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# Understanding UK inflation: the role of openness

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## Abstract

In this paper, inflation dynamics in the United Kingdom are re-examined. Standard specifications of traditional Phillips curves have tended to overpredict inflation in the recent low inflation, low unemployment era in the United States, the United Kingdom and the euro area. This has stimulated the 'New Phillips Curve' approach, which has had success for the United States and the euro area, both less open economies than the United Kingdom. The paper is divided into two parts. First, the overprediction problem is documented for the United Kingdom, and an attempt is made to solve it in a traditional Phillips curve framework by introducing external shocks (terms of trade shocks or domestically generated inflation). This does not fully solve the problem. It is argued that there is a further misspecification problem with traditional Phillips curve estimates, due to the presence of the regime changes and structural change in the UK economy. Second, 'New Phillips Curve' estimates are examined. They perform badly; real marginal cost is not significant in the baseline specification. The relationship between marginal cost and inflation disappears in the mid-1980s. When a labour share measure is used, real marginal cost becomes significant, but goodness of fit based on fundamental inflation remains poor. The 'New Phillips Curve' model is then extended to allow for open economy influences, taking into account imported intermediate goods. This is found to mitigate substantially the breakdown of the relationship between inflation and marginal cost. Fit improves, but a tendency to underpredict and then overpredict inflation remains. Finally, the open-economy measure of marginal cost is decomposed. The wage mark-up component is important and highly countercyclical. Relative price movements, of taxes relative to overall prices and of imported intermediate goods relative to wages, are found to have been a negative influence on marginal costs over the 1990s. Understanding likely future developments in these relative prices could contribute to the assessment of prospects for marginal costs and the pressures on inflation.

Key words: Inflation dynamics, open economy New Phillips Curve.

JEL classification: C51, C52, E31, F41.

**Summary**

This paper re-examines inflation dynamics in the United Kingdom. Our main motivation is the recent low inflation, low unemployment era in the United States, the United Kingdom and the euro area. This has led to overpredictions of inflation using standard specifications of traditional Phillips curves. This has been a major motivation for a 'New Phillips Curve' approach, which has had success for the United States and the euro area. The reason the United Kingdom is an interesting case to study is that it is a far more open economy than the United States or the euro area.

In this paper we analyse whether the openness can explain the overprediction problem in traditional Phillips curve estimates and whether it affects the performance of 'New Phillips Curve' estimates. The paper is divided into two parts. First, we document the overprediction problem for the United Kingdom and try to solve it in a traditional Phillips curve framework. We introduce external shocks from two sources: terms of trade shocks and domestically generated inflation (DGI). We find that external shocks do not fully solve the overprediction problem within this framework. We further argue that there is a more general misspecification problem with traditional Phillips curve estimates, due to the presence of regime changes and structural change in the UK economy.

Second, we look at 'New Phillips Curve' estimates. They do not perform particularly well: real marginal cost is not significant in our baseline specification. Further investigation suggests the relationship between marginal cost and inflation broke down around the mid-1980s. When we use a labour-share measure adjusted for the public sector, real marginal cost becomes significant, but the goodness of fit of the model — based on fundamental inflation — is still very poor.

Next, we extend our 'New Phillips Curve' model to allow for open-economy influences. In particular, we take into account imported intermediate goods. When we allow for imported intermediate goods the relationship between inflation and marginal cost improves significantly. Fundamental inflation performs better than previously, but still has a tendency to underpredict and then overpredict inflation: something also present in the traditional Phillips curve estimates.

Finally, we decompose the open-economy measure of marginal cost to learn more about its

driving forces. We find that a wage mark-up component is important and highly countercyclical. We also find that relative price movements, of taxes relative to overall prices and of imported intermediate goods relative to wages, have been a negative influence on marginal costs over the 1990s. Understanding likely future developments in these relative prices could contribute to the assessment of prospects for marginal costs and the pressures on inflation.

Time-varying desired mark-ups may, in part, explain why the open-economy New Phillips Curve still underpredicts and then overpredicts inflation. In the models considered in this paper, the desired mark-up is assumed to be constant. This is important to the extent that the desired mark-up varies cyclically and can be influenced by external factors. For example, recently there has been much speculation that the high level of sterling has forced manufacturers to cut their margins on exported goods. This is equivalent to a fall in the desired mark-up and will have a negative impact on inflation in the GDP deflator. This idea fits well in a customer market model. In a customer market model, firms are assumed to be monopolistically competitive, and set their own mark-up, taking the mark-up of other firms as given. However, there is a dynamic element to the firm's problem in that higher relative prices reduce market share. In addition, some consumers are assumed to pay a cost when switching from one firm to another. This kind of model provides a justification for firms to allow the desired mark-up to vary, in the short term, in order to stop the long-term loss to profitability of losing customers. It may also be a key factor that exporters take into account, by allowing margins to vary in reaction to changes in exchange rates, rather than the foreign price of the exported good. Recent high levels of sterling may have reduced the desired mark-up and thus potentially explain the overprediction of actual inflation by fundamental inflation. We plan to look at this in greater detail in future work.

## 1 Introduction

Inflation targeting has become the dominant form of monetary policy in recent years. Explaining and forecasting inflation has thus never been more important. In this paper, we analyse the dynamics of inflation in the United Kingdom.

Our main motivations for re-examining inflation dynamics, in the United Kingdom, are: the recent overprediction problem in Phillips curve estimates; and the recent success of New Phillips Curve estimates, for the United States and euro area (see Sbordone (2002), Galí and Gertler (1999) and Galí, Gertler and López-Salido (2000)). The puzzle of low inflation given low relative unemployment, or relatively high growth, has marked the recent economic history of the United States, the euro area and the United Kingdom. In the United Kingdom, for example, RPIX inflation has recently been around or below the target level of 2.5%, yet unemployment was still falling from a very low base of around 5% until the second half of 2001. Given these outcomes, it is not surprising that traditional Phillips curve estimates have tended to overpredict inflation.

In this paper we try explain what might cause such an overprediction problem. We consider two hypotheses. First, we consider an approach consistent with a traditional Phillips curve model — external shocks. The Phillips curve reflects mainly domestically generated pressures, in the form of an output or unemployment gap, on inflation. Yet we usually measure inflation in the form of the GDP deflator, though RPIX is the target index for the Bank of England. This obviously includes export prices and thus will be affected by external shocks. We consider two ways of controlling for this: using terms of trade shocks and considering measures of domestically generated inflation (DGI). Using terms of trade shocks is a fairly conventional way of controlling for external shocks in the literature. Using DGI as a measure of inflation is a novel feature of this paper. DGI is analogous to measures of core inflation that strip out erratic components, except that it is attempting to strip out the effects of exchange rate variation and external pressures on inflation. Bank of England staff have constructed various measures of DGI, which we utilise in this paper.

Second, it may be the case that the traditional Phillips curve is mis-specified and we need to consider a New Phillips Curve type approach. Many have suggested that there are two main problems with traditional Phillips curve models: how to estimate the output gap and the fact that the curve is not properly micro-founded (Rotemberg and Woodford (1999) among others). Measuring the output gap may be particularly hard for the United Kingdom given that the labour reforms, during the 1980s, have had a big impact on labour market flexibility. Many argue that since 1992, the United Kingdom has been on a new, more dynamic, adjustment path and that this was facilitated by the labour market reforms. A standard way of measuring output/unemployment gaps is to use a Hodrick-Prescott (HP) filter. It is unlikely such a method could capture the rich dynamics underlying recent UK labour market performance. If traditional Phillips curves are not properly micro-founded, this can lead to the Lucas critique being particularly pertinent, especially given the role that expectations play in inflation. Both the above reasons suggest a New Phillips Curve approach, micro-founded on a model of sticky prices, might be a way forward. Sbordone (2002) and Galí and Gertler (1999) develop and take such models to data. Galí and Gertler show that a variant of Calvo's (1983) model of sticky prices leads to a Phillips curve which has forward-looking and backward-looking inflation terms, and real marginal cost as the forcing variable. This is in contrast to traditional Phillips curves, which only have backward-looking inflation terms and an output gap type term as the forcing variable. We estimate a New Phillips Curve, based on the Galí and Gertler approach, for the United Kingdom, as an alternative solution to the specification problems with standard formulations of traditional Phillips curves. Further, we perform rolling regressions to test the structural stability of the estimates and calculate estimates of fundamental inflation.

An important feature of this paper is that we extend the New Phillips Curve model to an open economy. This is particularly important for the United Kingdom, as it is far more open than the United States or the euro area. The average levels of imports and exports as a percentage of GDP in 1998 were 33% for the United Kingdom, 16% for the euro area and 12% for the United States. We allow for the effect of imported intermediate goods in the production function. This is potentially very important for the United Kingdom, given that both the prices of imports and sterling have been very volatile over the past 30 years.

The paper is structured as follows; first, we describe the data used and how the DGI measures are constructed. Second, we estimate a standard specification of the traditional Phillips curve and show how it has overpredicted inflation, in recent years. We propose two solutions to the overprediction problem within the traditional Phillips curve framework a) introducing external shocks in the form of a terms of trade variable, and b) using a DGI measure as the inflation variable. We also perform structural stability analysis in the form of rolling regressions. Third, we present a New Phillips Curve model (NPC), in the spirit of Galí and Gertler (1999). We estimate the NPC on UK data and do various robustness checks for the NPC model: using different measures of inflation and different production functions with different measures of marginal cost. Next, we extend the New Phillips Curve model to an open-economy, and re-estimate a New Phillips Curve specification taking into account open-economy influences. Finally, extending Galí, Gertler and López-Salido (2000), we also decompose our marginal cost measure and try and explain its movements in terms of cyclical factors and the wage mark-up. We extend their analysis by taking into account the open-economy extension to the New Phillips Curve derived in the paper and the wedge between the consumption and product wage.

## 2 Data description

The data come from two main sources: ONS data, and various measures of DGI which staff at the Bank of England have constructed. Below we highlight some of the important nuances of the data, namely the various measures of: inflation, the output gap, terms of trade and marginal cost used.

### *2.1 Alternative measures of inflation*

We look at a GDP deflator, at factor cost, measure of inflation and a consumer price index, namely RPIX. RPIX is chosen as this is the price index which forms the inflation target of the Bank of England. RPIX is simply the retail price index (RPI) excluding mortgage interest payments. From both these indices of inflation we construct measures of DGI, which we describe below.

#### *2.1.1 DGI based on the GDP deflator*

For some, the GDP deflator is a measure of domestically generated inflation as it measures the price of domestic value added in the economy. Consequently it does not directly reflect the prices of imports. However, domestic value added includes value added in the export sector, which will be affected by external shocks. For example, the appreciation of sterling since 1996 could have caused UK exporters to cut their sterling prices in an attempt to remain competitive in overseas markets. This could have depressed the GDP deflator inflation rate. A measure of DGI based on the GDP deflator should exclude the effects of export prices. Because the weight of exports in GDP is known, the contribution of export prices to GDP deflator inflation can be calculated and stripped out.

There is a small complication that around a quarter of the components used in exports are imported. Thus export prices will be directly affected by import prices. The GDP deflator already excludes import prices, so stripping out total export prices from the GDP deflator would, in effect, remove the contribution from import prices twice. Thus we estimate DGI using the GDP deflator as:

$$(1-\alpha_x)dgi_{gdp} = \pi_{gdp} - \alpha_x \pi_x^*$$

where $\pi_{gdp}$ is the GDP deflator inflation rate, $\alpha_x$ is the share of exports in GDP and $\pi_x^*$ is the export price deflator once the effect of import prices have been stripped out. This is given by:

$$(1-\alpha_m)\pi_x^* = \pi_x - \alpha_m \pi_m$$

where $\alpha_m$ is the share of imports in exports and $\pi_m$ is the import price deflator. In the Bank of England estimates, it is assumed that $\alpha_m$ is equal to the share of imports in GDP.

### *2.1.2 DGI based on RPIX*

The Bank of England's inflation target focuses on a basket of consumers' goods and services measured by RPIX inflation, whereas the GDP deflator includes all domestic goods and services. Further the GDP deflator at factor cost excludes the effects from changes in taxes and subsidies. But changes in indirect taxes will affect RPIX inflation. Thus Bank of England staff have also constructed a measure of DGI based on RPIX inflation, as it may be more useful for monetary policy purposes.

A basket of goods and services in RPIX includes imports directly (such as Japanese video recorders) and indirectly (such as components of electrical appliances assembled in the United Kingdom). Input-output tables permit the calculation of the combined share of direct and indirect imports as a proportion of consumption. Thus we estimate DGI based on RPIX as:

$$(1-\phi_m)dgi_{rpix} = \pi_{rpix} - \phi_m \pi_m$$

where $\phi_m$ is the share of imports in consumption. We will discuss later how effectively DGI acts as a measure of domestic inflation.

### 2.1.3 Trends in DGI relative to inflation

It can be seen in Chart 1 that both sets of DGI measures were above actual inflation from the third quarter of 1995 to the end of the sample period in 1999. This is due to falling import and export prices, partly driven by the appreciation of sterling. As we will see later, this could be one explanation of the overprediction of inflation by traditional Phillips curves and help explain why baseline estimates of the New Phillips Curve do not perform well.

## 2.2 Output gap, terms of trade and marginal costs

We construct a measure of the output gap from that data we have on real GDP at factor cost. We consider two methods. First we regress real GDP on: a constant, a time trend and a quadratic time trend. We use the residual of this regression as one measure of the output gap. Second, we HP filter the data with $\lambda = 1600$ (the standard value chosen in the business cycle literature).

To measure the terms of trade, we just took import and export prices on goods and services, as provided by the ONS. Thus

$$ptot = 100 * \log(\frac{pimport}{pexport})$$

As we will see later, when we discuss the foundations of the New Phillips Curve, marginal costs are strongly related to the labour income share. Thus, the major part of constructing marginal cost measures involves measuring the labour share: $ls = \frac{wn}{py}$, where: $w$ are nominal wages and are taken to be the average earnings index measured by the ONS; $n$ are total employment heads (including self-employment); $y$ is real GDP at factor cost and $p$ is the GDP deflator.

# 3 Traditional Phillips curve estimate

As Galí, Gertler and Lopéz-Salido (2000) make clear, traditional Phillips curves come under attack for two main reasons. First, the Lucas critique remains an issue, especially as implicitly Phillips curves embed inflationary expectations. Shifts in policy could lead to shifts in private sector beliefs, causing the parameters of the Phillips curve to change. Second, for the United States and Europe, traditional Phillips curves have tended to overpredict inflation recently. In both the United States and Europe, inflation has been low despite robust output growth. In both cases measured output gaps have been positive despite low inflation, and thus have led to forecasts overpredicting actual outturns of inflation (for US studies, see Brayton, Roberts and Williams (1999), Stock (1998) and Katz and Krueger (1999)). In this section, we see if the overprediction problem also applies to the United Kingdom. We suspect that there is an issue, as in 2001 RPIX inflation was around or below the target level of 2.5%, yet unemployment was still falling from a very low base of around 5%. The suspicions are confirmed in this section. We also try to solve the discovered overprediction problem by a more traditional method than estimating a New Phillips Curve — we introduce external shocks. These factors should be more important for the United Kingdom than the United States or the euro area — as noted in the introduction, the United Kingdom is over twice as open an economy as the United States or euro area. We introduce external shocks in two ways: adding terms of trade shocks; and using DGI, instead of overall inflation, as the dependent variable in the Phillips curve regression.

### *3.1 Phillips curve in the UK model: the overprediction problem*

The traditional Phillips curve relates inflation to some measure of excess demand (or the output gap) plus lagged values of inflation. For example, let $\pi_t$ denote inflation, $y_t$ the log of real GDP and $y_t^*$ the log of the natural level of GDP. A common specification of the old Phillips curve is:

$$\pi_t = \sum_{i=1}^{h} \varphi_i \, \pi_{t-i} + \lambda \, (y_{t-1} - y_{t-1}^*) + \epsilon_t \qquad \textbf{(1)}$$

where $\epsilon_t$ is a random disturbance. Often the restriction is imposed that the sum of the weights on lagged inflation is unity, so that the model implies no long-run trade-off between output and inflation. Sometimes additional lags of the excess demand measure are added. Often alternative measures of excess demand are used.

