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Productivity Growth and Inflation: A Multi-Country Study

Vincent Hogan and Hongmei Zhao, University College Dublin

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Productivity Growth and Inflation: A Multi-Country Study

Hongmei Zhao[1]   Vincent Hogan

Abstract

Ball and Moffitt (2001) present a theory implying that the gap between productivity and wage aspirations can shift the traditional Phillips Curve. We examine their theory within the OECD. The results show that there is no clear cross country evidence for the theory. Although Ball and Moffitt's model works well in the U.S., it cannot, in general, be applied to other OECD countries. The time- varying NAIRU can better explain the economic performance for the OECD overall, and the UK in particular, during the late 1990s. In Germany, traditional Phillips Curve still kept its explanatory power during this period.

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[1] Corresponding author. Postal address: Institute of Economics, School of Economics, Nankai University, No.94 Weijin Road, Tianjin City, People's Republic of China. Postal Code: 300071. Email: hongmeizhao@nankai.edu.cn Tel: 0086-22-23503232. Fax: 0086-22-23503997.

Productivity Growth and Inflation: A Multi-Country Study

1. Introduction

The double decline of inflation and unemployment in U.S. at the end of 1990s has received a good deal of attention. Ball and Moffitt (2001) present a model to explain the favourable shift of the Phillips Curve by acceleration in productivity relative to wage claims. They point out that productivity grew faster than wage aspirations in the US during this period, so that the positive gap between productivity and aspirations generated deflationary pressure even as the unemployment rate was low. It has been also argued that the same process (with productivity lagging behind of wage aspirations) could explain the stagflation of the 1970s (see Grubb, et al. 1982).

Looking at the whole of the OECD, inflation and unemployment have exhibited a pattern similar to that of the U.S. As shown in Figure 1, both inflation and unemployment declined in the late 1990s in the OECD. The purpose of this paper is to ask whether this productivity explanation is robust for the US and, if so, whether it is also applicable to other OECD countries.

To study productivity in the OECD, we use panel data methods to estimate the Phillips Curve model with a new variable – the gap between productivity and wage aspirations (the "productivity gap"). The data for productivity and wage aspirations are constructed according to Ball and Moffitt (2001). If the addition of this new variable

improves the fit of the Phillips Curve during the late 1990s, we can say Ball and Moffitt (2001) can be generally applied to forecast inflation in OECD countries. However, there are other plausible explanations of the behaviour of inflation and unemployment in the late 1990s: positive supply shocks (Gordon, 1998; Lown and Rich, 1997) and a fall in the NAIRU (Gordon, 1997). We consider these possible alternative explanations for the behaviour of inflation and unemployment in the OECD.

In addition to the OECD overall, we study three single countries – the U.S, the UK and Germany. The reason is that, these countries had different productivity growth rates at the end of 1990s. Germany and the UK even experienced productivity slowdown. This provides the opportunity to investigate the effect of productivity gap in different situations.

The structure of this paper is as follows: after we introduce the data and methodology in section two, we investigate the failings of the traditional Phillips Curve in section three. The traditional Phillips Curve has systematically over-predicted inflation since 1996. In section four, we add the Ball and Moffitt (2001) productivity gap to the traditional model. Except for the US, this does not improve the fit over the traditional model. We then check the robustness of the role of productivity gap in the Phillips Curve by adding supply shock variable and the effect of time-varying NAIRU in sections five and six respectively. With these additional variables, productivity gap model always predicts inflation more precisely in the U.S, but this is not true in the OECD. The addition of the other variables makes the productivity gap model generate worse forecast results in the UK and Germany. Section seven concludes.

2. Data and Methodology

This paper is limited to the OECD member countries. Annual data for 19 OECD countries over 1961 – 2000 is available.[2] We will estimate models over 1961 – 1995, then use the estimates to forecast inflation for the rest of years. Most of the data used in this paper come from *OECD Economic Outlook (2000).* Detailed information about definition of the variables is given in Table 1. The inflation data is derived from Consumer Price Index (CPI), whose source is *International Financial Statistics (2000).* Productivity growth and wage aspirations are constructed on the base of raw data according to the method in Ball and Moffitt (2001). Data for the OECD as whole is just the average values for 19 member countries.[3]

In Ball and Moffitt (2001), output per hour data is used to construct productivity growth. However, this data is not available for all OECD countries. We use output per worker instead. This variable does not measure productivity perfectly because it contains the cyclical factors. In particular, it varies cyclically following the movement of workers effort. To rule out the cyclical effect of workers effort, we copy Ball and Moffitt's method, which suggests regressing the change of output per worker on the change of weekly hours for each country. The theoretical justification for doing this is that effort moves proportionately with average weekly hours of employed workers over the business cycle. Then we use the residuals from this regression to measure true

productivity growth, adding a constant to make the mean of productivity growth equal to the mean of the change of output per worker. The constructed result is shown in figure 2.[4]

