rennison, A. 2002. ‘‘Evaluating Output Gap Estimates with a Model Economy.’’Bank of Canada. Photocopy.

St-Amant, P. and S. van Norden 1997. *Measurement of the Output Gap: A Discussion of Recent Research at the Bank of Canada*. Technical Report No. 79. Ottawa: Bank of Canada.

Shank, S.E. 1998. ‘‘Women and the Labour Market: The Link Grows Stronger.’’ *Monthly Labour Review* (March).

Shimer, R. 2001. ‘‘The Impact of Young Workers on the Aggregate Labour Market.’’ *Quarterly Journal of Economics* 116(3): 969–1008.

Staiger, D., J.H. Stock, and M.W. Watson. 2001. ‘‘Prices, Wages, and the U.S. NAIRU in the 1990s.’’ In *The Roaring Nineties: Can Full Employment Be Sustained?*, edited by A.B. Krueger and R. Solow. New York.

Appendix A

A.1 Structure of the SVAR

The moving-average representation of the structural model can be expressed as:

$$Z_t = \Gamma(0)\varepsilon_t + \Gamma_1\varepsilon_{t-1} + \Gamma_2\varepsilon_{t-2} + \ldots = \Gamma(L)\varepsilon_t, \tag{A.1}$$

where ε_t represents shocks and Z_t the variables of the structural model. The matrix of long-run structural shocks is defined as:

$$\Gamma(1) = \Gamma(0) + \Gamma_1 + \Gamma_2 + \ldots + \Gamma_\infty, \tag{A.2}$$

where $E(\varepsilon_t\varepsilon_t) = I$. To simplify, the elements on the diagonal are considered equal to one. To estimate the structural model, the reduced-form autoregressive model is first estimated:

$$Z_t = \sum_{i=1}^{p} \Pi_i Z_{t-i} + e_t, \tag{A.3}$$

where p is the number of lags, e_t is a vector of estimated residuals, and $E(e_t e_t) = \Sigma$.

Given that the stochastic process is stationary, the moving-average representation is defined by the following relationship:

$$Z_t = e_t + C_1 e_{t-1} + C_2 e_{t-2} + \ldots = C(L)e_t \tag{A.4}$$

and the matrix of long-run effects of reduced-form shocks is defined as:

$$C(1) = 1 + C_1 + C_2 + \ldots + C_\infty. \tag{A.5}$$

Reduced-form residuals are thus linked to structural residuals by:

$$e_t = \Gamma(0)\varepsilon_t, \text{ whence} \tag{A.6}$$

$$E(e_t e_t) = \Gamma(0)\Gamma(0)', \text{ since } E(\varepsilon_t\varepsilon_t) = I. \tag{A.7}$$

Furthermore, the matrix of long-term impacts of reduced-form shocks, $C(1)$, is related to the equivalent matrix of structural shocks, $\Gamma(1)$, as follows:

$$\Gamma(1) = C(1)\Gamma(0) \tag{A.8}$$

For the structural model to be identified, enough restrictions must be imposed to identify all the elements of $\Gamma(0)$. The Blanchard-Quah decomposition consists of imposing restrictions on the

matrix of long-term effects of the structural shocks (i.e., $\Gamma(1)$) rather than imposing a structure in which the different variables are predetermined by restrictions on the matrix of the contemporaneous effects of the structural shocks (i.e., $\Gamma(0)$). Since Σ is symmetric, we need to impose supplementary restrictions. To identify the system, we simply impose that $\Gamma(1)$ be triangular. Given these restrictions, the equation system is soluble and the structural model is identifiable.

Appendix B

B.1 Results from the NAIRU Model

Figure B.1: Youth unemployment rate and NAIRU (NAIRU calculated from SVAR)

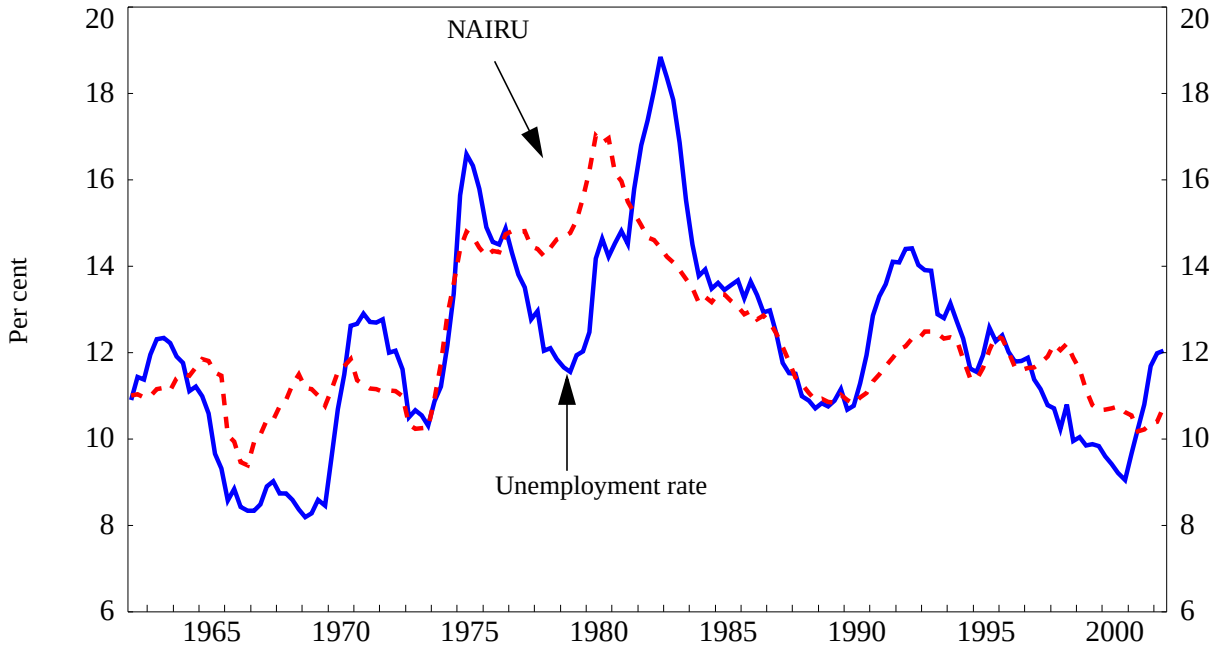


Figure B.2: Unemployment rate and NAIRU for 25-and-above labour force (NAIRU calculated from SVAR)