As Galí, Gertler and López-Salido (2000) note, despite considerable criticism, the traditional Phillips curve does a reasonably good job of explaining post-war inflation in both the United States and the euro area. For example, Rudebusch and Svensson (1999) show that a variant of equation **(1)** with four lags of inflation provides a good fit of US data over the period 1960-99. The output gap, which is approximated using detrended log GDP, enters significantly with a positive sign (standard errors are in the brackets below the coefficients) and the sum of the coefficients on lagged inflation does not differ significantly from unity. Galí, Gertler and López-Salido show that a similar relation fits well for the euro area, over the sample 1970-99:

$$\pi_t = \underset{(0.087)}{0.520}\pi_{t-1} + \underset{(0.073)}{0.233}\pi_{t-2} - \underset{(0.084)}{0.070}\pi_{t-3} + \underset{(0.086)}{0.256}\pi_{t-4} + \underset{(0.065)}{0.205}(y_{t-1} - y^*_{t-1}) + \epsilon_t$$

To allow a direct comparison they also estimated model for US data over the same sample, and obtained:

$$\pi_t = \underset{(0.041)}{0.602}\pi_{t-1} + \underset{(0.153)}{0.041}\pi_{t-2} + \underset{(0.119)}{0.152}\pi_{t-3} + \underset{(0.055)}{0.155}\pi_{t-4} + \underset{(0.055)}{0.192}(y_{t-1} - y^*_{t-1}) + \epsilon_t$$

Notice that the estimated coefficients are quite similar across the two areas. On the surface, the significance of lagged inflation suggests considerable persistence in inflation.

We estimate the Rudebusch-Svensson specification for the United Kingdom below:

$$\pi_t = +\underset{(0.108)}{0.243}\pi_{t-1} + \underset{(0.103)}{0.345}\pi_{t-2} + \underset{(0.096)}{0.214}\pi_{t-3} - \underset{(0.096)}{0.041}\pi_{t-4} + \underset{(0.032)}{0.096}(y_{t-1} - y^*_{t-1}) + \epsilon_t$$

The equation also shows similar properties in the United Kingdom as well, in that the output gap enters significantly with a positive sign and the sum of the coefficients on lagged inflation do not differ significantly from unity.(1)Chart 2, however, makes it clear that the overprediction problem also exists for the United Kingdom. The overprediction problem has got worse since 1995, as is the case in the United States and Europe, though it seems from Chart 2 that, for the United Kingdom at least, Phillips curve forecasts have been too high since 1989.(2)

### *3.2 Solving the overprediction problem: allowing for supply shifts*

One reason for the overprediction problem could simply be the effect of external shocks. We can think of inflation being affected by domestic and external pressures. Although there are obvious spillovers between the two, for example a reduction in import prices could put downward pressure on competing domestic prices, they can be very different. For example, there was substantial downward pressure on import and export prices in the late 1990s, as can be seen in Chart 3. From the third quarter of 1996 to the end of the sample period, both import and export price inflation were negative. This mirrors the movements in DGI relative to actual inflation outturns shown in Chart 1. DGI was higher than actual inflation from the third quarter of 1995 to the end of the

(1) All the above regressions include a constant.

(2) We get the same picture if we choose RPIX as our inflation measure, rather than the GDP deflator. The overprediction gets more pronounced from 1997 onwards, with RPIX, though.

sample period. This coincides with a worsening of the overprediction problem. The answer to the problem could simply be that the Phillips curve is really capturing domestic pressures and not *external* pressures. For example, the appreciation of sterling to the late 1990s was a major factor keeping export prices down — exporters need to keep competitive in overseas markets and thus they have to reduce the sterling price of their products. Import prices have also fallen because of the appreciation of sterling and a general fall in commodity prices, albeit interrupted by fluctuating oil prices. Neither of the falls is particularly related to the output gap, or more generally domestic pressures. Thus it is unlikely that the Phillips curve forecasts will capture these effects.

### *3.2.1 Using DGI as a measure of inflation*

One way to control for external shocks is simply to use a different measure of inflation in the Phillips curve equation **(1)**. In particular, we could use the DGI measures we discussed earlier which attempt to strip out the effects of external shocks. As we noted in Section 2.1.3, DGI has been above the actual inflation rate since the third quarter of 1995. This seems to coincide with the overprediction problem, allowing for potential lags. We thus estimate the Rudebusch-Svensson specification with $dgi_{gdp}$ as the inflation variable.[3] The estimated equation is given below:

$$\pi_t = \underset{(0.052)}{-0.036}\pi_{t-1} + \underset{(0.052)}{0.012}\pi_{t-2} - \underset{(0.050)}{0.057}\pi_{t-3} + \underset{(0.053)}{0.819}\pi_{t-4} + \underset{(0.049)}{0.159}(y_{t-1} - y^*_{t-1}) + \epsilon_t$$

Again the equation shows similar properties to previous estimates, in that the output gap enters significantly with a positive sign and the sum of the coefficients on lagged inflation does not differ significantly from unity. Chart 4, however, shows that the overprediction problem still exists. Thus using DGI to control for external shocks does not seem to control the overprediction problem.

### *3.2.2 Controlling for terms of trade shocks*

An alternative way of controlling for external shocks, instead of changing the inflation variable, is to control for terms of trade shocks. Below we estimate a Rudebusch-Svensson specification, but add four lags of quarterly changes in the terms of trade, $\Delta ptot$. We keep the GDP deflator as the

(3) We also estimate the same equation with $dgi_{rpix}$ as the inflation variable. There are few qualitative differences from the results for $dgi_{gdp}$ and thus we do not discuss these results in detail.

inflation variable. The results are given below:

$$\pi_t = \underset{(0.086)}{0.164}\pi_{t-1} + \underset{(0.069)}{0.288}\pi_{t-2} + \underset{(0.093)}{0.307}\pi_{t-3} + \underset{(0.108)}{0.077}\pi_{t-4} + \underset{(0.032)}{0.067}(y_{t-1} - y^*_{t-1})$$
$$+\underset{(0.061)}{0.113}\Delta ptot_{t-1} + \underset{(0.064)}{0.019}\Delta ptot_{t-2} + \underset{(0.067)}{0.184}\Delta ptot_{t-3} + \underset{(0.054)}{0.190}\Delta ptot_{t-4} + \epsilon_t$$

The coefficients on lagged inflation and the output gap are as expected. Also some of the lags of $\Delta ptot$ are positive and significant, thus suggesting it is important to control for external shocks.

Chart 5 plots the actual against fitted values (converted from quarterly rates to annual ones). It seems there is an overprediction problem from around 1994 on, but it does not persist. It seems to disappear during 1997.

### *3.2.3 Comparison of the two methods and a critique of DGI*

A more precise way of comparing the various methods is to look at the evolution of the Mean Squared Error (MSE). We do this in Chart 6. Surprisingly, this suggests the DGI method performs worse than the unadjusted Rudebusch-Svensson model, with adjusting for terms of trade shocks delivering the lowest MSE. Further, when we run the Rudebusch-Svensson model with DGI and terms of trade shocks, the terms of trade shocks turn out to be significantly positive.[4] This suggests that DGI does not fully strip out external shocks. These two results could be due to strong spillovers between external and domestic pressures, which are hard to disentangle with a simple DGI measure, especially during times of severe inflationary pressures. Aoki (2001) makes a similar point. He uses an optimising model, with a flexible-price and a sticky-price sector, to argue that the current measures of 'core inflation' are flawed. This is because such measures generally strip out erratic components, or in the case of DGI external components. They fail to take into account possible interactions between erratic components and other components of inflation. The mechanism in Aoki's paper is a substitution effect between the flexible and sticky price goods sector. Namely, if we have an increase in the relative price of flexibly priced goods, this leads to an increase in demand, via substitution, for sticky-price goods. This will eventually

(4) These results are available on request.

lead to an increase in the relative price of sticky-priced goods. Exactly the same kind of intuition could be applied to the effect of import prices on domestic prices. Another possible mechanism could be that if exporters are getting squeezed by strong sterling and this forces them to reduce margins in this sector, they could try and increase margins they make on products in the domestic sector. Thus a potential reduction in exports goods inflation could lead to higher domestic inflation. The general point is that there are rich interactions between domestic and external inflationary pressures, which will not be captured with such a simple measure as DGI. In Section 5, when we look at an open-economy version of the New Phillips Curve, we try and address this problem, by allowing for substitution between imported intermediate goods and labour.

#### *3.2.4 Lucas Critique and structural shifts — could this explain the under and then overprediction*

The above discussion suggests that controlling for external effects does not fully solve the overprediction problem. Adding terms of trade variables seems to solve for more of the overprediction problem than using DGI as a measure of inflation. As the above discussion argues, this is probably because DGI does not fully strip out external influences on domestic inflation. So far we have not commented on another problem apparent in Charts 2, 4, and 5 — that of misspecification, evidenced by autocorrelation. The Rudebusch-Svensson model has a tendency to underpredict up to 1988 and then a tendency to overpredict, though this seems less obvious when we control for terms of trade. This suggests that structural breaks due to changes in the policy regime, and/or due to the evolution of the labour market in the United Kingdom, may be playing a significant role.

Changes in the monetary policy framework

To clarify, consider a version of the expectations-augmented Phillips curve:

$$\pi_t = \pi_t^e + \lambda\,(y_{t-1} - y_{t-1}^*) + s_t + \epsilon_t \qquad \textbf{(2)}$$

where $\pi_t^e$ is the inflationary expectation at time $t$, and $s_t$ is a supply shock. The Rudebusch-Svensson specification can be thought of as using a combination of lags of inflation to proxy for inflationary expectations. Ignoring for the moment that the specification does not have any forward-looking terms, it is clear from the Lucas Critique (1976), that the way these expectations are formed can change as the policy regime changes.

There have been several changes in the UK monetary policy framework over the past 30 years. By the mid-1970s, in reaction to a sharp increase in inflation, frameworks for monetary policy set out to target nominal magnitudes explicitly — in particular different measures of the money supply, with varying degrees of emphasis during 1976-86. The exchange rate was targeted implicitly in 1987-88 (shadowing the DM) and explicitly in 1990-92 (within the ERM). Since 1992, the inflation rate has been targeted, with the Bank of England given operational independence in 1997.

Estimating the Rudebusch-Svensson model can be seen as providing an average rule for the formation of inflationary expectations. Yet it is plausible that various changes in policy frameworks have changed the expectation formation rules. Haldane and Quah (1999) argue that, since the late 1970s, UK policy-makers have become more informed and credible. This could be consistent with the view that compared to the average rule estimated, inflationary expectations have been lower after 1988, and higher before 1988. This could explain why we see a consistent underprediction and overprediction before and after 1988 respectively.(5) Sargent (2000) in his primer 'The Conquest of American Inflation', provides an explanation of recent US inflation dynamics. His explanation of how US inflation returned to being low, in the late 1980s and 1990s, is a combination of adaptive expectations and learning of a government with a simple view of the Phillips curve. Some of these forces have also probably been at play in the United Kingdom, though the United Kingdom is different from the United States in the number of changes in the framework monetary policy has had in the past 30 years. We will perform a simple test below in Section 3.2.5 to see if the changes in the UK monetary policy regime have made monetary policy more credible over time. If this is true, it may be argued that the United Kingdom has experienced a more extreme learning process than Sargent suggests took place in the United States.

Structural reforms

The standard way of measuring $y^*$ in equation **(2)** is to apply an HP filter, or linear and quadratic time trends, to $y$. However, the labour reforms during the 1980s have had a big impact on labour market flexibility. Many argue that, since 1992, the United Kingdom has been on a new, more dynamic, adjustment path and that this was facilitated by the labour market reforms (Brown *et al* (1998)). That the reforms did not convert into improved wage performance until 1992, was due to

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(5) Haldane and Quah (1999) go even further. They argue that the changes in regime could also have changed the parameter $\lambda$. They show, in a simple monetary model, with authorities both fully informed about the structure of the economy and aware of long-run neutrality, that the Phillips curve can be horizontal or even that $\lambda < 0$.

lags of adjustment and the need for a shock to move the UK economy on to a new dynamic adjustment path. Possible candidates for this catalyst are: the 1990-92 recession, which may have led to the kind of cleansing effects advocated by Caballero and Hammour (1994); the exit of the United Kingdom from the ERM and the adoption of inflation targeting in 1992; and, possibly, an increasing belief on the part of labour market participants that labour market reforms would not be reversed. It is unlikely that the standard methods of detrending could capture the rich dynamics underlying the recent UK labour market performance.[6] The measures of $y^*$ we employ are likely to be subject to measurement error. This could distort our estimates of the Phillips curve.

#### *3.2.5 Rolling regressions to test for structural breaks*

To check the importance of structural breaks and shifting expectations, we perform some rolling regressions. In particular, we perform rolling regressions of equation **(1)**, with the GDP deflator as the inflation variable.[7] We vary the terminal date from 1980:1 to 1999:3. We construct, as a measure of the formation of inflationary expectations, the sum of the constant plus the coefficients on lagged inflation, from the estimated regression.

In Chart 7, we plot the results for the formation of inflation expectations, $\pi^f$, and $\lambda$. It is noticeable how $\pi^f$ tends to fall as the sample size increases. This is consistent with the idea that the changes in the UK monetary policy framework have made the regime more credible and have thus reduced inflationary expectations. As outlined earlier, this could explain the under and overprediction problem. $\lambda$ seems to show a downward trend from 1987 onwards. This could be because if our measure of $y^*$ does not properly capture a reduction in the natural rate of unemployment, then our estimates of the output gap would be too high. This would downwards bias $\lambda$.

### *3.3 Summary of evidence on the traditional Phillips curve*

In this section, we have estimated standard specifications of the traditional Phillips curve and found that they overpredict inflation. We have tried to solve this by taking into account external shocks and have found that this partly solves the problem, but still leaves a problem of

(6) We will discuss, in more detail, at the end of Section 4, where we decompose the measure of marginal cost, paying special attention to the wage mark-up.
(7) When we add terms of trade terms to the regression, the results are very similar — the measure of inflation expectations falls over time.

misspecification. Further, we have argued that this misspecification problem could be due to two main factors: changes in the monetary policy framework and structural changes in the UK labour market causing the parameters in the UK Phillips curve to have shifted. One potential solution, at least to the problem of structural change, would be to use a more sophisticated measure of the output gap than recovered by using an HP filter or a quadratic trend. One approach would be to follow Gordon (1998) and use a Kalman filter to estimate a time-varying NAIRU. Another would be to use IMF or OECD estimates of the output gap. All the above mentioned approaches would be valid options. We choose a different approach in this paper, namely a New Phillips Curve approach. The advantage of this approach is that it is rigorously micro-founded and allows for forward-looking behaviour. As we will see in the following section, this allows us to document clearly when the output gap can proxy movements in real marginal costs and thus act as the forcing variable in the Phillips curve. In future work we intend to look at other potential solutions within the traditional Phillips curve framework.

## 4 New Phillips Curve estimates

The above analysis suggests that structural modelling of inflation is desirable, in the same way that it is desirable for all other aspects of a macroeconomic framework. Indeed, in recent years, there has been considerable effort devoted toward deriving an aggregate relation for inflation, based on individual optimisation. The approach is based on staggered nominal price-setting, in the spirit of earlier work by Taylor (1980) and Fischer (1977). A key difference is that price-setting is based on optimisation by individual firms subject to constraints on the frequency of price adjustment. Aggregating across the decision rules of firms then leads to an aggregate Phillips curve relation.