Wage aspirations are constructed from real wage data. Again, following Ball and Moffitt (2001), we assume current wage aspirations growth is a function of last year's wage aspirations growth and last year's real wage growth:

$$A_t = \mu A_{t-1} + (1-\mu)(w-\pi)_{t-1} \tag{1}$$

where A is wage aspirations growth, $w-\pi$ is real wage growth and $0 \leq \mu \leq 1$. Iterating equation (1) implies that current wage aspirations growth is related to the real wage growth back to the infinite past. But due to the limitation of our sample size, we simply assume the earliest available trend real wage growth is equal to that year's wage aspirations growth.[5] The following years' wage aspirations growth is calculated from the previous year's level according to equation (1) following Ball & Moffitt (2001). The coefficient μ in wage aspirations definition is set to 0.95 so as to reflect the characteristic that wage aspirations not only capture the important changes of real wage, but also move along a relatively smooth path.[6] The constructed wage aspirations

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[4] This data is available upon request.

[5] The trend real wage growth of each individual country in the base year is measured by the Hodrick – Prescott filter over the whole sample for that country with smoothing parameter 1000.

[6] We impose $\mu = 0.95$ following Ball and Moffitt (2001). The reason is that the estimated μs are imprecise, which is reflected by the wide standard error bands around the estimated values. According to Ball and Moffitt (2001), we include the new variable - productivity gap ($\theta - A$) into the traditional Phillips Curve model, then jointly estimate μ with other coefficients by nonlinear least square. The estimated μs and the associated standard errors are OECD: 0.772(1.063), US: 0.427(0.736), UK: 0.855(0.304), Germany: 0.259(2.652). Furthermore, F test results show that the estimated μ values and the imposed value 0.95 are not significantly different. The p values of the F test for the hypothesis that the estimated μ equals 0.95 are: OECD: 0.868, US: 0.483, UK: 0.754 and Germany: 0.796.

are shown in Figure 3.

We estimate four specifications of the Phillips Curve for the whole OECD and three single countries – the U.S., the UK and Germany. We first estimate the traditional Phillips Curve model and use the estimates to forecast inflation. Then we add productivity gap to the model and investigate if the extension increases the precision of inflation forecast.[7] Finally, in order to test the robustness of the productivity model, we examine the role of productivity and wage aspirations in a supply shock model and a time – varying potential output model (we use time-varying potential output model to capture the effect of time-varying NAIRU due to the convenience of potential output data). The reason of choosing supply shock and potential output model is that both supply shock and time – varying NAIRU are considered by many as the credible explanations for the double decline of inflation and the unemployment rate in the U.S. (Gordon, 1997; Lown and Rich, 1997). Therefore, two additional models are estimated where one model includes supply shock and productivity gap, while the other model includes time-varying potential output and productivity gap. The relative importance of productivity gap should be shown clearly by doing this. In the course of analysing each specification, we will not only provide the panel result for the whole OECD, but also the results for the three single countries (US, UK and Germany).

3. The Traditional Phillips Curve

The traditional price inflation Phillips Curve is specified as

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[7] The Phillips Curve specifications we compared in this paper are similar to those in Gruen, Pagan and Thompson (1999).

$$\pi_t = \overline{\alpha}(L)\pi_{t-1} + \beta(L)(U_t - U^*) \qquad (2)$$

Where π_t is the rate of inflation, π_{t-1} is lagged inflation representing the adaptive inflation expectation, u is the unemployment rate, u* is the NAIRU, u-u* is the unemployment gap indicating the excess demand stimulating inflation and $\overline{\alpha}(L)$ and $\beta(L)$ are polynomials in the lag operator. Usually several lags for inflation and unemployment are included in order to capture the inertia in the adjustment of expectation and unemployment. If the NAIRU is assumed to be constant, u* can be treated as the parameter, and (2) may be re-written as

$$\pi_t = C + \overline{\alpha}(L)\pi_{t-1} + \beta(L)U_t + \varepsilon_t \qquad (3)$$

where $C = -\beta(L)U^*$ and ε_t represents the random shocks to inflation.

To estimate the Phillips Curve, we need to impose the restriction on equation (3) that the sum of coefficients of lagged inflation is unity. The reason is that the NAIRU exists only in the condition of this restriction, i.e. the NAIRU is equal to the unemployment rate when inflation is stable. So we replace inflation of (3) by the first difference of inflation then get:

$$\Delta\pi_t = C + \alpha(L)\Delta\pi_{t-1} + \beta(L)U_t + \varepsilon_t \qquad (4)\ [8]$$

Where $C = -\beta(1)U^*$

We use the data and methods mentioned previously to estimate (4) for the OECD overall and separately for the US, the UK and Germany over the period 1961 - 1995.