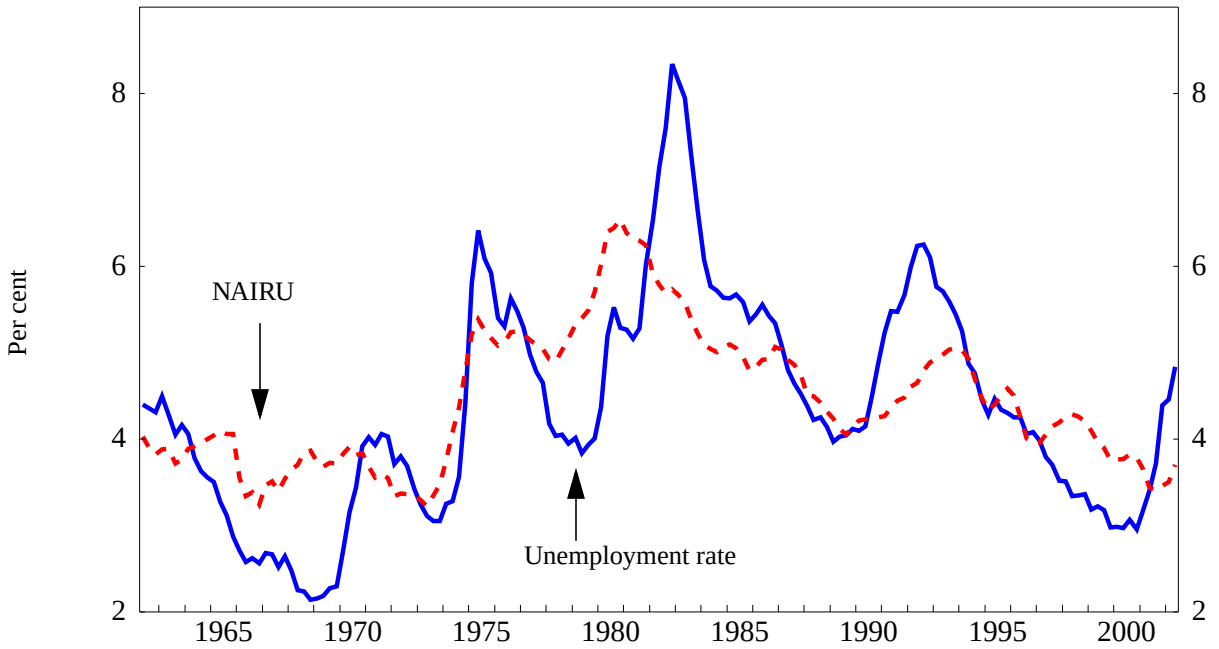


Figure B.3: Unemployment-rate gaps

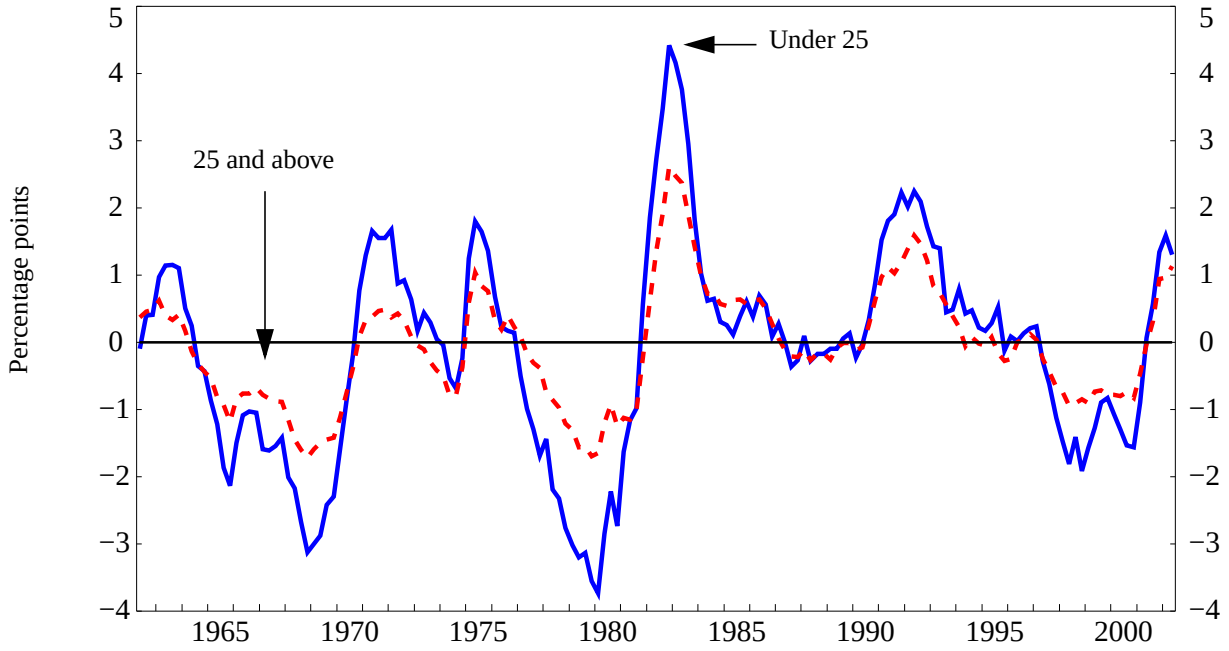


Figure B.4: Aggregate unemployment rate and NAIRU

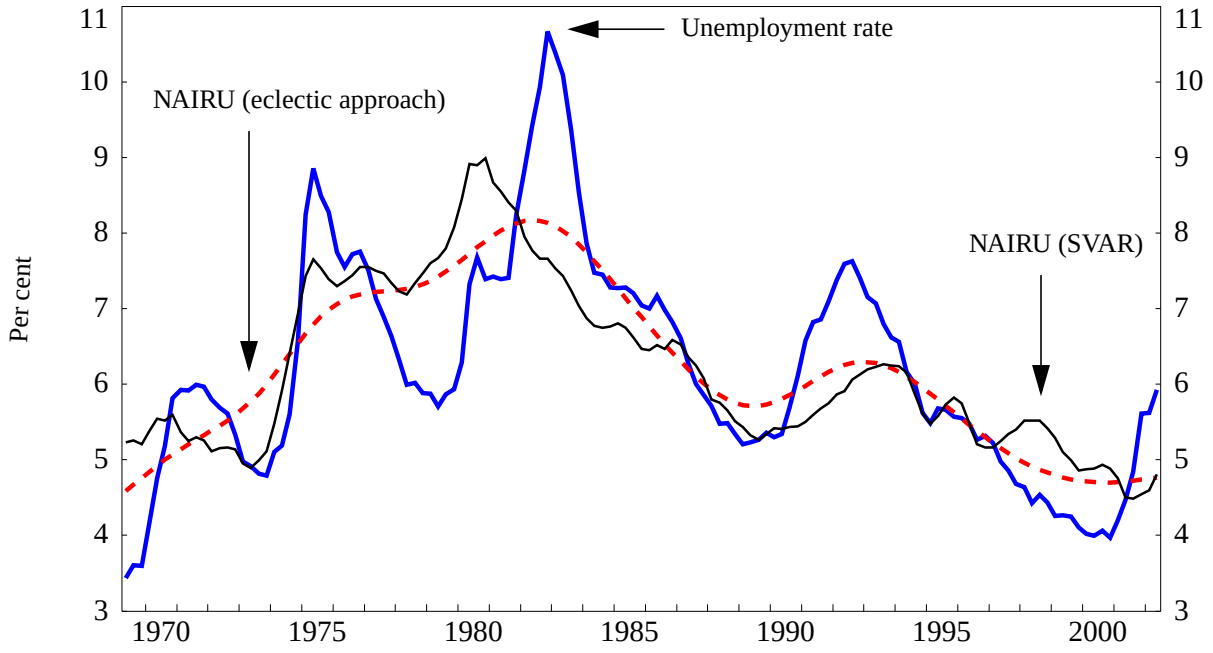
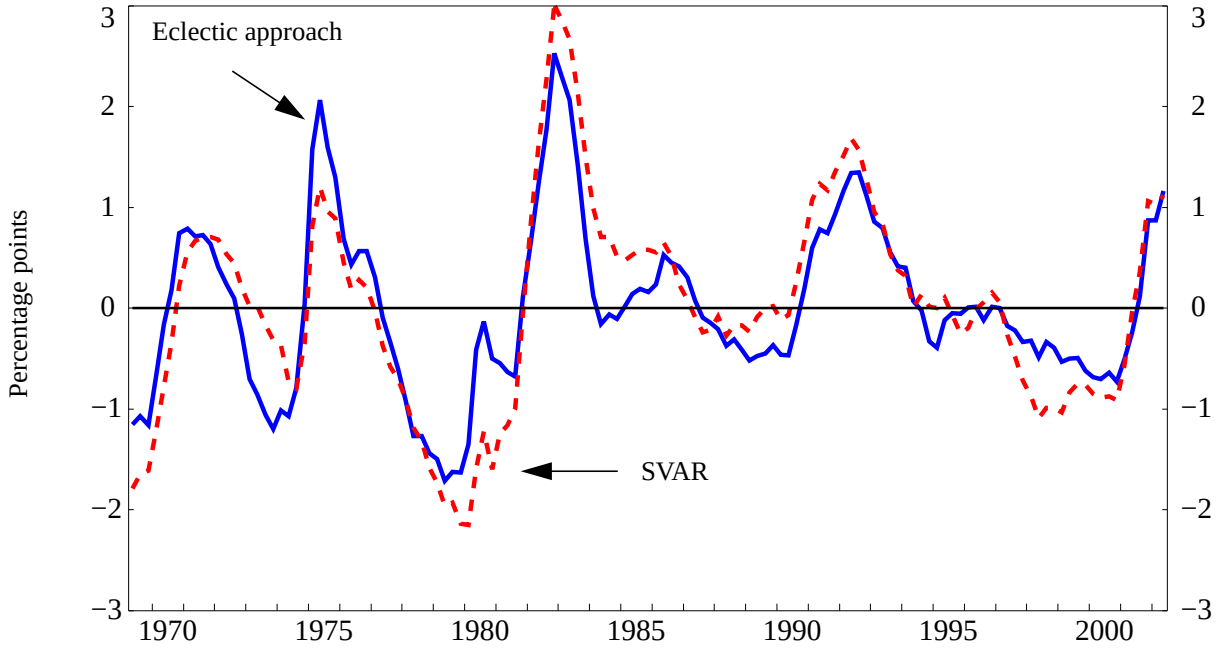