This kind of approach, as we will see below, leads to a relationship between inflation and marginal cost as opposed to inflation and the output gap. However, Rotemberg and Woodford (1997) have shown that, under certain restrictions on technology, within the neighbourhood of the steady state, real marginal costs are proportionately related to the output gaps. This leads to the standard New Phillips Curve formulation:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa\ (y_t - y_t^*) \qquad \textbf{(3)}$$

As shown by Galí and Gertler (1999), for the United States, and Galí, Gertler and López-Salido (2000), for the euro area, this formulation of the New Phillips Curve breaks down when applied to data.[8] This is probably due to the assumed proportionate link between real marginal costs and the output gap. As Galí, Gertler and López-Salido (2000) demonstrate, this link is unlikely to hold if there are labour market frictions, either in the form of real or nominal wage rigidities. For example, they show that if $\mu_w$ is the wage mark-up, then the New Phillips Curve should be:

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda \; \widehat{\mu}_t^w + \kappa \; (y_t - y_t^*)$$

This illustrates another problem with traditional Phillips curves estimates — the focus on output gaps as opposed to marginal costs. Even if we do get a reliable measure of the output gap, this may still lead to under or overprediction in Phillips curve estimates, if the wage mark-up varies a lot over the cycle. Variations in the wage mark-up will be the focus of the last section of this paper.

We follow Sbordone (2002), Galí and Gertler (1999) and Galí, Gertler and López-Salido (2000) and use Calvo's model (1983) of staggered price-setting. We only summarise the model and the derived aggregate equations here, as the main derivations have been covered in the aforementioned papers.[9]

### *4.1 Baseline model*

Firms are monopolistic competitors who set prices in staggered fashion based on the expected path of future marginal costs. Aggregating across the price-setting behavior of individual firms yields the inflation equation:

$$\pi_t = \beta \; E_t\{\pi_{t+1}\} + \lambda \; \widehat{mc}_t \qquad \textbf{(4)}$$

where $\widehat{mc}_t$ is average real marginal cost (in per cent deviation from its steady-state level). The slope coefficient $\lambda$ depends on primitive parameters of the model. In particular $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$, where $1-\theta$ is the frequency of price adjustment and $\beta$ is the subjective discount factor. Iterating equation **(4)** forward we obtain:

$$\pi_t = \lambda \; E_t \sum_{k=0}^{\infty} \beta^k \; \widehat{mc}_{t+k} \qquad \textbf{(5)}$$

In other words, the measure of inflation pressure stemming from real sector activity is a

(8) In general $\kappa > 0$ in Phillips curve estimates. Yet if we note that $\beta \approx 1$, it is clear that the New Phillips Curve formulation with output gaps implies that $\kappa < 0$.
(9) Wolman (1999) has argued that the Calvo specification leads to implausibly sticky prices. Further, he suggests that incoporating features such as: overhead labour, labour adjustment costs and variable capital utilisation would increase the empirical viability of sticky-price models. The analysis, in Section 4.3, suggests that such extensions make very little difference to the results.

discounted stream of expected real marginal costs. Intuitively, because firms' prices may be locked in for a period of time, firms set prices based on the expected future path of marginal costs. Because not all firms are changing price at the same time, the movement in marginal costs affects the rate of inflation, as opposed to the price level.

### *4.2 Hybrid model*

Equation **(4)** is the baseline relation for inflation that we estimate. An alternative to equation **(4)** is that inflation is principally a backward-looking phenomenon, as suggested by the strong lagged dependence of this variable in traditional Phillips curve analysis (see Fuhrer and Moore (1995)). To allow for this, we follow Galí and Gertler (1999) and consider a hybrid model that allows a fraction of firms to use a backward-looking rule of thumb. All firms continue to reset price with probability $1-\theta$. However, only the fraction $1-\omega$ reset prices optimally, as in the baseline Calvo model. The remaining fraction $\omega$ choose the price $p_t^b$ (in logs) according to a simple backward-looking rule of thumb, given by:

$$p_t^b = p_{t-1}^* + \pi_{t-1}$$

where $p_{t-1}^*$ is the average reset price in $t-1$ (across both backward and forward-looking firms). Backward-looking firms see how firms set prices in the last period and then make a correction for inflation, using lagged inflation as the predictor.

Since we are following Galí and Gertler (1999), we simply report the resulting hybrid version of the marginal cost based Phillips curve:

$$\pi_t = \gamma^b \pi_{t-1} + \gamma^f E_t\{\pi_{t+1}\} + \lambda_1 \widehat{mc}_t \qquad \textbf{(6)}$$

with

$$\lambda_1 \equiv (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1} \quad ; \quad \gamma^b \equiv \omega\phi^{-1} \quad ; \quad \gamma^f \equiv \beta\theta\phi^{-1} \qquad \textbf{(7)}$$

where $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$.

Those interested in the derivation are referred to Galí and Gertler (1999). Note that the hybrid model nests the baseline model in the limiting case of no backward-looking firms (ie $\omega = 0$).

### *4.3 Econometric specification: marginal cost estimates*

To estimate equation **(6)**, we first need to obtain a measure of real marginal cost. We consider various production functions to generate different measures of marginal cost. We consider: a simple Cobb-Douglas production (c-d); a c-d with overhead labour, a c-d with labour adjustment costs and a CES production function. We derive the marginal cost for the Cobb-Douglas case below and document the other cases in the appendix.

Let $Y_t$ be output, $Z_t$ be technology, $K_t$ capital and $N_t$ total labour.

Thus output is given by:

$$Y_t = Z_t K_t^{\alpha} N_t^{1-\alpha} \qquad \textbf{(8)}$$

Real marginal cost is given by the ratio of the wage rate to the marginal product of labour, ie, $\psi_t = \frac{W_t}{P_t} \frac{1}{\frac{\partial Y_t}{\partial N_t}}$. Hence, given equation **(8)**, we have:

$$\psi_t = \frac{\frac{W_t}{P_t}}{(1-\alpha)\frac{Y_t}{N_t}} = \frac{s_t^n}{1-\alpha}$$

where $s_t^n \equiv \frac{W_t N_t}{P_t Y_t}$ is the labour income share (equivalently, real unit labour costs). This implies that:

$$\widehat{mc}_t = \widehat{\psi}_t = \widehat{s}_t^n \qquad \textbf{(9)}$$

where $\widehat{}$ implies percentage deviation from steady state.

In Chart 8, we plot real marginal costs under the different production functions. There are few differences to the evolution of real marginal costs for the United Kingdom between the different scenarios. As expected, this implies that the results change very little with different production functions and thus we simply present the results for a Cobb-Douglas specification.

Combining equations **(6)** and **(9)** yields the following econometric specification for inflation:

$$\pi_t = \gamma^b \pi_{t-1} + \gamma^f \pi_{t+1} + \lambda_1 \widehat{s}_t^n + \varepsilon_{t+1} \qquad \textbf{(10)}$$

where $\varepsilon_{t+1} = E_t\{\pi_{t+1}\} - \pi_{t+1}$, which under rational expectations, is uncorrelated with information available at time $t$. It follows that variables dated $t$ and earlier are valid instruments for estimation of equation **(10)**. In addition $\lambda_1$, $\gamma^b$ and $\gamma^f$ must satisfy the restrictions given in equation **(7)**.

All data are quarterly time series over the sample period 1970:1-1999:3. To measure inflation we use the GDP deflator. We measure real marginal cost as the log of the labour income share, in a way consistent with **(9)**. Hence, we use the log deviation of the labour income share, from its mean, as a measure of $\widehat{mc}_t$. Finally, we use log of GDP detrended with a quadratic trend to measure the output gap.

Chart 9 displays our measure of marginal cost, together with that of inflation, for the United Kingdom. From the picture, there seems to be some relationship in that the variables seem to move in the same direction and the timings of the peaks coincide. But the ordering, over the peaks, seems different — the highest peak for marginal cost is in the recession of the early 1990s, whereas for inflation it is immediately after the first oil price shock. There seems to be a de-coupling of the relationship after 1983. We will return to this problem later in the paper. Certainly the relationship does not seem as close as it is for the euro area, or the United States, as shown in Galí, Gertler and López-Salido (2000).

Next, we provide more formal tests — we estimate reduced-form versions of both the baseline and the hybrid model for the United Kingdom.

### *4.4 Reduced-form estimates*

Our approach to estimating equation **(10)** is relatively straightforward. First we discuss reduced-form estimates. In other words, we let the coefficients on $\widehat{mc}_t$, $\pi_t$, and $\pi_{t-1}$ be free and do not impose on $\lambda_1$, $\gamma^b$ and $\gamma^f$ the restrictions given in equation **(7)**. Let $\mathbf{z}_t$ denote a vector of variables observed at time $t$. Under rational expectations, **(10)** defines the set of orthogonality conditions:

$$E_t\{(\pi_t - \gamma^f \pi_{t+1} - \gamma^b \pi_{t-1} - \lambda\, \widehat{mc}_t)\, \mathbf{z}_t\} = 0$$

We then estimate the model using a generalised method of moments (GMM), based on the previous orthogonality conditions. Our vector of instruments $\mathbf{z}_t$ includes: four lags of inflation, the marginal cost, output gap, and wage inflation.[(10)] We estimate both the baseline model (ie where there is no term in $\pi_{t-1}$) and the hybrid version. The baseline inflation equation for the United

(10) We perform the Hansen (1982) chi-squared test, of the overidentifying restrictions, in all specifications discussed. The overidentifying restrictions are never close to being rejected in any of the specifications and thus we do not report the results here — they are available on request.

Kingdom is given by (standard errors in brackets):

$$\pi_t = \underset{(0.058)}{0.963}\ E_t\{\pi_{t+1}\} + \underset{(0.019)}{0.019}\ \widehat{mc}_t$$

The hybrid inflation equation for the United Kingdom is given by:

$$\pi_t = \underset{(0.100)}{0.843} E_t\{\pi_{t+1}\} + \underset{(0.018)}{0.020}\ \widehat{mc}_t + \underset{(0.076)}{0.103} \pi_{t-1}$$

Overall, the empirical model does not seem to fit particularly well. The slope coefficient on marginal cost is positive, as implied by the model but insignificant in both the baseline and hybrid model. Also, the estimate of the discount factor $\beta$ of 0.84 is a bit low, in the hybrid model, but is within the realm of reason, especially after taking into account the standard error.

The seeming lack of importance of real marginal costs confirms the suspicions outlined earlier, when discussing the relationship between real marginal cost and inflation, illustrated in Chart 9. In the next section, we use an alternative measure of the labour share and see if this makes a difference.

### *4.5 Robustness — an alternative measure of the labour share*

One explanation for the lack of significance of marginal cost could be the data used to construct it. In this section we estimate the New Phillips Curve model outlined above, with an alternative measure of the real marginal cost — the adjusted labour income share. The adjusted labour income share factors out the effect of the public sector. This is done by taking out the compensation of employees by the general government from self employed adjusted total compensation and factoring out general government resources from GDP at factor cost.(11) The idea behind this, is that the concepts of labour and capital shares may only make sense with regard to the market sector of the economy. In Chart 10 we compare our measure of marginal costs (measured as the real unit labour costs) with the adjusted labour income share and the inflation rate.

Over the total sample period the correlation between these two series is not very high: 0.69. Thus, it is straightforward to see that there are some differences affecting the short-term movements of these two measures. In particular, three comments are worth noting. First, our measure of marginal

(11) We are grateful to Nicoletta Batini, Brian Jackson and Stephen Nickell (BJN henceforth) for proposing this measure, and in particular to Brian Jackson for supplying data, which BJN are using in as yet unpublished work.

cost peaks in the early 1990s, while the adjusted labour income share peaks in the mid-1970s. Second, the two measures are closely related from the mid-1970s until the mid-1980s. In fact the sample correlation between the two measures, between 1976:1 and 1983:4, is 0.89, though it is still true that, after 1983, there is a clear de-coupling between the evolution of the adjusted labour income share and the inflation rate. The implications of this will become apparent below.

We proceed by estimating both the baseline model (ie where there is no term in $\pi_{t-1}$) and the hybrid version, using the adjusted labour income share as a proxy for the real marginal costs. The reduced-form equation for the forward-looking and hybrid model are respectively given by:

$$\pi_t = \underset{(0.058)}{0.830}\, E_t\{\pi_{t+1}\} + \underset{(0.034)}{0.080}\, \widehat{mc}_t$$

$$\pi_t = \underset{(0.092)}{0.657} E_t\{\pi_{t+1}\} + \underset{(0.029)}{0.082}\, \widehat{mc}_t + \underset{(0.063)}{0.161} \pi_{t-1} \qquad \textbf{(11)}$$

Now, contrary to our previous results, the new measure of the marginal cost is significant in both specifications. In addition, the lagged value of inflation is also significant although it is quantitatively less important than the forward-looking one.

Chart 11 plots the evolution of the point estimates, and the 95% confidence intervals, of the parameters $\lambda_1$ and $\gamma^b$ in the hybrid model. The values are the results of a rolling regression on the reduced-form equations, varying the terminal date from 1980:1 up to 1999:3. In particular, we observe that the value of $\lambda$ starts to fall from the end of the1980s, though it still remains significant. Again there is some evidence of a backward-looking inflation term.

#### *4.5.1 Fundamental inflation — a goodness of fit measure*

As noted above, with the adjusted measure of labour share as a measure of marginal cost, $\lambda$ becomes significant. This implies we can follow Galí and Gertler (1999) and compare the evolution of 'fundamental inflation' to actual inflation, to get a sense of the model's goodness of fit. As in Galí and Gertler (1999), fundamental inflation is the solution to the hybrid model difference equation in inflation, equation **(10)**. This is given by:

$$\pi_t = \delta_1 \pi_{t-1} + \left(\frac{\lambda_1}{\delta_2 \gamma_f}\right) \sum_{k=0}^{\infty} \left(\frac{1}{\delta_2}\right)^k E[\widehat{mc}_{t+k} | z_t]$$

where $\delta_1$ and $\delta_2$ are the stable and unstable roots, respectively, to equation **(10)**, and $z_t$ is the information set available at time $t$. To provide more intuition of what fundamental inflation really means, we consider an illustration for the basic forward-looking model:

$$\pi_t = \beta \, \pi_{t+1} + \lambda \, \widehat{mc}_t + \varepsilon_{t+1}$$

Fundamental inflation is obtained by iterating forward this equation:

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k \, E_t\{\widehat{mc}_{t+k}\} \equiv \pi_t^*$$

In other words, fundamental inflation $\pi_t^*$ is a discounted stream of expected future real marginal costs. To the extent that the baseline New Phillips Curve model is correct, and inflation depends on real marginal costs, fundamental inflation will capture the dynamics of inflation. Thus fundamental inflation can be seen as a measure of the model's goodness of fit. It is not a measure of core inflation, but simply an alternative way of measuring the models performance than looking at the $R^2$ statistic. A key question is how to measure the expected discounted stream of marginal costs. One way would be to forecast the discounted stream based on information available at time $t$:

$$\pi_t^* = \lambda \sum_{k=0}^{\infty} \beta^k \, E\{\widehat{mc}_{t+k} \mid \mathbf{z}_t\}$$

We choose our vector of instruments, $z_t$, to be the same as that used in the GMM estimation of the reduced-form model, ie based on current and past values of inflation, marginal cost, the output gap and wage inflation and used the reduced-form estimates of the hybrid model **(11)**. Chart 12 plots the evolution of fundamental and actual inflation. It is clear that the model has an overprediction problem from around 1989 on. This is caused by the de-coupling between inflation and marginal costs. Thus even though marginal costs are significant in the New Phillips Curve model with an adjusted labour share measure, the goodness of fit of the model is not very high.