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[8] Coefficient $\alpha(L)$ in equation (4) is related to $\overline{\alpha}(L)$ in equation (3) by the relationship that

$\alpha(L) = \sum \overline{\alpha}(L)$

Following Grub (1986), we take two lags of each variable in the regressions to maximize adjusted R^2.

Table 2 shows the estimation results from the traditional Phillips Curve model. Each estimator in the table shows the sum of coefficients on that variable. The statistic in parentheses is the p-value from a F-test of the hypothesis that sum of coefficients on the variable is zero. The sums of coefficients on the lagged change of inflation are highly significant in OECD but insignificant in all the single countries. This means that inflation expectation adjusts more quickly in the three example countries than in the OECD.

In each regression, the unemployment rate has the expected negative sign. The p-values are particularly high for the UK and Germany, which raises the possibility that unemployment has no effect on inflation. Using the coefficients, we can calculate the sacrifice ratio $(1/\sum B(L))$ for these countries. The sacrifice ratio in the U.S. is 2.06, which implies that the unemployment rate would have to go up by 2.06 percentage point in order for inflation to fall by one percentage point. Those of the OECD, UK and Germany are 11.67, 4.12 and 14.08 respectively. The sacrifice ratio in the OECD and Germany is very high, which relates to a low coefficient on the rate of unemployment. In the OECD, there are two types of estimation bias could explain this. First, some variables do affect inflation, but they are omitted from the traditional Phillips Curve. This may also cause the high sacrifice ratio in Germany. Second, in the pooled OLS regression, there is only one constant, the NAIRU cannot vary across countries. In fact, the NAIRU could be different in each country. So it could be this

unreasonable restriction that leads to a bias. If we look at the within model, where the constant differs over countries, the sacrifice ratio for OECD falls to 4.9. For this reason, we'll use the within result to forecast inflation for the OECD.

To test the usefulness of this Phillips Curve specification, we construct an out-of-sample forecast of inflation. We use the coefficients estimated from Equation (4) to generate the dynamic inflation forecast results for the period 1996-2000. The difference between the true value and predicted value illustrates the accuracy of the model. As shown in Figure 4, the Phillips Curve of equation (4) has clearly and systematically over-predicted inflation within the OECD. We also report the mean of forecast error and the standard deviation of predicted inflation in Table 2. The positive sign on the mean of the forecast error shown in Table 2 implies that the over-prediction from the traditional Phillips Curve is systematic in the OECD. This can also be seen from Figure 4. For the OECD overall, the predicted value of inflation remains above the actual inflation all the time. These two standard error bands mean that the actual inflation rate could be anywhere between the two bands within a 95 per cent confidence interval. The wide standard error bands imply an amount of uncertainty about forecast result from the traditional Phillips Curve model. In any year, we cannot reject the hypothesis that forecasted inflation equals actual inflation.

In the U.S. and the UK, the over-prediction of traditional Phillips Curve is more obvious than in the OECD. None of the predicted values is under actual inflation. The forecast error in both countries is considerable. However, Germany is an exception. Inflation is predicted precisely most of the time in late 1990s. Standard deviation of the

forecast result is the smallest among all the countries. The standard model explains Germany well.

4. The Phillips Curve with Productivity Gap

Workers' wage aspirations may adjust slowly to the unexpected productivity growth. Any temporary gap between productivity and wage aspirations could disturb the traditional relationship between inflation and the unemployment rate. In this section, we add productivity gap to the conventional Phillips Curve model and investigate how it shifts the inflation – unemployment relation. This new variable is treated as a "supply shock" following Ball and Moffitt (2001). This means that, given the NAIRU, the unemployment rate can stay at low without raising inflation when productivity accelerates so that the gap between productivity and aspirations is above zero.

The modified Phillips Curve specification is:

$$\Delta \pi_t = C + \alpha(L)\Delta \pi_{t-1} + \beta(L)U_t + \gamma(L)(\theta - A)_t + \varepsilon_t \tag{5}$$

where $C = -\beta(1)U^*$ and $\theta - A$ is the gap between productivity (θ) and wage aspirations (A). Table 3 shows the estimated parameters from equation (5). The coefficient on productivity gap is negative for all the countries. This implies a rise in productivity growth relative to wage aspirations has a negative effect on inflation. However, this effect is insignificant in all the countries.[9] We cannot reject the hypothesis

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[9] The US result is different with that of Ball and Moffitt (2001) where they show $\theta - A$ has significant effect on inflation. The reason is that we include two lagged terms for $\theta - A$, whereas Ball and Moffitt included only the current $\theta - A$ in the Phillips Curve model. In other words, the US result presented in Table 3 shows the accumulated effect of $\theta - A$ on inflation, but Ball and Moffitt (2001) implies that the immediate effect of $\theta - A$ is significant. Our dynamic analysis of $\theta - A$ is shown in Table 4,

that the sum of the coefficient on productivity gap is zero at any significant level. This indicates that the productivity gap has no effect on inflation in the long run. To explore more information about the effect of the productivity gap, we investigate the individual coefficients of this variable. The detailed estimated coefficient on productivity gap is presented in Table 4.