Figure B.5: Aggregate unemployment-rate gap



Appendix C

C.1 Results from the Trend Participation-Rate Model

Figure C.1: Youth participation-rate level and trend

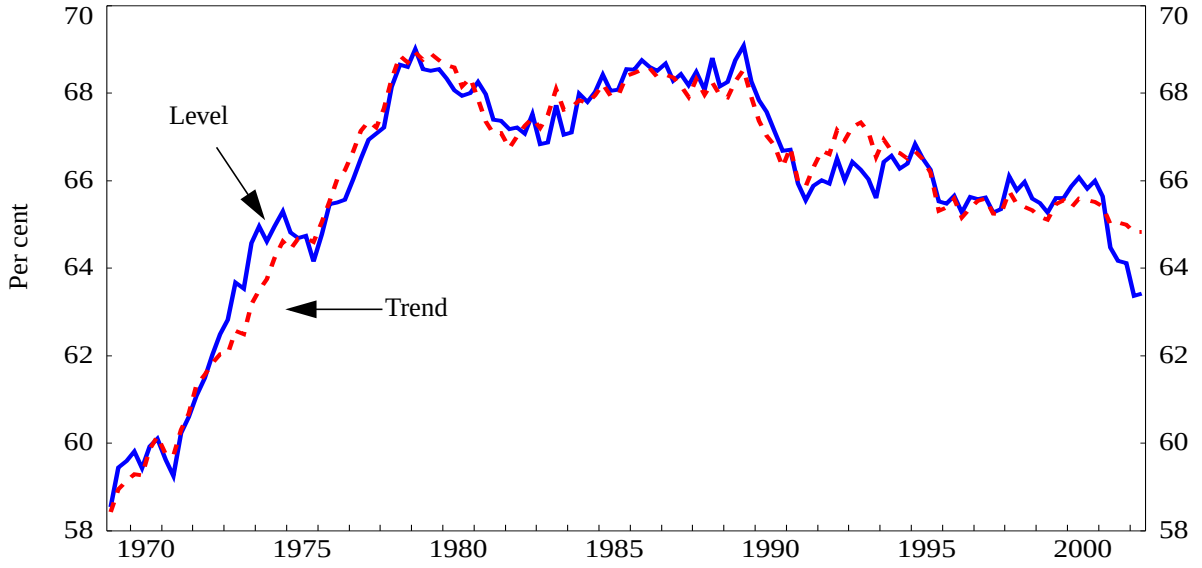


Figure C.2: Transitory component of the youth participation rate

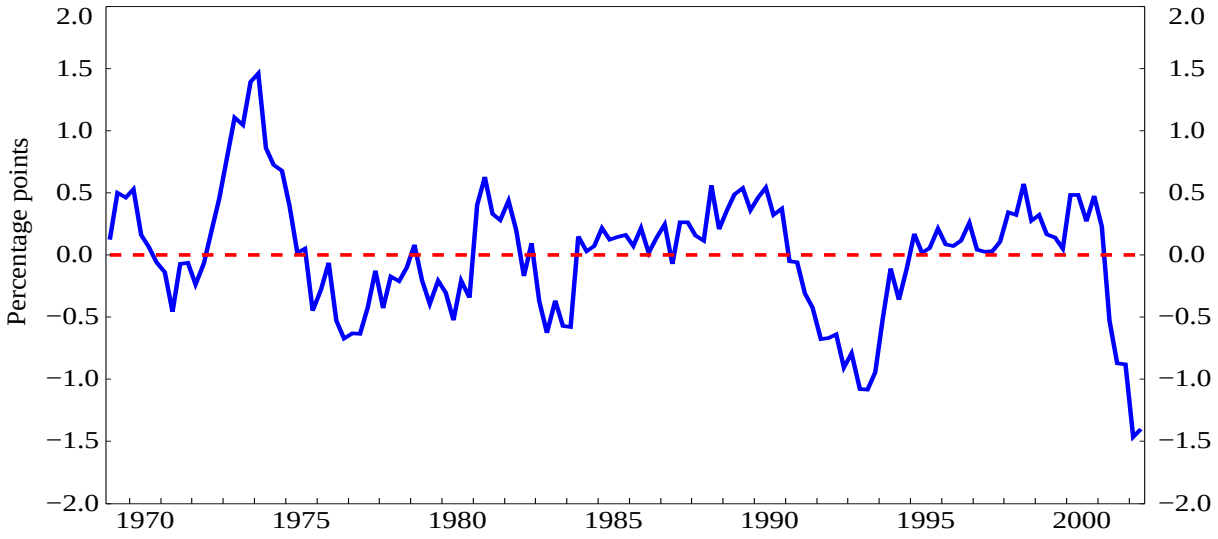


Figure C.3: Women's participation-rate level and trend

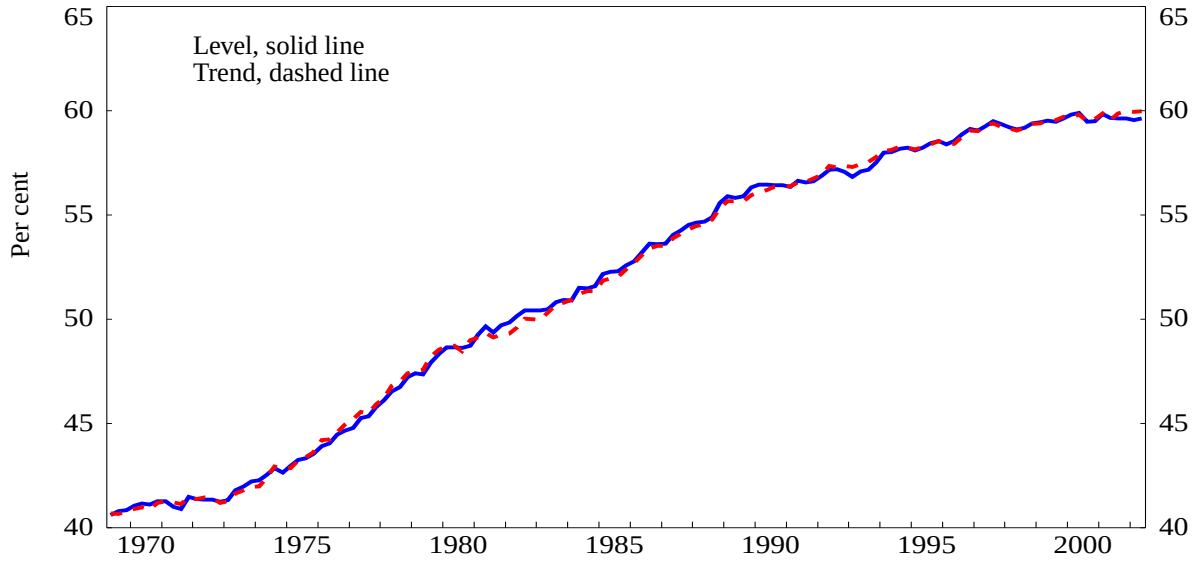