## 5 Open-economy considerations in the New Phillips Curve

So far analysis of the New Phillips Curve for the United Kingdom has not been particularly encouraging. Depending on what data we use for the labour share, either marginal cost is not significant or the model does not fit the data very well, with a strong overprediction problem in the 1990s. This is in stark contrast to results for the euro area and United States (see Galí, Gertler and López-Salido (2000)). So far we have only used a closed-economy model to generate the New Phillips Curve. Yet, as pointed out when discussing the traditional Phillips curve, the United Kingdom is considerably more open than the United States or the euro area. This could be a key reason why the results for New Phillips Curve estimates for the United Kingdom are not good. In this section we explicitly take into account open-economy considerations and show how they affect the measure of marginal costs, or introduce an extra variable into the New Phillips Curve. We do this[12] by introducing imported intermediate goods into the production function.[13] This implies that movements in the real prices of imported materials constitute an independent source of variation in the marginal costs, which will be affected by movements in the exchange rate. Bentolila and Saint-Paul (1999) have stressed the importance of these movements to understand the dynamic of the labour income share. Nevertheless, their approach contrasts with the one taken in this paper. Those authors consider a perfectly competitive framework in the product market, while our approach is based upon a monopolistically competitive framework. This is a crucial difference in linking movements in the exchange rate and the marginal costs. In particular, we will show below that instead of the ratio of import prices to product prices being the relevant variable affecting the marginal costs, it is the evolution of relative costs — the ratio of import prices to wages — that is key. In a sense this addresses one of the key criticisms of DGI made in Section 3.2.3 — we are allowing for a substitution effect between externally produced inputs and domestic labour. We will discuss this in more detail below in Section 5.1.

### *5.1 The role of fluctuations in imported materials*

Movements in the exchange rate can fuel domestic inflation through its effect on import prices. In particular, there is an extensive literature that emphasises the pass-through from movements in the exchange rate to import prices and from import prices to domestic inflation. In Section 3.2.3, we noted how DGI may fail to fully strip out external factors, as it doesn't allow for substitution between the external goods sector and the domestic goods sector. In this section we allow for one such substitution channel that between intermediate imported goods and the domestic labour input. Below, we show how this new channel allows the evolution of import prices to affect our measure of marginal costs, and so the dynamics of inflation.

More formally, let us assume the following CES production function:

$$Y_t = F(N, M) = [\alpha_N (Z_t N_t)^{1-\frac{1}{\sigma}} + \alpha_M (M_t)^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$$

---

(12) We also consider a second approach, but only discuss it in Appendix B as the results are not substantially different to those previously reported; namely, an extension of the approach of Galí and Monacelli (2000). Those authors note that marginal cost can be redefined in terms of the real consumption wage and a relative price. The analysis of marginal cost and the wage mark-up in Section 4.6 was based on a similar approach. As can be seen from equation **(17)** the marginal cost now involves a relative price term, as Galí and Monacelli suggest. This relative price term can be shown to be a function of the real exchange rate and the tax wedge.

(13) This extension has been also pursued by Galí and López-Salido (2000) for the analysis of Spanish inflation.

where $M_t$ represents imported materials (ie intermediate goods), and $\sigma$ is the elasticity of substitution between the two inputs. From cost minimisation, we know that the following equilibrium condition holds:

$$\frac{N_t}{M_t} = \left(\frac{P_{M_t}}{W_t}\right)^{\sigma} \qquad \textbf{(12)}$$

where $P_{M_t}$ is the price of imported materials, and $W_t$ is the nominal wage. Following the analysis described in Appendix A for the case of a CES in labour and capital, under these circumstances the expression for the real marginal costs is:

$$mc_t = \frac{s_t}{1 - \kappa(\frac{Y_t}{M_t})^{\frac{1}{\sigma}-1}} \qquad \textbf{(13)}$$

Substituting expression **(12)** into expression **(13)**, and log-linearising the resulting expression, yields the following specification for real marginal costs:

$$\widehat{mc_t} = \widehat{s_t} + \phi(\widehat{p_{M_t} - w_t}) \qquad \textbf{(14)}$$

where $\phi = (\frac{1-\mu s}{\mu s})(\sigma - 1)$. Notice that now real marginal costs depend upon real unit labour costs and an additional term related to the relative price of the two inputs. The parameter $\phi$ determines how changes in the ratio of relative prices would translate into movements in marginal costs, and so therefore into inflation. When $\sigma > 1$, an increase in the prices of imported materials below the increase in the nominal wage will decrease the marginal cost.[14] Finally, it is worth pointing out that movement in the exchange rate would affect the evolution of the import prices, and so the dynamics of marginal costs.

In Chart 15 we plot the evolution of the ratio of prices $(\widehat{p_{M_t} - w_t})$ and domestic annual inflation (GDP deflator).[15] As the chart shows, there is a clear downward pattern in the relative price of inputs in parallel with disinflationary periods. This evolution suggests that this component can be an additional and independent source of movements in marginal costs that is relevant to understanding the evolution of UK inflation. We explore this further in Chart 16. Here, we compare the evolution of inflation with three different measures of marginal costs[16] corresponding to three values of the elasticity of substitution: $\sigma = 0.8$, $\sigma = 1$ (ie the Cobb-Douglas case), and $\sigma = 1.5$. A clear result emerges, namely that allowing for a high degree

(14) Notice that as $\sigma \to 1$ the production function becomes a Cobb-Douglas function and thus marginal costs become independent of the movements in the relative prices of labour and imported materials.

(15) Our measure of prices of imported intermediate inputs is based upon a combination of *The Economist* commodity price index and the Brent crude price up to 1989:4 and the Bank of England commodity series from 1990:1 onwards. The two series are spliced together. This composite variable is only available for the period 1975-99. Alternative definitions of this variable produce similar results.

(16) In this section we have reverted to using the original measure of the labour share. We have performed the same experiments with the adjusted labour share measure and the results are very similar — these are available on request.

of substitution between imported inputs and labour mitigates the de-coupling between marginal costs and inflation after 1983. In fact, allowing for the impact of the relative price of inputs affecting the marginal costs implies a clear co-movement between inflation and the latter variable. The intuition is that high wage inflation during the economic boom in 1988-90 was ameliorated by substitution into imported intermediate goods from labour. Since import goods inflation was lower than wage inflation in this period, this had a negative impact on marginal costs.

To explore in detail the importance of this casual evidence we perform the following experiment. We analyse how different values of the steadystate mark-up ($\mu$) and the elasticity of substitution ($\sigma$) will affect the estimates of the slope of the New Phillips Curve ($\lambda$). The sample period is now 1975:1-1999:3. The results are presented in Table A. These results confirm the previous intuition. The slope coefficient tends to be weakly significant once we allow for a high degree of substitution and/or steady-state mark-up. We consider the parameterisation corresponding to $\mu = 1.2$ and $\sigma = 1.3$ as our baseline model.

Chart 16 reports the reduced-form estimates of the forward-looking model using the previous parameterisation, to compute the real marginal costs. As shown the slope coefficient becomes weakly significant at the end of the sample period. Also, importantly, the estimate of $\lambda$ in Chart 17 is much more stable than when we do not take imported goods into account.

In Chart 18 we compute the corresponding fundamental inflation for the model with imported goods. Notice how the problem of overprediction since 1995 disappears — in fact fundamental inflation slightly underpredicts. But the model still overpredicts from around 1987-95. Also it tends to underpredict from 1977-80. This is remarkably similar to the story we presented with the Rudebusch-Svensson model earlier. In this case, though, we do not have such a problem of getting realistic estimates of the output gap, as we are using the labour share as a proxy for marginal cost, which is our forcing variable.

## 6 A decomposition of marginal costs: the role of the labour market

In this section we decompose the movement in real marginal cost in order to isolate the factors that drive this variable. We follow the analysis of Galí, Gertler and López-Salido (2000, 2001), but take into account the wedge between the consumption and product wage and the open-economy extension derived in Section 5. Our decomposition requires some restrictions from theory. Suppose the representative household has preferences given by $\sum_{t=0}^{\infty} \beta^t U(C_t, N_t)$, where $C_t$ is non-durable consumption and $N_t$ is labour, and where usual properties are assumed to hold. Without taking a stand on the nature of the labour market (eg competitive versus non-competitive, etc), we can without loss of generality express the link between the real wage and household preferences as follows:

$$\frac{W_t}{P_t}^* = -\frac{U_{N,t}}{U_{C,t}} \mu_t^w \qquad \textbf{(15)}$$

where $\frac{W_t}{P_t}^*$ is the consumption wage and $-\frac{U_{N,t}}{U_{C,t}}$ is the marginal rate of substitution between consumption and labour. Because the latter variable is the marginal cost to the household in consumption units of supplying additional labour, the variable $\mu_t^w$ is interpretable as the gross wage mark-up (in analogy to the gross price mark-up over marginal cost, $\mu_t$). Assuming that the household cannot be forced to supply labour to the point where the marginal benefit $\frac{W_t}{P_t}$ is less than the marginal cost $\frac{-U_{N,t}}{U_{C,t}}$, we have $\mu_t^w \geq 1$.

Conditional on measures of $\frac{W_t}{P_t}$ and $\frac{-U_{N,t}}{U_{C,t}}$, equation **(15)** provides a simple way to identify the role of labour market frictions in the wage component of marginal cost. If the labour market were perfectly competitive and frictionless (and there were no measurement problems), then we should expect to observe $\mu_t^w = 1$, ie the real wage adjusts to equal the household's true marginal cost of supplying labour. With labour market frictions present, we should expect to see $\mu_t^w > 1$ and also possibly varying over time. Situations that could produce this outcome include: households having some form of monopoly power in the labour market, staggered long-term nominal wage contracting, and informational frictions that generate efficiency wage payments. To measure the consumption wage, we simply deflate the AEI by the taxes and prices deflator (TPI), as opposed to the GDP deflator. The TPI includes the effects of indirect and direct taxes, which cause a wedge between the product and consumption wage and are not present in the GDP deflator, which excludes the effects of taxes and subsidies. Thus we set $\frac{W_t}{P_t}^* = \frac{W_t}{P_t^{TPI}}$.

Using equation **(15)** to eliminate the real wage in the measure of the labour share yields the following decomposition:

$$s_t = \frac{\left(W_t/P_t^{tpi}\right) P_t^{tpi}/P_t}{(Y_t/N_t)} = -\frac{(U_{N,t}/U_{C,t})}{Y_t/N_t} \mu_t^w \frac{P_t^{tpi}}{P_t} \qquad \textbf{(16)}$$

According to equation **(16)**, labour share is the product of three components: (i) the wage mark-up $\mu_t^w$, (ii) the ratio of the TPI to GDP deflator $\frac{P_t^{tpi}}{P_t}$ and (iii) the ratio of the household's marginal cost of labour supply to the average product of labour, $\frac{-U_{N,t}/U_{C,t}}{Y_t/N_t}$. We refer to this latter component as the ‘inefficiency wedge’, since it is a proportionate measure of output relative to the efficient level of output, ie the one corresponding to the frictionless competitive equilibrium. For our purposes, the key point is that when there are labour market frictions the labour share and thus the real marginal cost also depend on the wage mark-up, opening up a possible source of inertia.

The wage mark-up itself can be thought as similar to a preference shock. Indeed, Holland and Scott (1996) allow for a preference shock to the utility function of the representative household, such that one can get large variations in employment, but small variation in real wages. Holland and Scott find that the preference shock is critical to explaining a substantial part of UK employment fluctuations, though they also find that it is not truly exogenous. Looking at equation **(15)**, it is clear that the wage mark-up performs a similar role to Holland and Scott’s preference shock but with very different economic implications (see Galí, Gertler and López-Salido (2001)). Changes in $\mu_w$ account for changes in the relationship between consumption and employment, $-\frac{U_{N,t}}{U_{C,t}}$, which are not explained by changes in real wages. The substantial difference between $\mu_w$ and the Holland and Scott preference shock is that $\mu_w$ is neither assumed to be exogenous, nor a shock. We will see later that it is highly inertial and as we argued above probably reflects labour market frictions.

### *6.0.1 Separable preferences*

Assume that $U(C_t, N_t) = \log C_t - \frac{1}{1+\varphi} N_t^{1+\varphi}$, implying $U_{C,t} = \frac{1}{C_t}$ and $U_{N,t} = -N_t^{\varphi}$. Log-linearising equation **(16)** and substituting into equation **(14)** while ignoring constants, yields an expression for marginal cost and its components that is linear in observable variables (all in log terms):

$$\widehat{mc}_t = \widehat{\mu}_t^w + [(\widehat{c}_t + \varphi\,\widehat{n}_t) - (\widehat{y}_t - \widehat{n}_t)] + (\widehat{p}_t^{tpi} - \widehat{p}_t) + \phi(\widehat{p_{M_t} - w_t}) \qquad \textbf{(17)}$$

with

$$\widehat{\mu}_t^w = (\widehat{w}_t - \widehat{p}_t^{tpi}) - (\widehat{c}_t + \varphi\,\widehat{n}_t) \qquad \textbf{(18)}$$

where the parameter, $\varphi$, is the inverse of the elasticity of labour supply. Notice the difference the open-economy extension makes to the marginal cost decomposition — there is an extra term which reflects movements in the relative price of intermediate imported goods to domestic wages.

#### 6.0.2 *Non-separable preferences*

Some authors, see for instance Christiano, Eichenbaum and Evans (1997) and Dotsey, King and Wolman (1999), have advocated the importance of having no income effect in the labour supply to understand monetary business cycle models. In particular, those authors use the following specification for preferences:

$$U(C_{it}, N_{it}) = \log\left(C_t - Z_t \frac{1}{1+\varphi} N_t^{1+\varphi}\right) \quad \textbf{(19)}$$

this specification implies that the $MRS_t$ is independent on consumption. King and Wolman (1999) argue that $Z_t$ is a random preference shifter that also acts as a productivity shock.[17]

Thus, after taken logs, the wage mark-up is given by the following expression:

$$\widehat{\mu}_t^w = (w_t - \widehat{p}_t^{tpi}) - (z_t + \varphi n_t)$$

#### 6.0.3 *Results*

We now proceed to calculate the (log) wage mark-up for both specifications. As is apparent from equation **(18)**, to identify such a component of the marginal cost we need information on (non-durable) consumption per household, $c_t$, and employment per household $n_t$, as well as two variables we used earlier: the real wage $(w_t - p_t)$ and average labour productivity $(y_t - n_t)$. We take 10 as our benchmark value of parameter $\varphi$, implying a labour supply elasticity $(1/\varphi)$ of 0.1, in line with the microeconomic empirical evidence (see, for example, Pencavel (1986)).[18] $\phi$ is calibrated using values for the baseline open-economy model, namely $\mu = 1.2$ and $\sigma = 1.3$. Finally, $z_t$ is a measure of the productivity trend obtained from a regression of productivity on a time trend.

Charts 19 and 20 present the estimates of the wage mark-up and the marginal costs for the previous specifications of preferences and the evolution of the relative prices $(\widehat{p}_t^{tpi} - \widehat{p}_t)$ and $\phi(\widehat{p_{M_t} - w_t})$. As can be seen in Chart 19, the wage mark-ups are very similar in both cases. After the 1970s, the wage mark-up presents a clear business cycle pattern. In particular, it moves in opposite direction to the marginal costs which suggests the presence of important nominal wage rigidities affecting the dynamic of this variable. For instance, the increase in the wage mark-up

(17) This ensures the existence of a balanced growth.
(18) The results are not sensitive to values of the parameter $\varphi$ between 2 and 10.

during the recession of the early 1980s is consistent with the idea that workers change their expectations slowly in responses to changes in the economic conditions. This fits in with the conclusions of Holland and Scott (1996) namely that preference shocks are important, but predictable and not truly exogenous. They find that the preference shocks are predicted to a large degree by terms of trade variables, oil prices, money supply variables and the price level (see also Galí, Gertler and López-Salido (2001)).

From 1992 onwards there seems to be a downward trend in the wage mark-up, that may be related to the structural labour market reforms throughout the 1980s and early 1990s. Furthermore, this continuous fall in the wage mark-up since 1992 is consistent with some views that the United Kingdom has been on a new dynamic growth path and the shocks that cause this adjustment took place in or around 1992. Section 3.2.4 mentioned possible candidates for this catalyst: the adoption of inflation targeting; the exit of the United Kingdom from the ERM; the 1990-92 recession, which may have led to the kind of cleansing effects advocated by Caballero and Hammour (1994); and an increasing belief on the part of labour market participants that the structural reforms would not be reversed.

As Charts 19 and 20 illustrate clearly, neither the wage mark-up nor the relative price movements can explain the high marginal cost during the mid to late 1980s. Thus the high marginal cost during that period is obviously due to movements in the wedge. Chart 21, shows that the dynamics of the inefficiency wedge are highly pro-cyclical and move in the opposite direction to the wage mark-up. It seems that the boom of the late 1980s was the cause of a high inefficiency wedge and thus a high marginal cost.

Perhaps more importantly for the future behaviour of inflation, Chart 20 shows that both sets of relative price movements have had an increasingly negative impact on inflation since around 1987. Although the absolute size of the relative price effects are small relative to the size of the wage mark-up or the inefficiency wedge (see right-hand scales in Charts 19, 20 and 21), they are large relative to the size of overall marginal cost movements. The key question is how likely are they to remain such a strongly negative influence on marginal costs? Clearly, part of the negative impact of the relative import price term has been the strength of sterling through the 1990s, except in the immediate aftermath of sterling's exit from the ERM. Chart 20 shows a tick-up in the level of the relative import price term around the end of 1992 before it continues its downward trend. If sterling were to fall,[19] then there could be a pick-up in the relative import price term. This could lead to an increase in marginal costs. Conditional on the open-economy New Phillips Curve being a good description of the inflation process (and we have noted above that the fit is far from perfect), that could in turn put upward pressure on inflation.

## 7 Conclusions

This paper re-examines inflation dynamics in the United Kingdom. Our main motivation is the recent low inflation, low unemployment era in the United States, the United Kingdom and the euro area. This has led to standard specifications of traditional Phillips curves overpredicting inflation. This has been a major motivation for a 'New Phillips Curve' approach, which has had success for the United States and the euro area. The reason the United Kingdom is an interesting case to study is that it is a far more open economy than the United States or the euro area.

In this paper, we look at whether this could be a factor in explaining the overprediction problem in traditional Phillips curve estimates and whether it affects the performance of New Phillips Curve estimates. The paper is split in two parts. First, we document the overprediction problem for the United Kingdom and try solving it in a traditional Phillips curve framework — by introducing external shocks. We introduce external shocks by considering terms of trade shocks, or domestically generated inflation. We find that external shocks do not fully solve the overprediction problem. We further argue that there is a more general misspecification problem with traditional Phillips curve estimates, due to the presence of the regime changes and structural change in the UK economy.

Second, we look at New Phillips Curve estimates. They do not perform particularly well — real marginal cost is not significant in our baseline specification. Further investigation suggests the relationship between marginal cost and inflation broke down around the mid-1980s. We find that when we use a labour share measure adjusted for the public sector, real marginal cost becomes significant but the goodness of fit of the model based — on fundamental inflation — is still very poor.

Next, we extend our New Phillips Curve model to allow for open-economy influences. In

(19) This has been identified as a risk in, for example, Bank of England (2002).

particular, we take into account imported intermediate goods and varying mark-ups. We find that allowing for imported intermediate goods reduces significantly the de-coupling of inflation and marginal cost. Fundamental inflation performs better than previously, but still has a tendency to underpredict and then overpredict inflation — something also present in the traditional Phillips curve estimates.

Finally, we decompose the open-economy measure of marginal cost and see what can be learned about what is driving it. We find that a wage mark-up component is important and highly counter-cyclical. We also find that relative price movements, of taxes relative to overall prices and imported intermediate goods relative to wages, have been a negative influence on marginal costs over the 1990s. Understanding likely future developments in these relative prices could contribute to the assessment of prospects for marginal costs and thus pressures on inflation.

One possible reason why the open-economy New Phillips Curve still does not fit the data very well is the existence of time-varying desired mark-ups. In the models considered in this paper, the desired mark-up is assumed to be constant. Yet Rotemberg and Woodford (1991, 1999) regenerated interest in the importance of varying desired mark-ups. This is important to the extent that the mark-up varies cyclically and can be influenced by external factors. For example, recently there has been much speculation that the high level of sterling has forced manufacturers to cut their margins on exported goods. This is equivalent to a fall in the mark-up and will have a negative impact on inflation in the GDP deflator. Following Rotemberg and Woodford (1999), it is easy to show that the New Phillips Curve with variable mark-ups becomes:

$$\pi_t = \gamma^b \pi_{t-1} + \gamma^f E_t\{\pi_{t+1}\} + \lambda_1 \widehat{mc}_t + \lambda_1 \widehat{\mu}_t \qquad \textbf{(20)}$$

where $\mu_t$ is the desired log mark-up of price over marginal cost at time $t$. Previously, when we log-linearised the pricing equation around its steady state, the mark-up dropped out as it was assumed constant. Could this help explain the overprediction of inflation inherent in Chart 18? Two possible stories could be:

1) The late 1980s were a period of strong economic growth. A combination of large wage increases and a rising real exchange rate for sterling could have forced firms to cut their margins temporarily, so exports would be competitive abroad, and their products aimed at the domestic market could compete with cheaper imports. This idea fits well in a customer market model, along the lines of Britton, Larsen and Small (2000). In a customer market model, firms are assumed to

be monopolistically competitive, and set their own mark-up taking the mark-up of other firms as given. However, there is a dynamic element to the firm's problem in that higher relative prices reduce market share. In addition, some consumers are assumed to pay a cost when switching from one firm to another. This kind of model provides a justification for firms to allow the desired mark-up to vary, in the short term, in order to stop the long-term loss to profitability of losing customers. It may also be a key factor that exporters take into account by allowing margins to vary in reaction to changes in exchange rates, rather than the foreign price of the exported good.

2) The effect of the Single Market Act in 1986 was to remove internal barriers within the European Union and thus increase product market competition facing UK firms over time. Both factors would reduce the desired mark-up and thus potentially explain the overprediction of actual inflation by fundamental inflation. We plan to look at this in greater detail in future work.

**Appendix A: Derivation of various marginal cost measures**

The purpose of this appendix is to derive alternative measures of firm's marginal costs. In this case, the real marginal costs, $mc_t$, (ie the inverse of the mark-up) is given by: $mc_t = \frac{\omega_t}{F_{N_t}}$, where $\omega_t$ is the real wage and $F_{N_t}$ is the partial derivative of the production function (ie of output) with respect to labour. Under the previous assumptions, the real marginal costs can be expressed as follows:

$$mc_t = \frac{\omega_t}{F_{N_t}} = \frac{s_t}{\gamma_t}$$

where $s_t$ is the labour income share, and $\gamma$ is the elasticity of output with respect to labour. In log-deviations from steady state ($mc = \frac{1}{\mu} = \frac{s}{\gamma}$, where $\mu$ is the steady-state mark-up), the previous expression is just:

$$\widehat{mc_t} = \widehat{s_t} - \widehat{\gamma}_t \qquad \textbf{(A-1)}$$

The benchmark case used in this paper is based upon the assumption of no adjustment costs, and a Cobb-Douglas production function (ie $Y_t = F(K, N) = Z_t K_t^{1-\alpha} N_t^{\alpha}$). In this case, $\gamma_t = \alpha$, thus expression **(A-1)** collapses to: $\widehat{mc_t} = \widehat{s_t}$.

Assuming a CES production function: $Y_t = F(K, N) = [\alpha_k K_t^{1-\frac{1}{\sigma}} + \alpha_N (Z_t N_t)^{1-\frac{1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}$, the elasticity of output with respect to labour can be written as a function of the average productivity of capital ($YK_t \equiv Y_t/K_t$): $\gamma_t = 1 - \kappa (YK_t)^{\frac{1}{\sigma}-1}$. Log-linearising around steady state this yields to: $\widehat{\gamma}_t = -\eta\, \widehat{yk_t}$, with $\eta = (\frac{1-\mu s}{\mu s})(\frac{1-\sigma}{\sigma})$. Using expression **(A-1)** we get:

$$\widehat{mc_t} = \widehat{s_t} + \eta\, \widehat{yk_t} \qquad \textbf{(A-2)}$$

We calibrate the model following Rotemberg and Woodford (1999). Thus, $s = 0.7$, $\mu = 1.25$, $\frac{1}{\sigma} = 2$, which implies a value of $\eta = 0.14$.

Rotemberg and Woodford (1999) also considers the case where technology is isoelastic in non-overhead labour: $Y_t = F(K, N) = Z_t K_t^{1-\alpha} (N_t - \overline{N_t})^{\alpha}$. In this case, $\gamma_t = \alpha \frac{N_t}{N_t - \overline{N}}$, and in log-deviations from the steady state: $\widehat{\gamma}_t = -\delta \widehat{n_t}$, where $\delta = \frac{\overline{N}/N}{1-\overline{N}/N}$, so the new expression for the marginal costs is:

$$\widehat{mc_t} = \widehat{s_t} + \delta \widehat{n_t} \qquad \textbf{(A-3)}$$

To calibrate the model we follow Rotemberg and Woodford (1999) using a zero profit condition in steady state. In particular, it can be shown that the ratio of average costs to marginal costs can be written as follows: $\frac{AC_t}{MC_t} = [\chi + \alpha(\frac{\overline{N}}{N_t - \overline{N}})]$. This implies the following steady-state relationship: $AC = \frac{\chi}{\mu} + \frac{\delta}{1+\delta}s$. Non-negative profits require $AC_t \leq 1$, implying that $0 \leq \delta \leq \frac{\mu - \chi}{\chi - \mu(1-s)}$. We calibrate $\delta$ in expression **(A-3)** following Rotemberg and Woodford (1999). Under zero profits, and using that $s = 0.7$, $\mu = 1.25$, and $\chi = 1$ this implies $\delta = 0.4$.

Finally, we consider the effect of having costs of adjusting labour. These costs take the form: $U_t N_t \phi(N_t/N_{t-1})$, where $U_t$ is the price of the input required to make the adjustment. In this case, the real adjustment costs associated with hiring an additional worker for one period is given by:

$$(U_t/P_t)\{\phi(N_t/N_{t-1}) + (N_t/N_{t-1})\phi'(N_t/N_{t-1})\} - E_t[q_{t,t+1}\{(U_{t+1}/P_{t+1})(N_{t+1}/N_t)^2\phi'(N_{t+1}/N_t)\}]$$

letting $\zeta_t \equiv \frac{q_{t-1,t}(U_t/P_t)}{(U_{t-1}/P_{t-1})}$, and $g_{N_t} \equiv (N_t/N_{t-1})$, we can approximate the previous expression by:

$$(U_t/P_t)\phi''(1)\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\}$$

Assuming that the ratio $U_t/W_t$ is stationary, the real marginal costs are given by:

$$mc_t = (\frac{s_t}{\gamma_t})[1 + (U/W)\phi''(1)\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\}]$$

which, in terms of deviations from steady state yields

$$\widehat{mc_t} = \widehat{s_t} - \widehat{\gamma}_t + \xi\{\widehat{g_{N_t}} - \zeta E_t[\widehat{g_{N_{t+1}}}]\} \quad \textbf{(A-4)}$$

where $\xi = \mu^{-1}(U/W)\phi''(1)$. Under the assumption that the employment follows a random walk, then

$$\widehat{mc_t} = \widehat{s_t} - \widehat{\gamma}_t + \xi\{\widehat{g_{N_t}}\}$$

## Appendix B: Extension of the Galí-Monacelli open-economy model

As discussed in Section 4.3, in a closed-economy framework, real marginal cost is given by the ratio of the wage rate to the marginal product of labour, ie $mc_t = \frac{W_t}{P_t}\frac{1}{\frac{\partial Y_t}{\partial N_t}}$, where $P_t$ corresponds to an index of domestic goods prices, ie the GDP deflator in our previous estimates. Nevertheless, Svensson (1999) and Galí and Monacelli (2000) argue that there is a simple relationship between this measure of marginal costs and the terms of trade (and so on the real exchange rate). We extend their analysis to take into account the affect of taxes. More formally, as shown in Section 4.6 and illustrated in equation **(17)**

$$\widehat{mc_t} = \left[(\widehat{\omega}_t - \widehat{p}_t^{tpi}) - (\widehat{y}_t - \widehat{n}_t)\right] + (\widehat{p}_t^{tpi} - \widehat{p}_t)$$

Now if $p$ included the same taxes as $p^{tpi}$ and truly reflected only domestic prices, we could argue that $(\widehat{p}_t^{tpi} - \widehat{p}_t)$ is the real price of imported goods, and thus can be expressed as a function of the terms of trade. That is, it would be straightforward to show that the following relationship holds: $(\widehat{p}_t^{tpi} - \widehat{p}_t) = \rho\widehat{tot}_t$, where $\widehat{tot}_t$ represents the log-linearisation of the terms of trade, ie the price of foreign goods in terms of domestic goods, and $\rho$ is the fraction of domestic consumption allocated to imported goods. But since we measure $p$ as the GDP deflator at factor cost, which is not a pure measure of domestic prices (it includes export prices) and it excludes any tax effects, whereas $p^{tpi}$ includes both direct and indirect taxation, this relationship does not hold. Instead we could argue that $(\widehat{p}_t^{tpi} - \widehat{p}_t) \approx \rho\widehat{tot}_t + \widehat{t}$, where $t$ is the tax wedge. Notice that it is very simple to relate the terms of trade with the real exchange rate ($rer$) as follows: $\widehat{rer}_t = (1-\rho)\widehat{tot}_t$. Using both relationships, the real marginal costs are a function of the real exchange rate and the tax wedge, and the new expression for the inflation is:

$$\begin{aligned}\pi_t &= \beta\, E_t\{\pi_{t+1}\} + \lambda\, \widehat{mc}_t = \beta\, E_t\{\pi_{t+1}\} + \\ &\quad \lambda\left[(\widehat{\omega}_t - \widehat{p}_t^{cpi}) - (\widehat{y}_t - \widehat{n}_t) + \frac{\rho}{(1-\rho)}\widehat{rer}_t + \widehat{t}\right]\end{aligned}$$

Two comments are in order. First, notice that a real depreciation fuels domestic inflation. Second, now the real wages are obtained in terms of TPI instead of the GDP deflator. This measure does not correspond to the labour income share. We now proceed to estimate the parameter $\lambda$ given a calibration for the parameter $\rho$. In particular, we set the parameter $\rho = 0.3$. In the top panel of Chart 13, we plot our baseline measure of real marginal cost (labelled 'Closed' in the chart) against the new measure corrected by the movements of the terms of trade. In the bottom panel we compare the corrected measure of marginal costs against domestic inflation. Two comments are in order. First, over the 1990s, the real appreciation of the pound has led to a sharper reduction in the marginal costs. Even so, after 1983 there is still a clear decoupling between the dynamic of inflation and this measure of marginal costs. In Chart 14 we plot the reduced-form parameters of the model (for our baseline case $\rho = 0.3$) as well as the corresponding structural parameters, under both the hybrid and the forward-looking specifications. As in our previous estimates, the parameter $\lambda$ is weakly significant.