Figure C.4: Transitory component of the women's participation rate

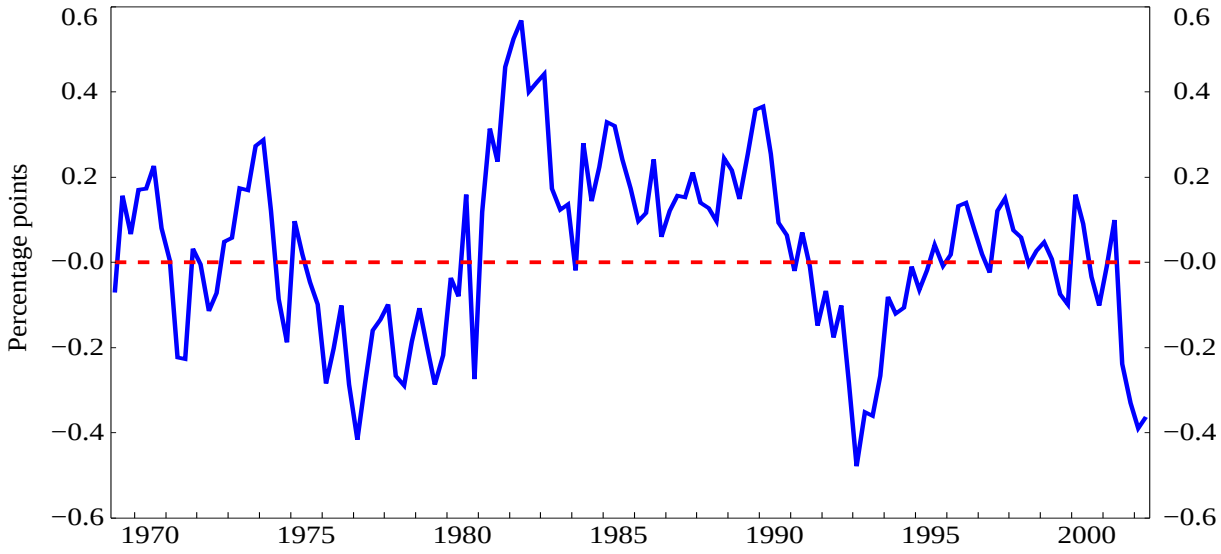


Figure C.5: Men's participation-rate level and trend

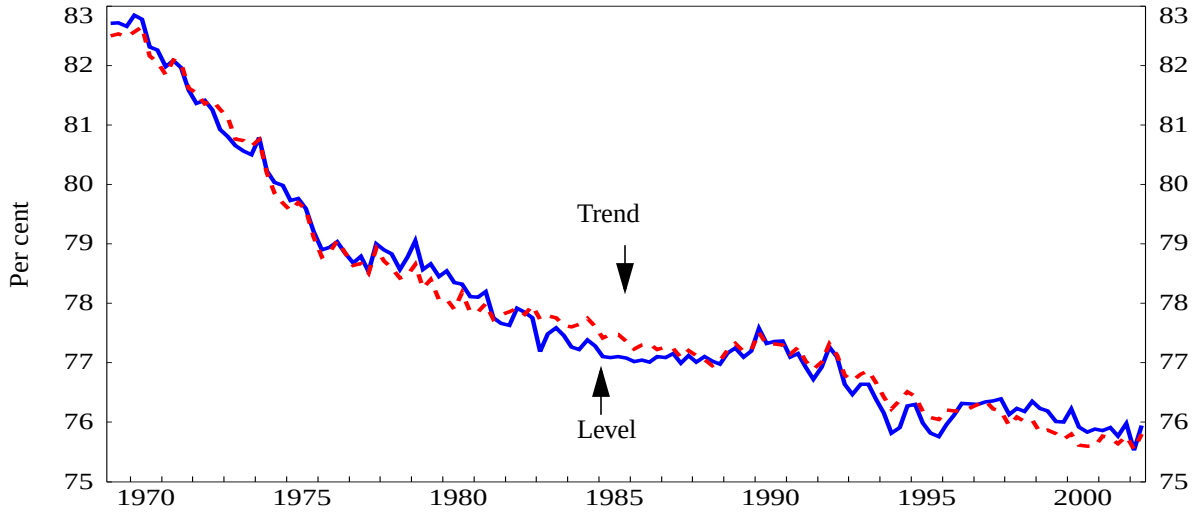


Figure C.6: Transitory component of the men's participation rate

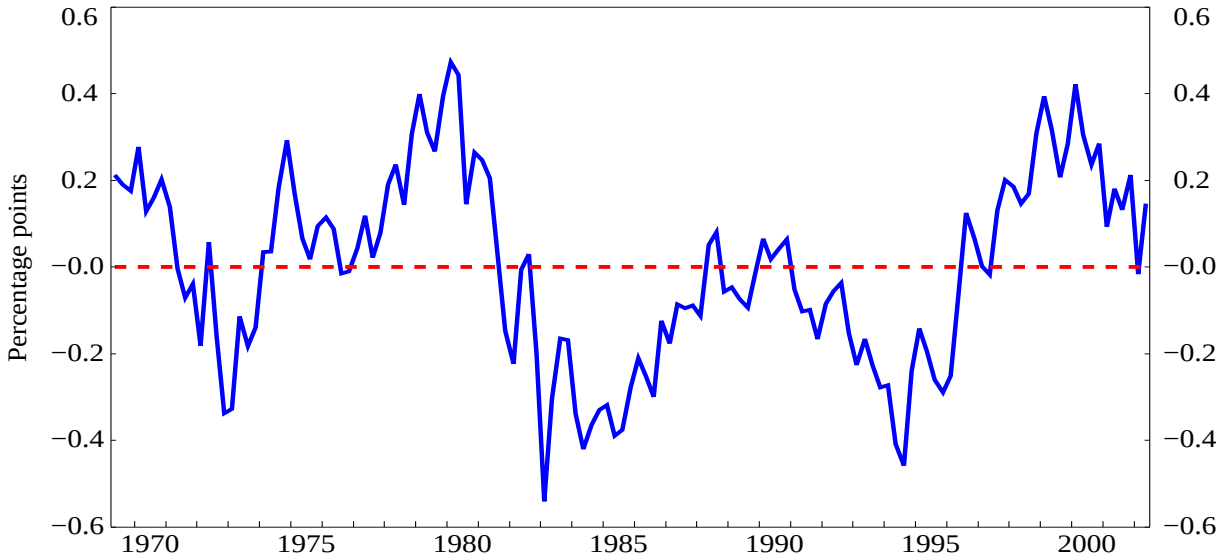


Figure C.7: Aggregate participation-rate level and trend
(trend generated by aggregation of the three SVARs)