## Appendix C: Table

**Table C1**

**Estimates ($\lambda$)**

*Forward-looking model*

| | $\mu = 1.1$ | $\mu = 1.2$ | $\mu = 1.3$ |
|---|---|---|---|
| $\sigma = 0.9$ | 0.010<br>(0.015) | 0.012<br>(0.018) | 0.015<br>(0.020) |
| $\sigma \to 1$ | 0.020<br>(0.020) | 0.020<br>(0.020) | 0.020<br>(0.020) |
| $\sigma = 1.1$ | 0.038<br>(0.025) | 0.32<br>(0.023) | 0.027<br>(0.024) |
| $\sigma = 1.2$ | 0.043<br>(0.027) | 0.042<br>(0.026) | 0.034<br>(0.024) |
| $\sigma = 1.3$ | 0.025<br>(0.023) | 0.043<br>(0.027) | 0.040<br>(0.025) |
| $\sigma = 1.4$ | 0.013<br>(0.016) | 0.031<br>(0.025) | 0.044<br>(0.026) |
| $\sigma = 1.5$ | 0.008<br>(0.012) | 0.019<br>(0.020) | 0.043<br>(0.027) |

Note: Sample period 1975-98. The average labour income shares are set to be equal to 0.68 (we are grateful to BJN for this unpublished estimate). Instruments are four lags of each of inflation, detrended output, real unit labour costs and wage inflation.

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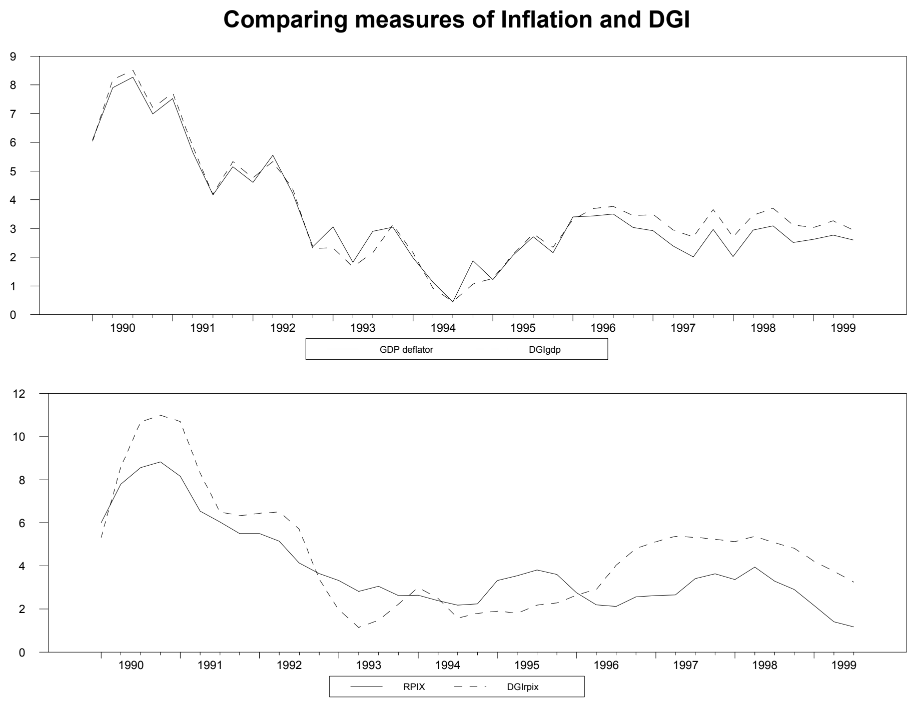
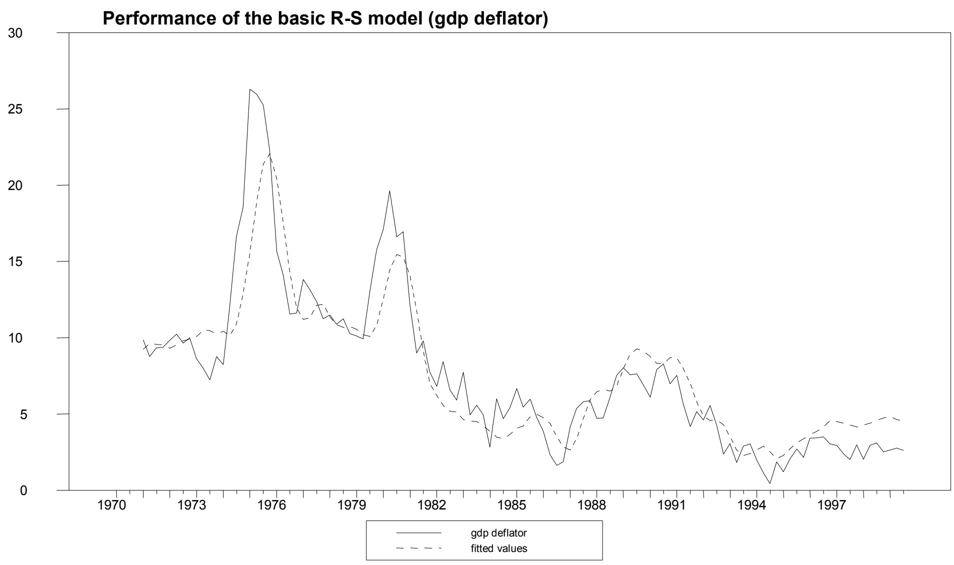
## Appendix D: Charts

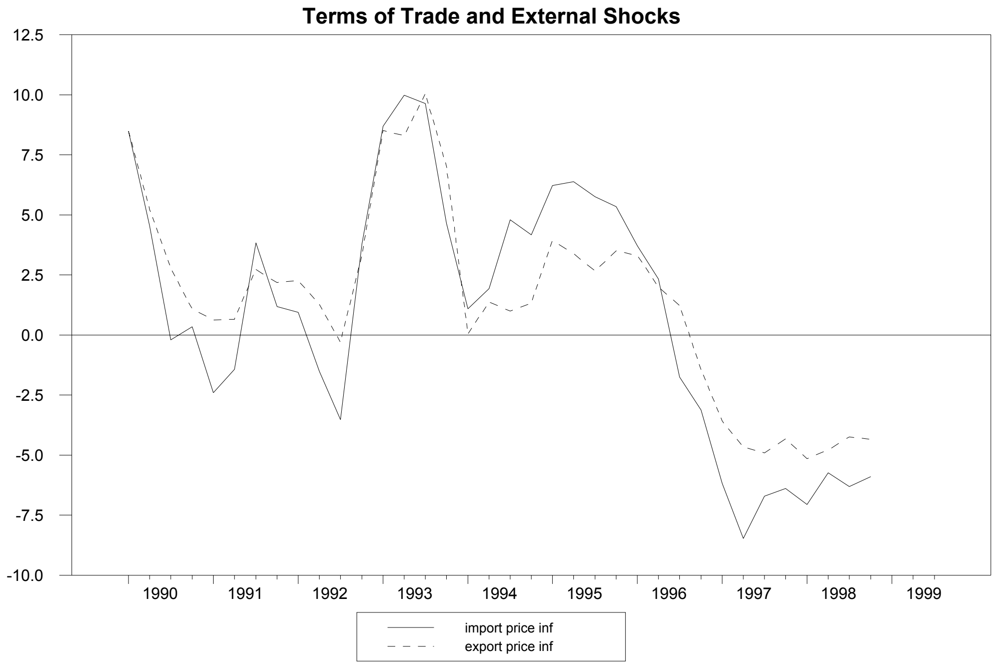
# Chart 1




# Chart 2



# Chart 3

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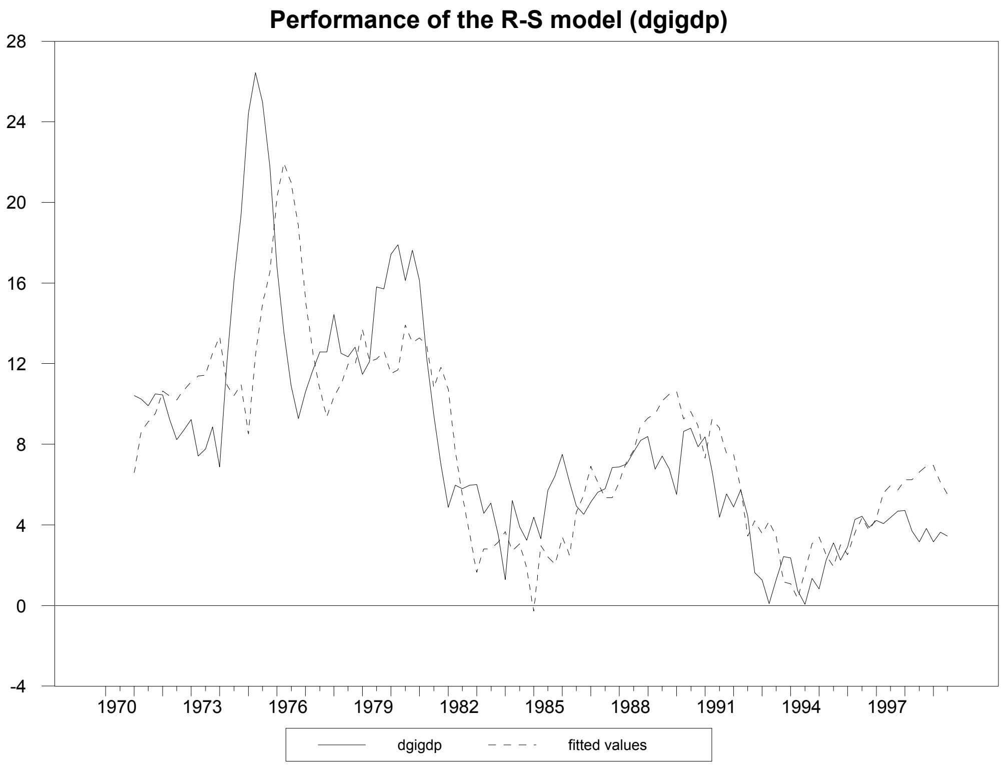

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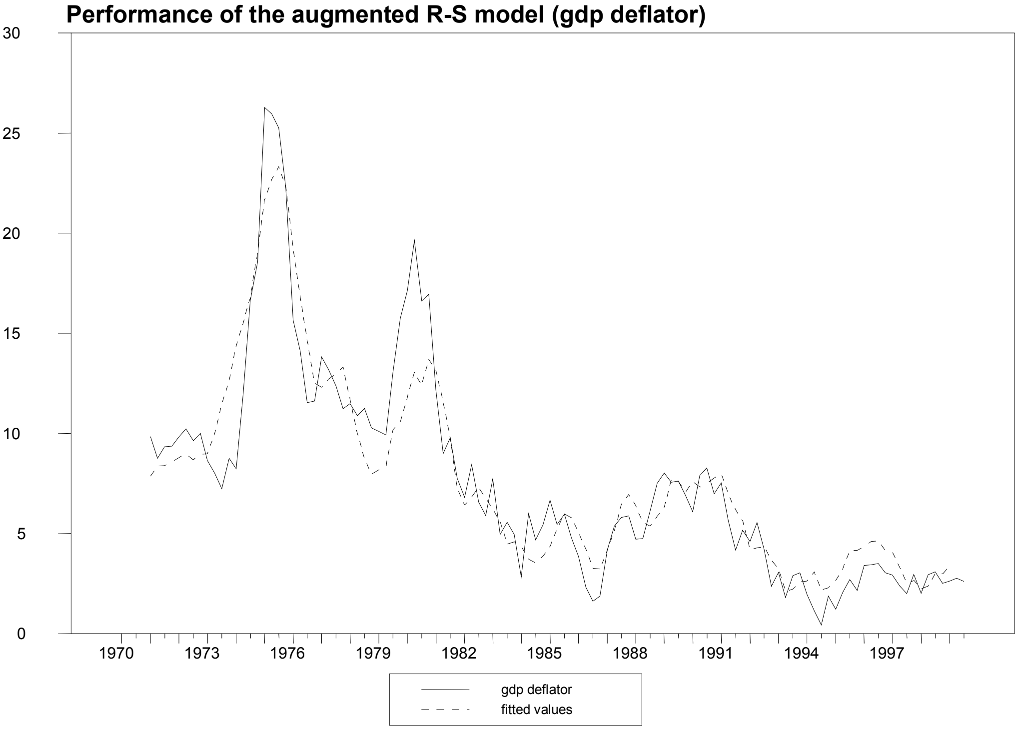
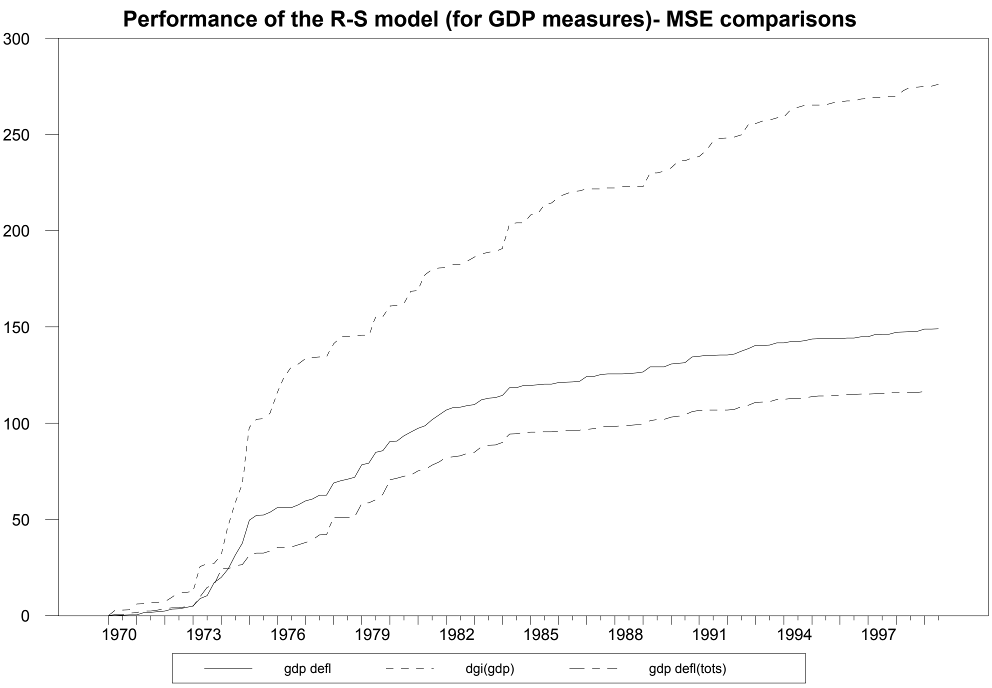