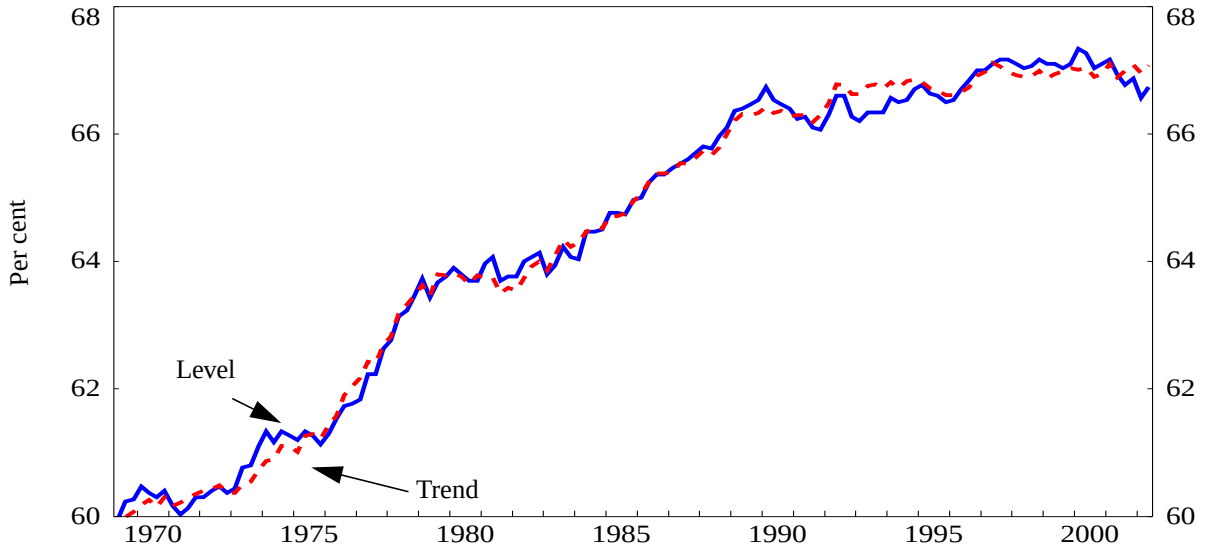


Figure C.8: Trend of the aggregate participation rate

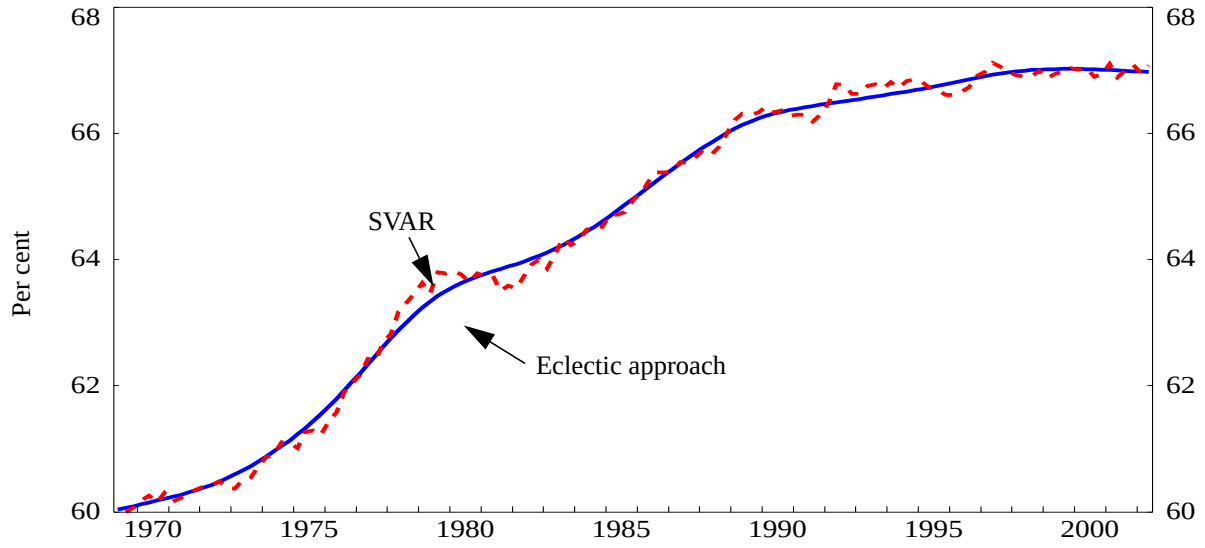
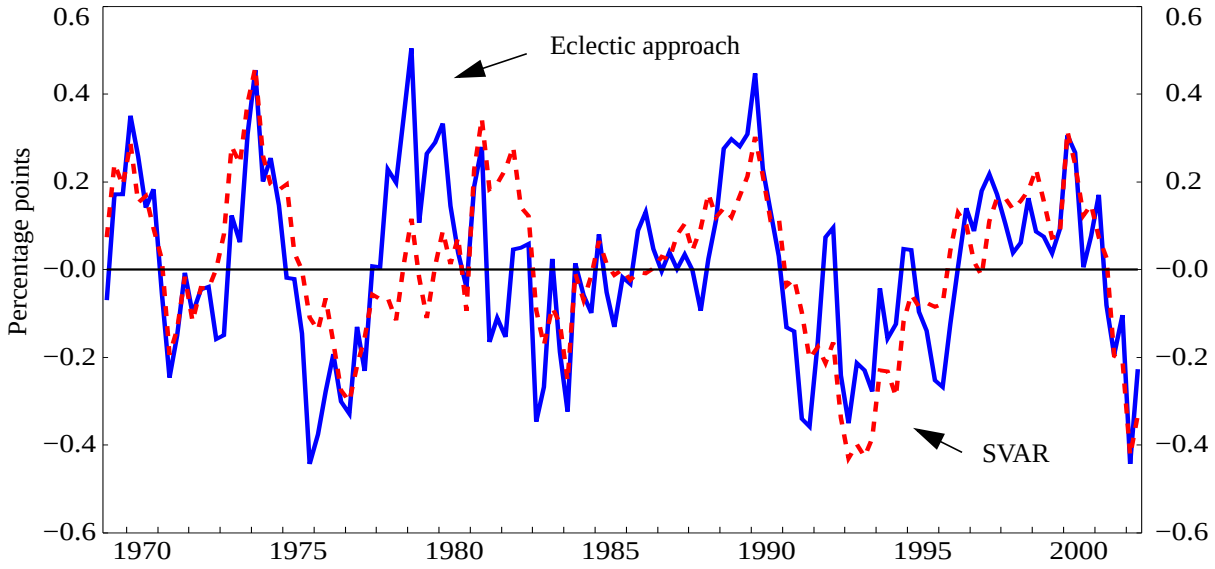


Figure C.9: Transitory component of the aggregate participation rate



Appendix D

D.1 Results from the Trend Labour-Productivity Model

Figure D.1: Non-farm labour-productivity level and trend

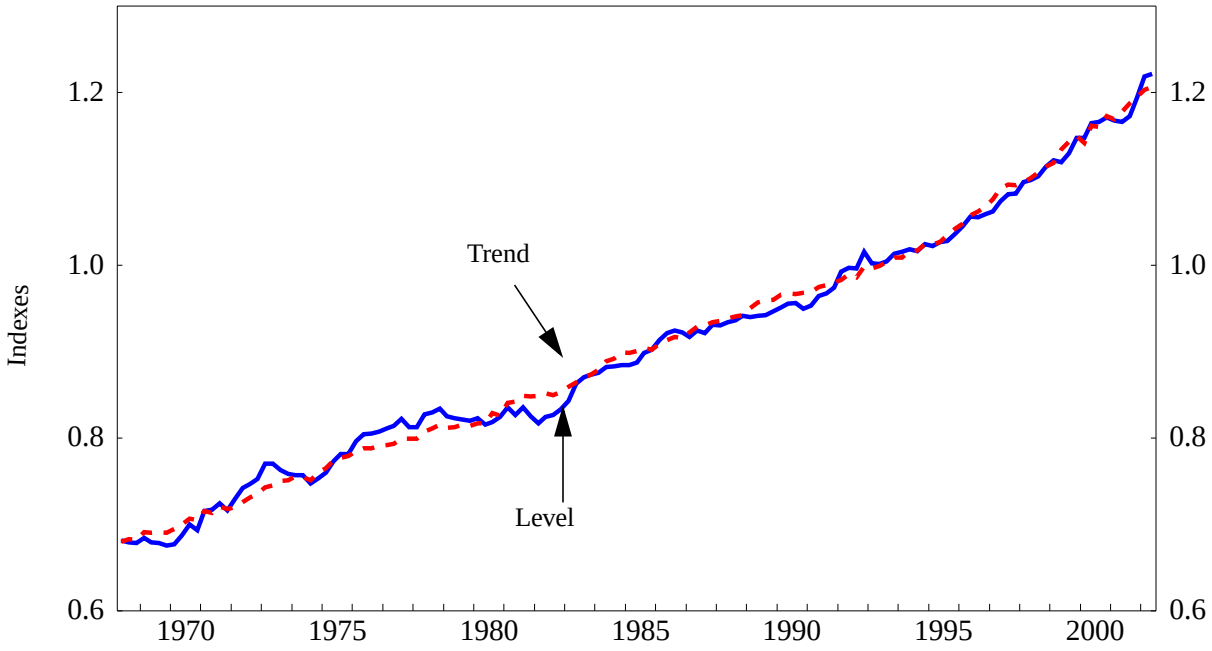


Figure D.2: Year-over-year growth in level and trend of non-farm labour productivity