# Chart 6



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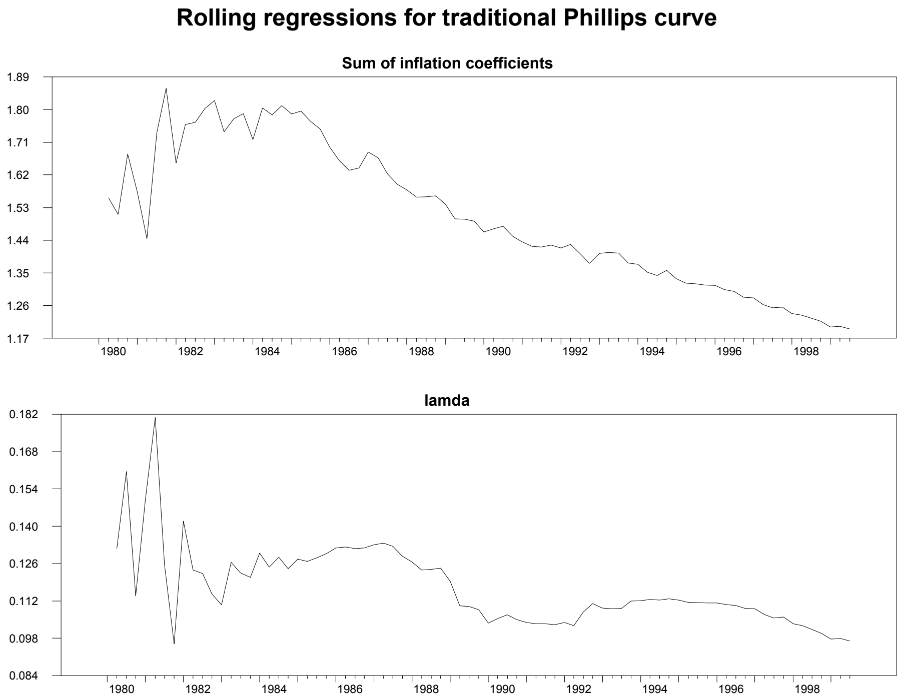
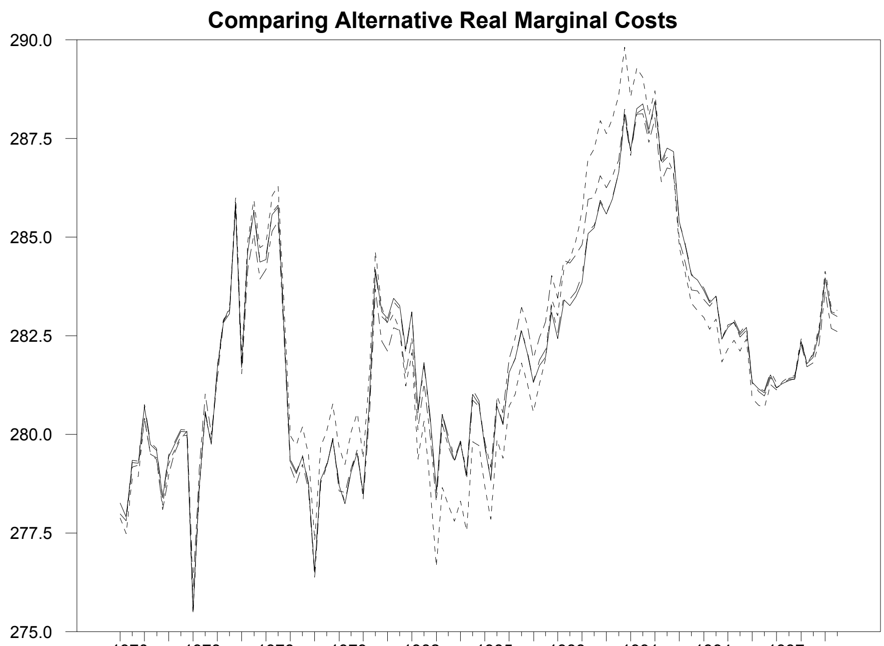
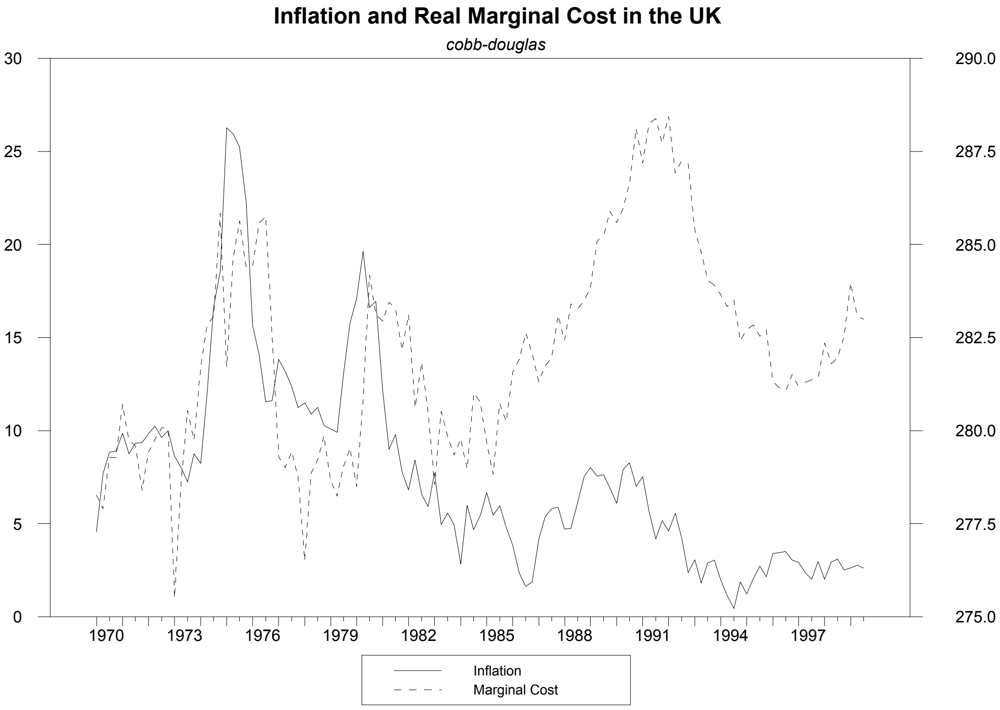



# Chart 8

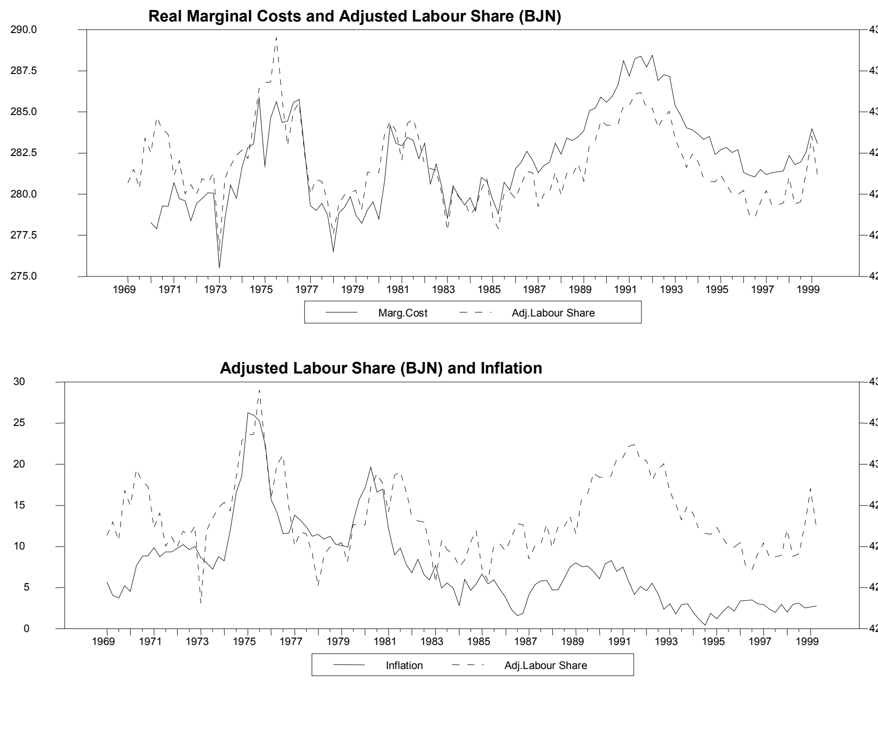


# Chart 9

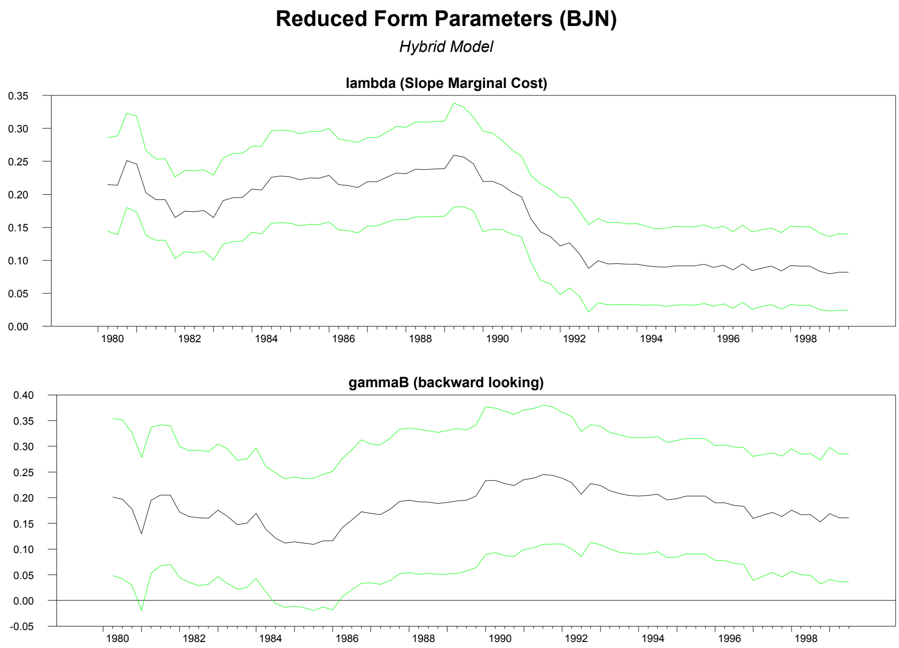



# Chart 10

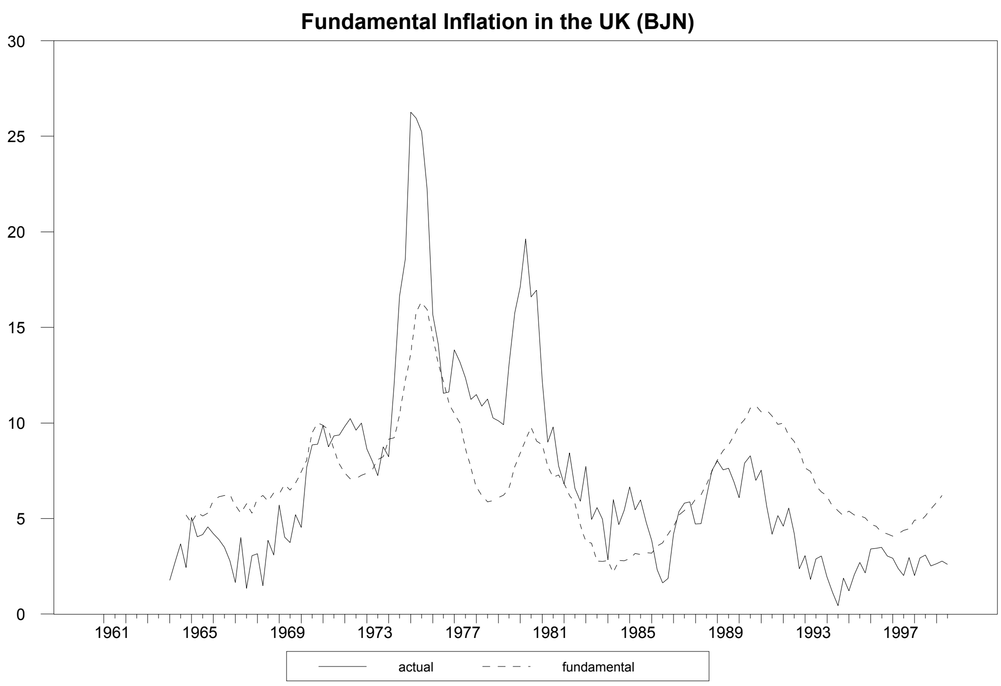
## Marginal Costs, Adjusted Labour Share (BJN) and Inflation



# Chart 11

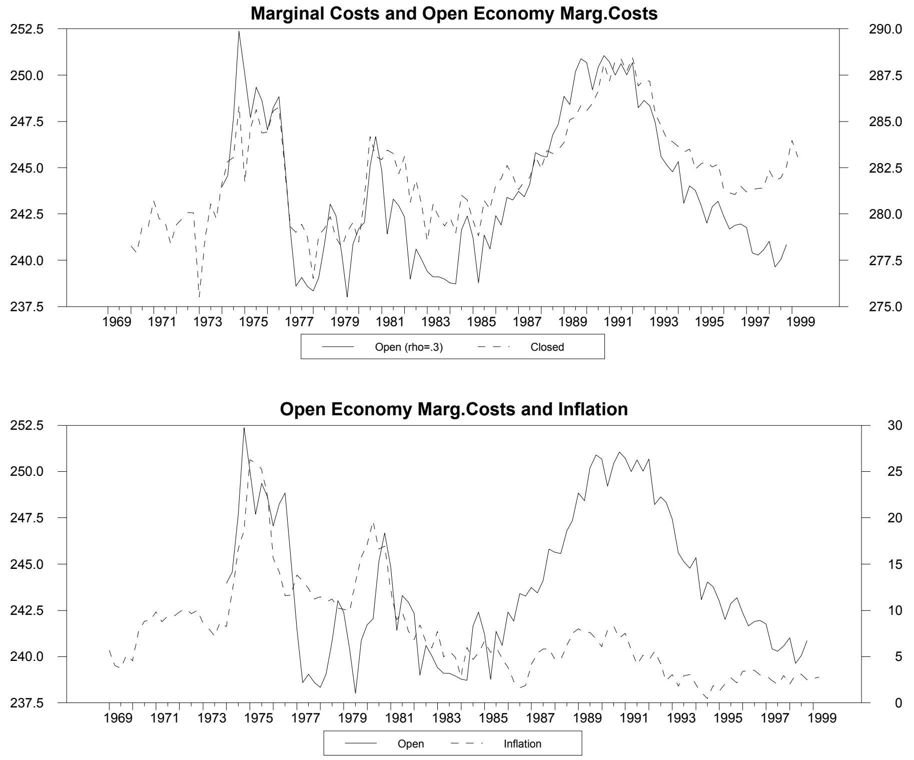



# Chart 12



# Chart 13

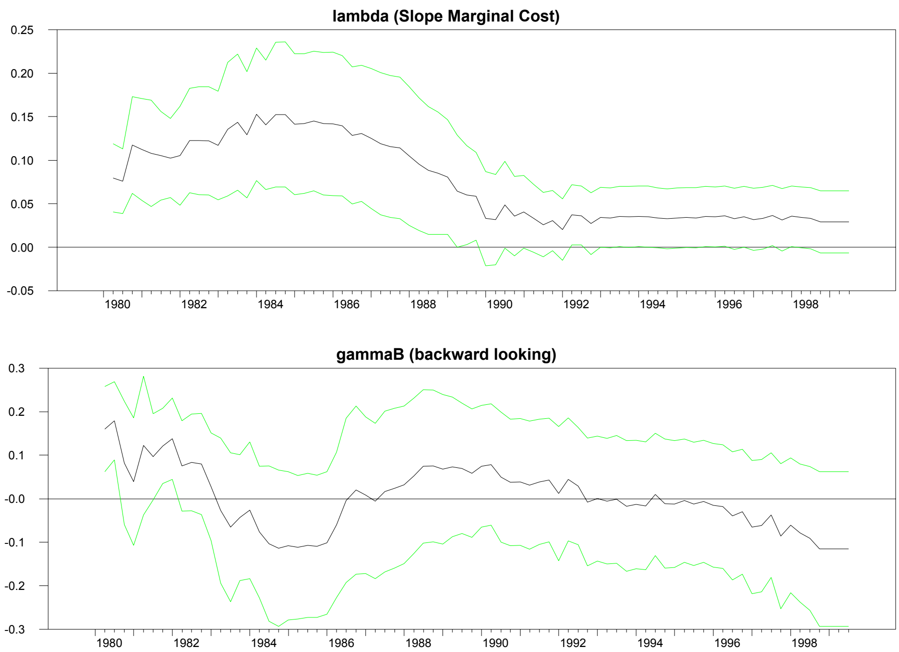
## Marginal Costs, Open Economy Marginal Costs and Inflation