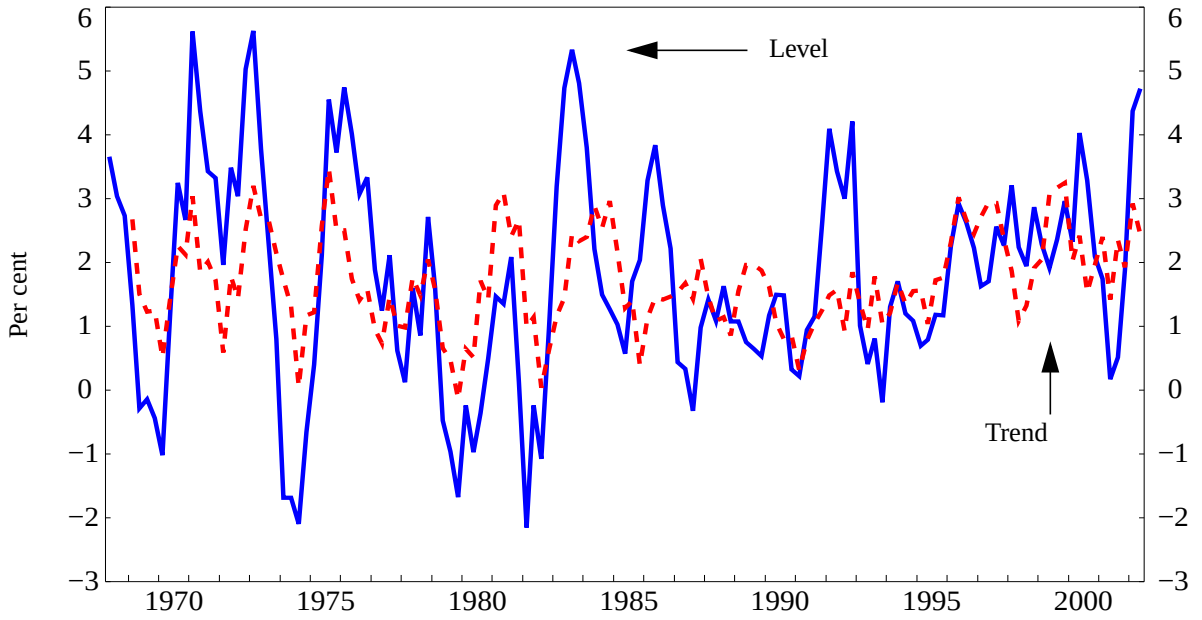


Figure D.3: Transitory component of non-farm labour productivity

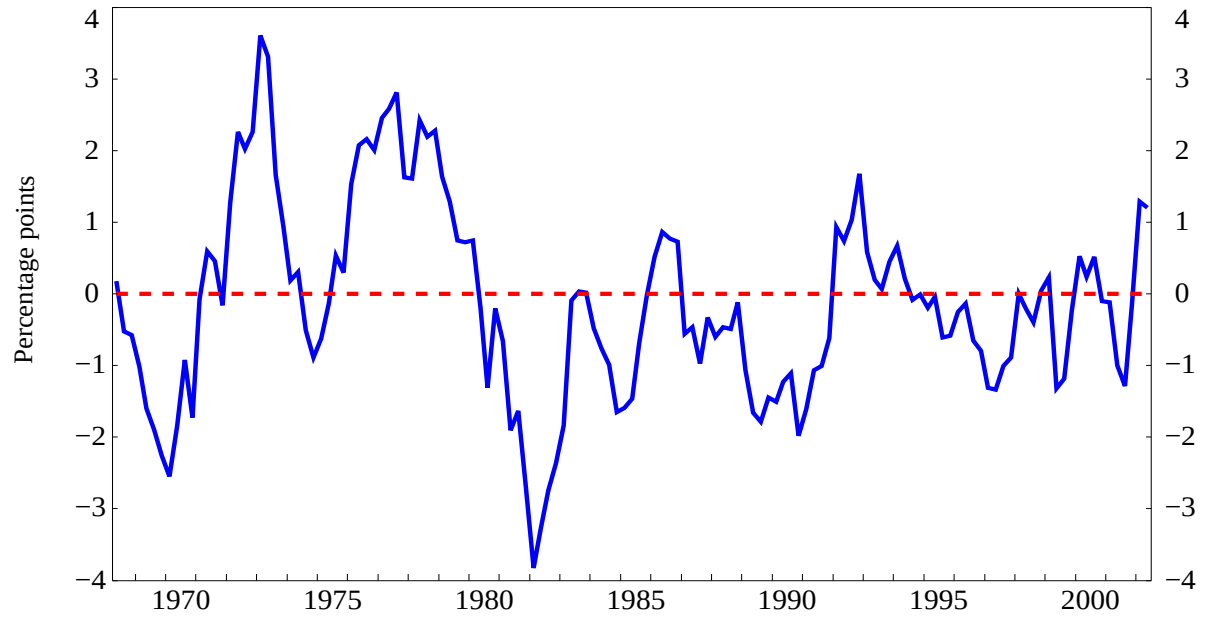


Figure D.4: NAICUR gap (manufacturing sector)

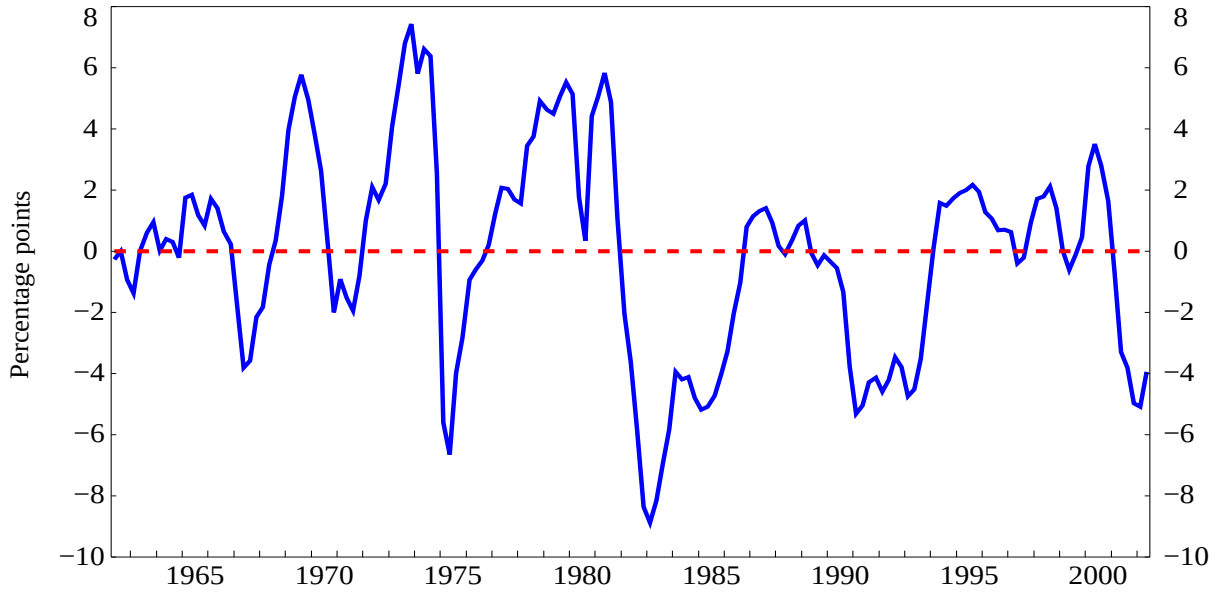


Figure D.5: Transitory components of productivity and labour input in the manufacturing sector

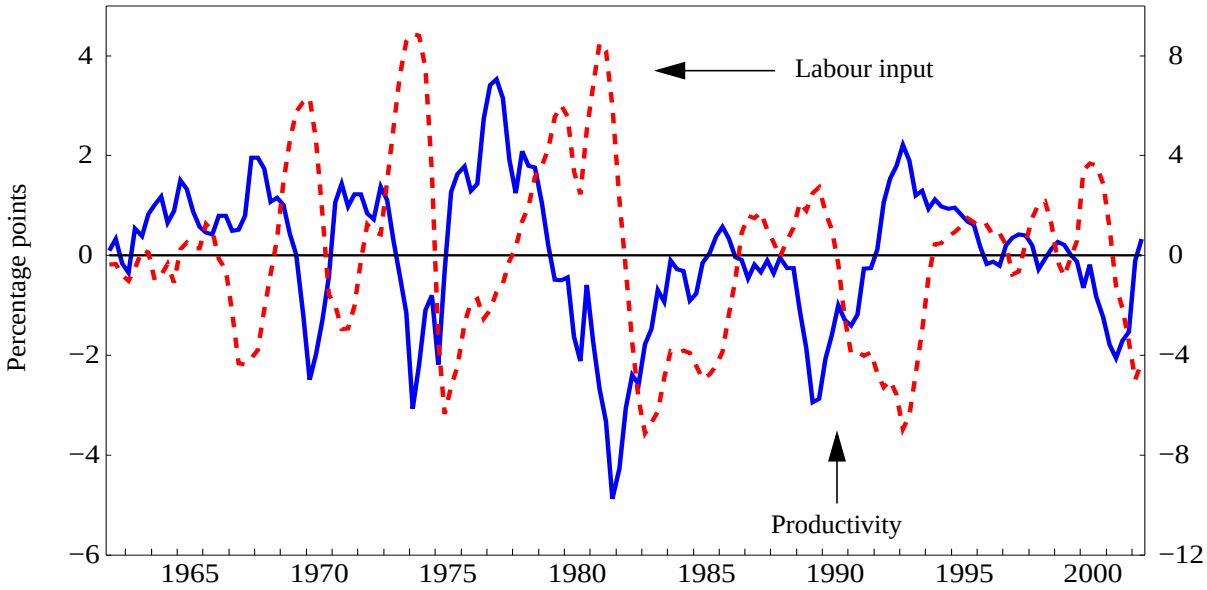


Figure D.6: Transitory components of labour productivity

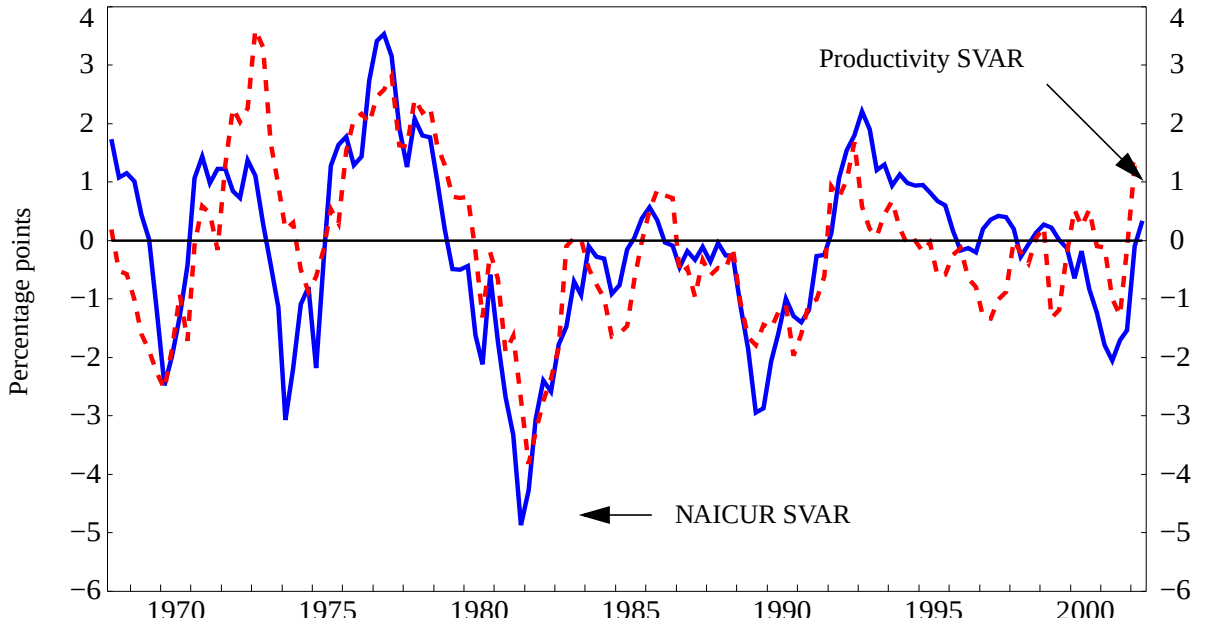


Figure D.7: Year-over-year growth in the level of total productivity (real GDP / hours worked) and in the trend yielded by the eclectic approach

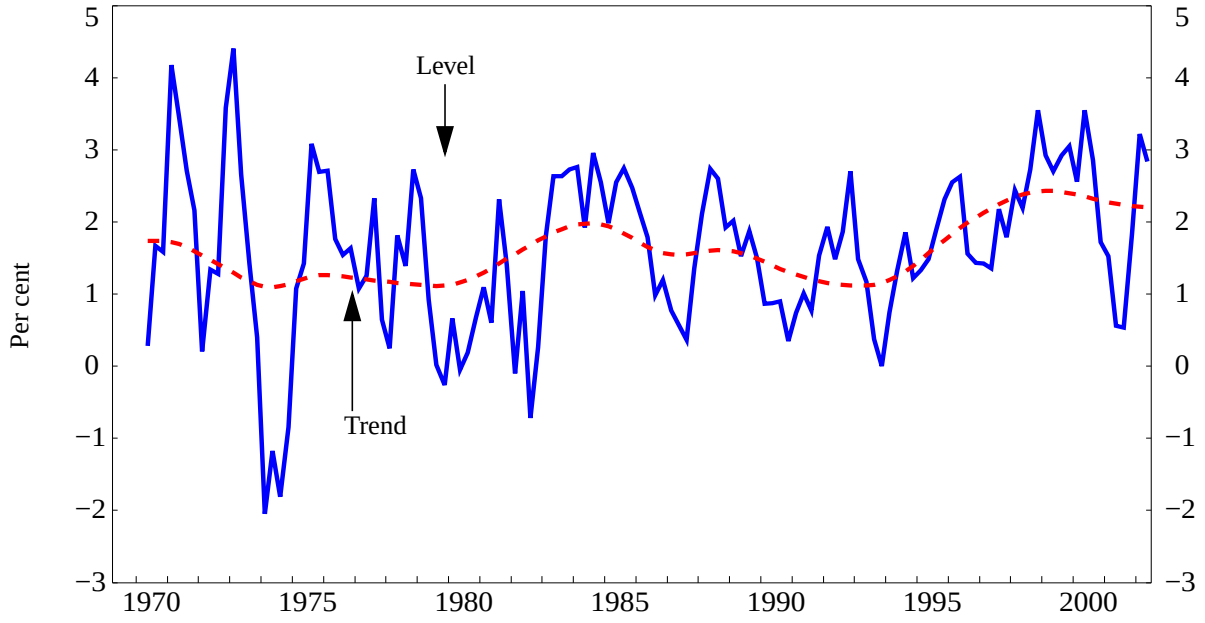
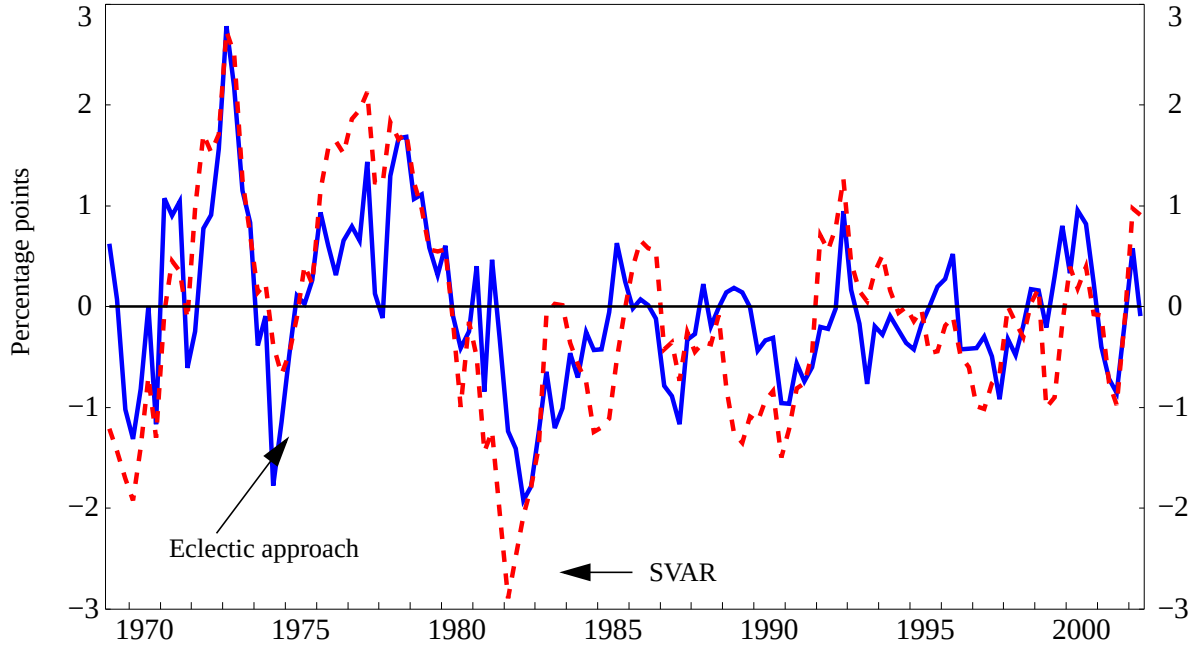