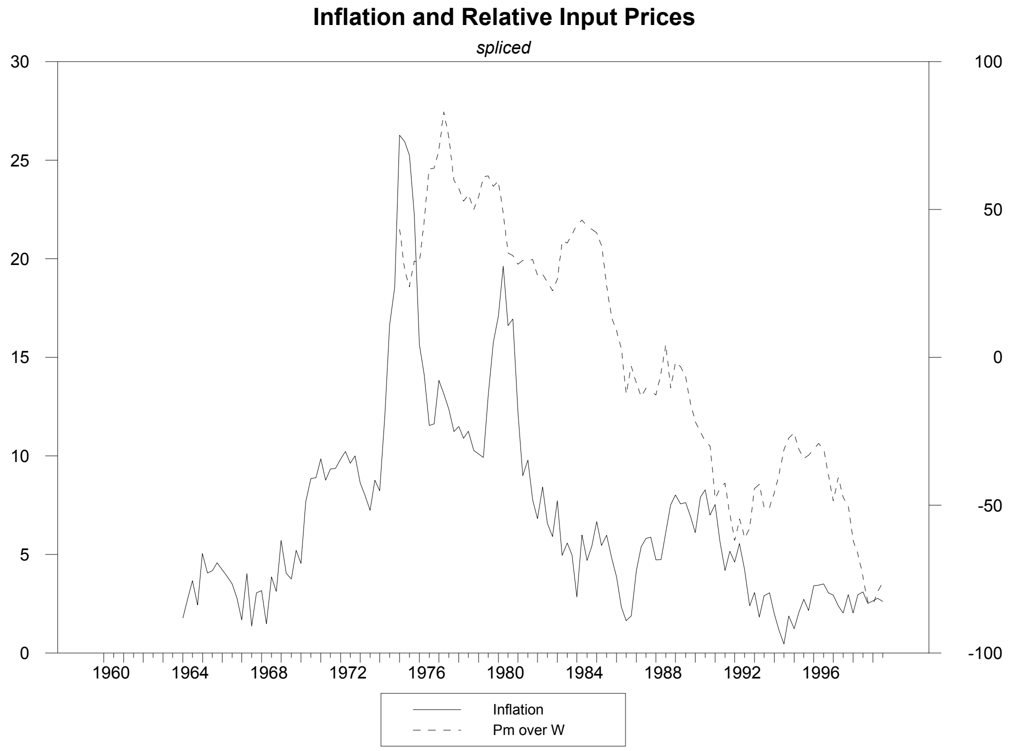

# Chart 14

## Reduced Form Parameters (Open Economy)

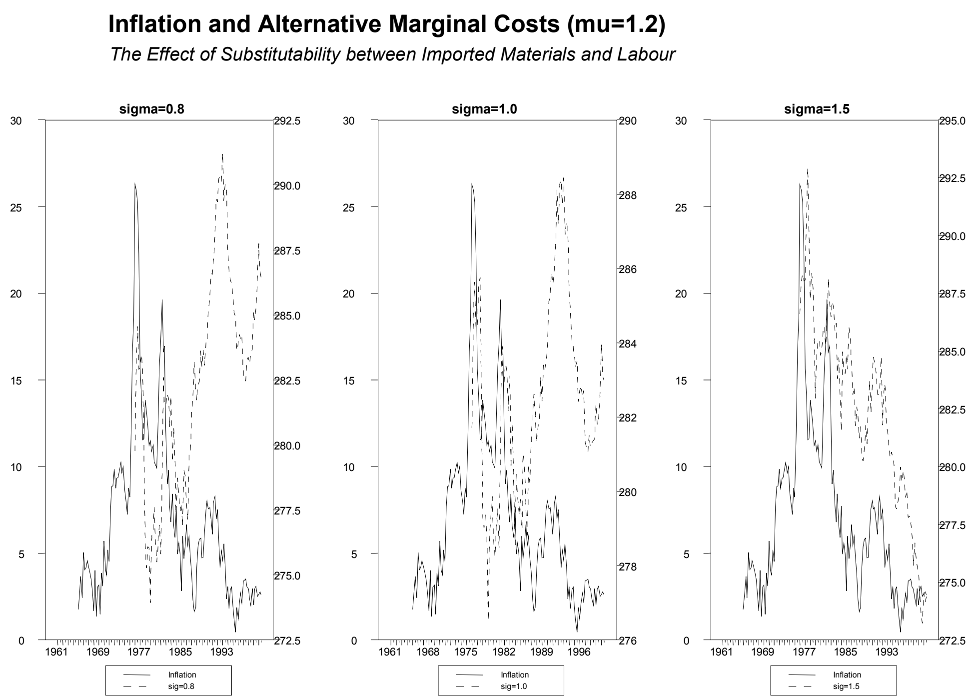
*Hybrid Model*



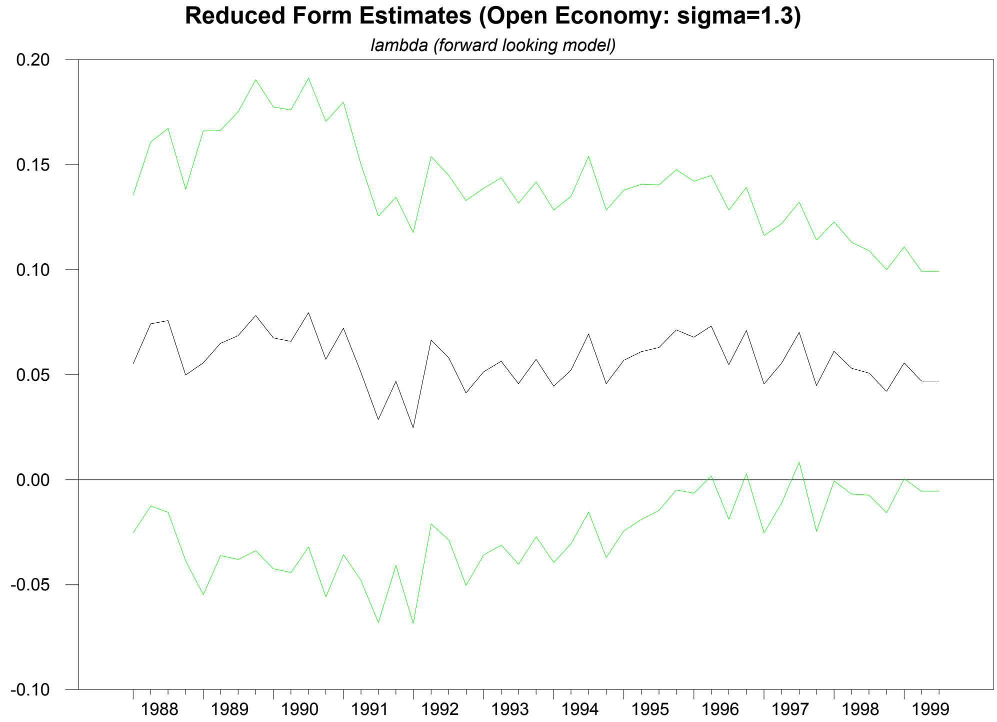
## Chart 15



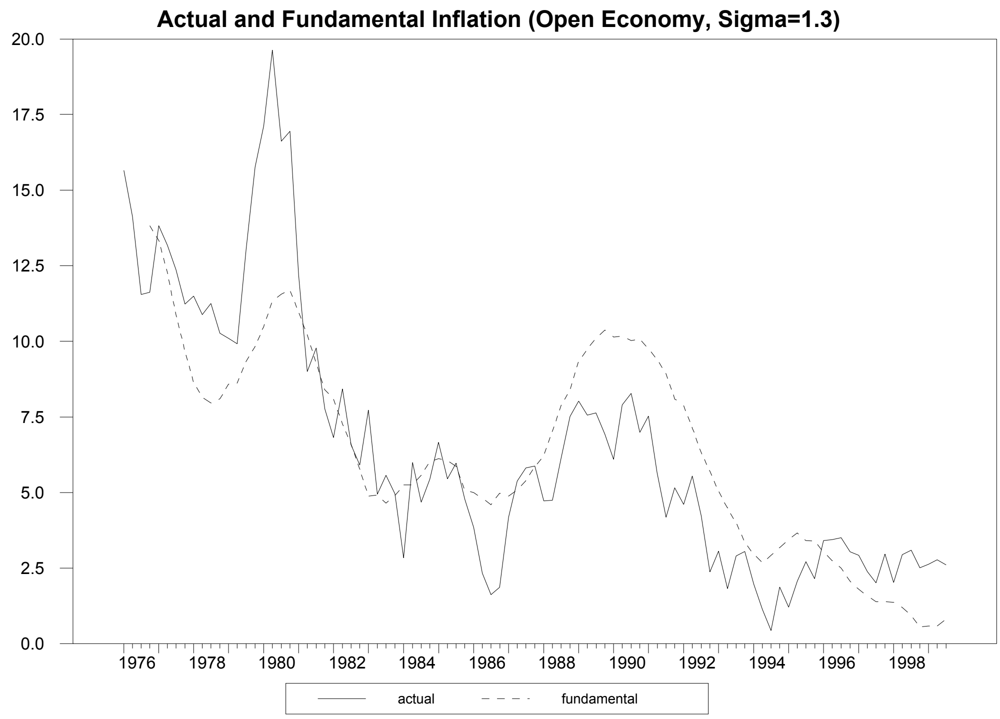

## Chart 16



# Chart 17

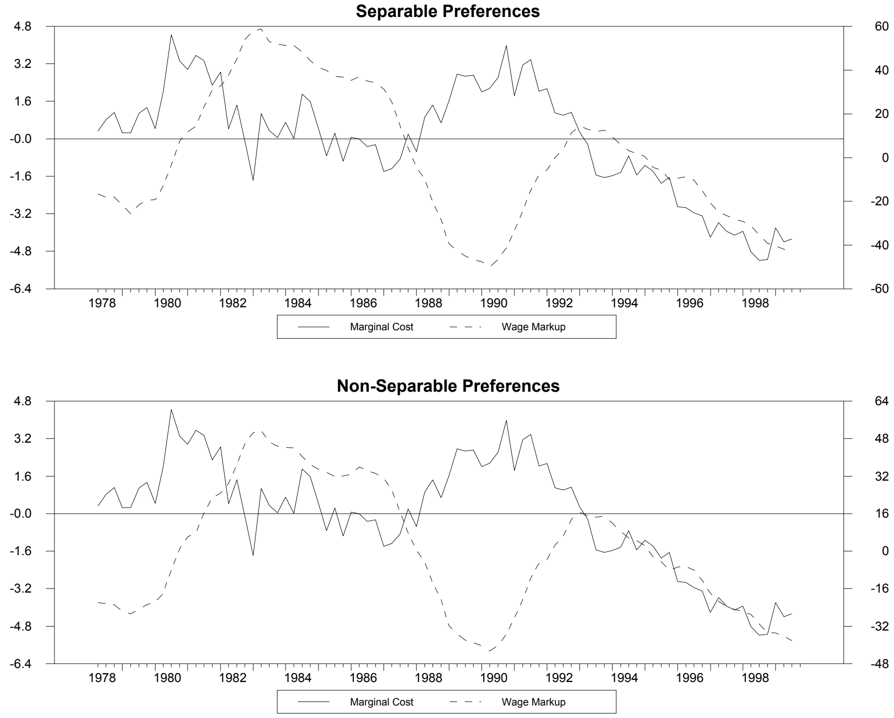



# Chart 18



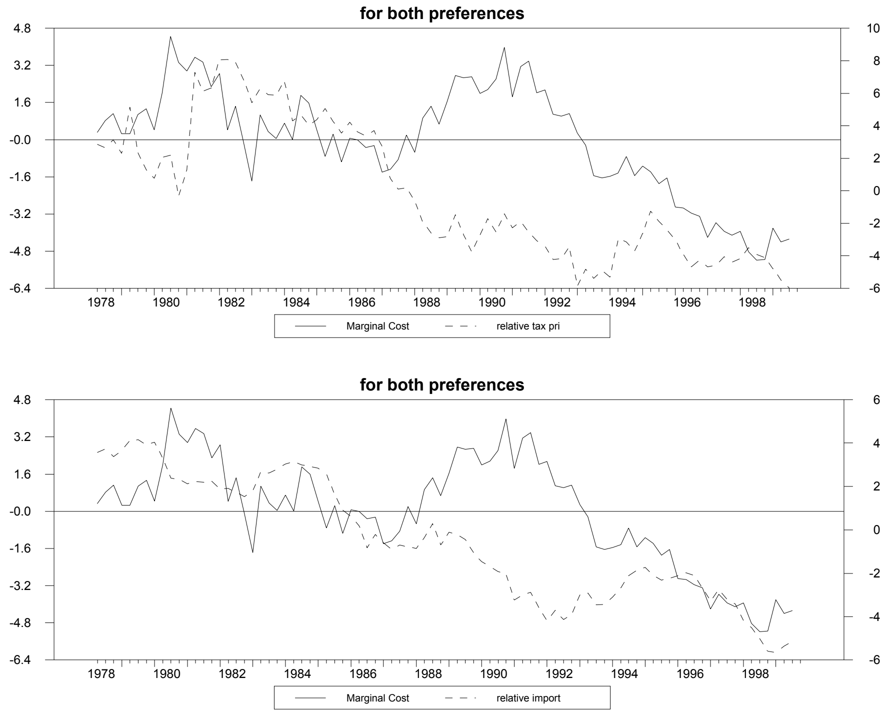
# Chart 19

## Marginal Cost and Wage Markup (phi=10.0)

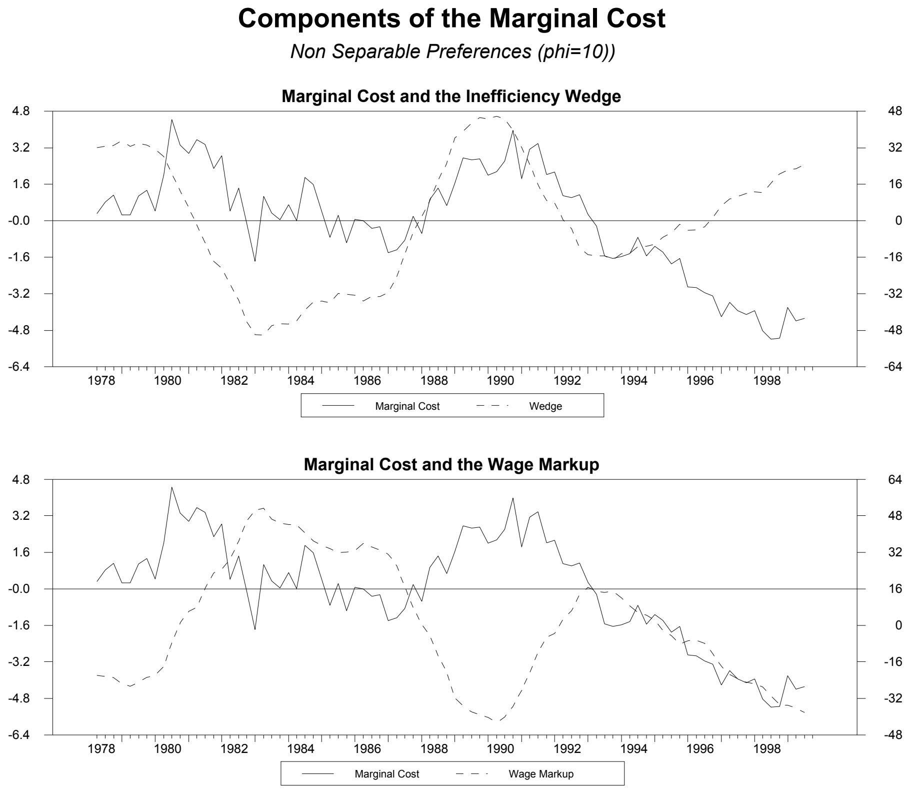



# Chart 20

## Marginal Cost and relative prices (phi=10.0)



# Chart 21



Components of the Marginal Cost
Non Separable Preferences (phi=10))
Marginal Cost and the Inefficiency Wedge
4.8
3.2
1.6
-0.0
-1.6
-3.2
-4.8
-6.4
48
32
16
0
-16
-32
-48
-64
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Marginal Cost
Wedge
Marginal Cost and the Wage Markup
4.8
3.2
1.6
-0.0
-1.6
-3.2
-4.8
-6.4
64
48
32
16
0
-16
-32
-48
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
Marginal Cost
Wage Markup