Figure D.8: Gap between the productivity level and trend



Appendix E

E.1 Potential Output

Figure E.1: Real GDP

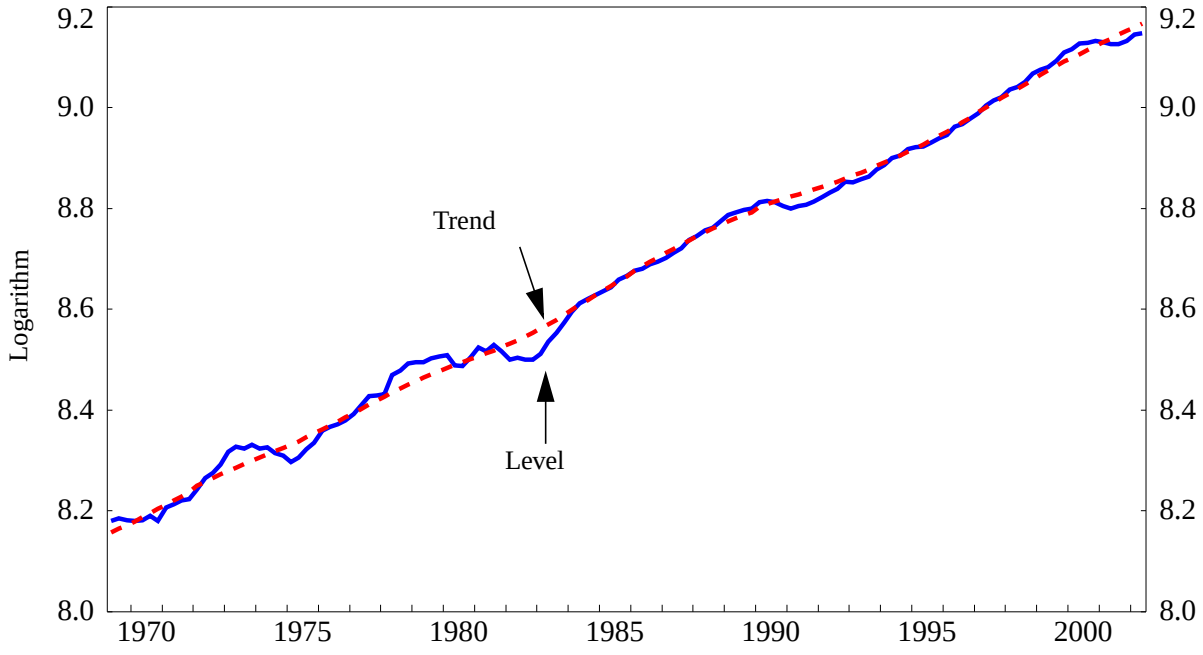


Figure E.2: Year-over-year growth in potential and real GDP

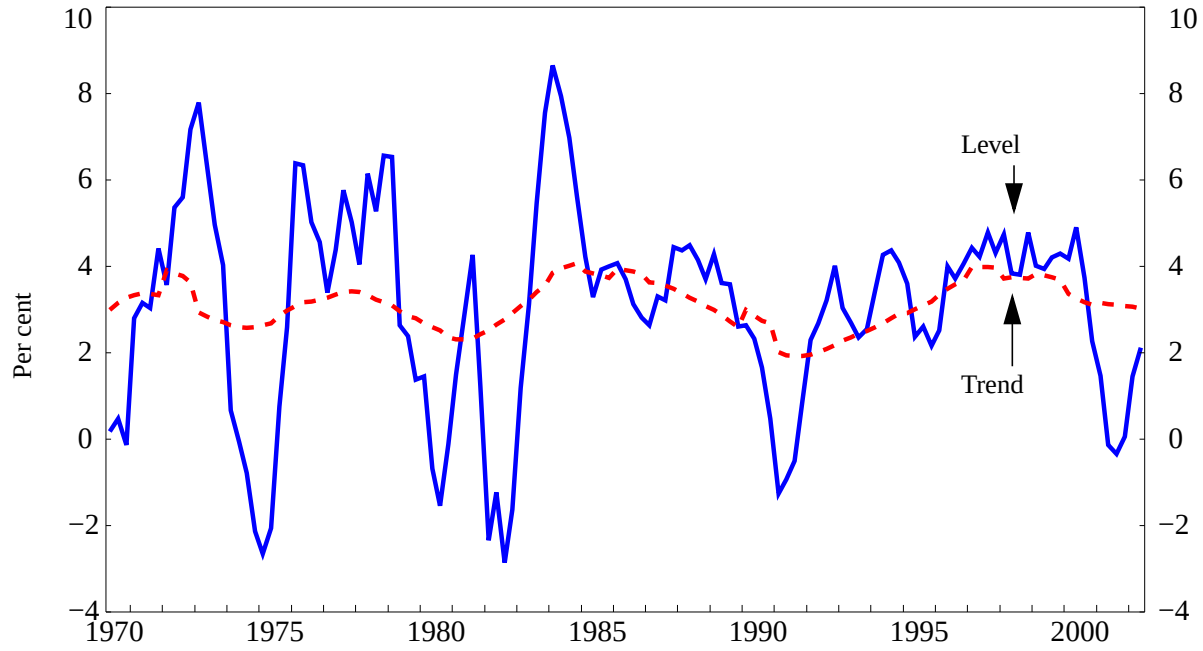
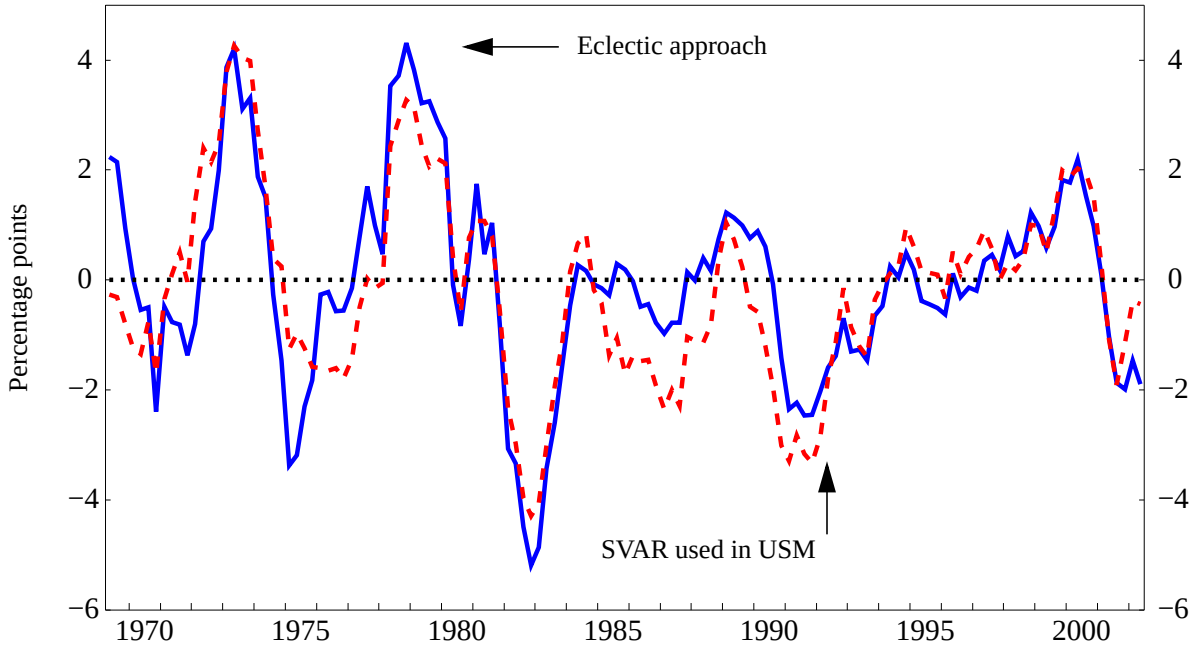


Figure E.3: Output gap



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