Seen from Table 4, productivity gap has immediate and negative effect on inflation significantly in the OECD and the UK but no significant effect in the US and Germany. The effect lasts for more than one year in both countries, which implies that wage aspirations adjust quickly in the OECD and the UK following the fluctuations of productivity growth.

In Table 3, the coefficient on lagged change of inflation is similar to those in the traditional model for all the countries. Through a F-test,[10] we know the coefficient on this variable is not significantly different across the models. This implies that our estimation of the inflation expectation adjustment process is robust to the inclusion of other variables in the model.

All the coefficients on the unemployment rates get the expected negative signs. Compared with the previous model, coefficients (absolute value) on the unemployment

which is also different with the result of Ball and Moffitt (2001) due to the different model specifications.

[10]The null hypothesis is that the sum of coefficient on lagged change of inflation in the productivity model is equal to that in the traditional model. The test P-value is: OECD: 0. 384; U.S: 0.808; UK: 0.17; Germany: 0.741. Under the null hypothesis, we estimate the traditional model and take the sum of coefficient on lagged change of inflation, then estimate productivity model and test the hypothesis that the sum of coefficient on lagged change of inflation equal to the former value.

rate slightly fall but are statistically equal in all the countries. [11] Therefore, adding the productivity gap, the Phillips Curve relation between inflation and the unemployment rate keeps relatively stable. The sacrifice ratio in this model is 5.07 per cent in the OECD, 2.57 per cent in the U.S, 5.3 per cent in the UK and 161.29 per cent in Germany. However, 161.29 per cent is unreliable both because its incredible size and because it results from an estimate that is insignificantly different from zero. Furthermore, the NAIRU derived from the productivity model is higher than before due to the slight fall of the coefficient of unemployment rate. It seems incredible that the UK and Germany have the NAIRU of 25.4 per cent and 16.1 per cent respectively compared with their average unemployment rate 6.89 per cent and 8.92 per cent. All of these imply that the inclusion of the productivity gap does not improve the ability of Phillips Curve to model the UK and Germany experience.

The inflation forecast results from the productivity model are shown in Figure 5. With the productivity gap, the Phillips Curve model over predicts inflation again in the OECD. All the predicted values are above the actual ones. Both the forecast error and standard deviation, which average to 1.09 per cent and 1.33 per cent respectively, are higher than those from the traditional model. In the U.S, productivity gap reduces a part of over-prediction of inflation from the traditional model. But the standard deviation is approximately equal to that of the previous model. In the UK and Germany, the inflation forecasts from the new model are worse than the traditional model. The mean of the

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[11] The hypothesis that the coefficients on the unemployment rate are the same as that in the previous model can *not* be rejected at the conventional significant levels for all the individual countries. The P-value for this F-test is: OECD: 0.915, U.S.: 0.673, UK: 0.888 and Germany: 0.646.

forecast error is bigger. The standard deviation of the forecast values is higher. Therefore, we need to examine the role of productivity gap further.

5. Supply Shock and Productivity Gap

Supply shock variables are usually included in the estimated Phillips Curve models, because supply shocks create an extraneous positive correlation between inflation and unemployment. This also is the reason why supply shocks were used to explain the double decline of inflation and unemployment in the late 1990s for the U.S. (Gordon, 1998). In this section, we put productivity gap and the supply shock together and check the significance of productivity gap in the Phillips Curve model. We use import price to measure supply shock. It picks up the effect of a change in the value of local currency, as well as changes in the international prices of commodities. In the estimated model, we use the first difference of the variables to represent the supply shock. This captures the notion that a shock is the difference between the actual value of a variable and the value that was anticipated when agents make the economic decisions that determined the NAIRU (i.e. we assume expectations are based on a random walk). Our supply shock model with productivity gap is given by equation (6)

$$\Delta \pi_t = C + \alpha(L)\Delta\pi_{t-1} + \beta(L)U_t + \gamma(L)(\theta - A)_t + \delta(L)\Delta importp_t + \varepsilon_t \qquad (6)$$

where $C = -\beta(1)U *$.

Table 5 presents the estimation results from supply shock model with and without

the productivity gap added. The effect of productivity gap is still insignificant in all the circumstance where other supply shock variable is included. The estimated coefficients are all associated with a very high P-value, which implies that   productivity gap has no effect on inflation in the long run.

Compared with the uncertainty of the effect of productivity gap across different models, the import price has stable effect on inflation. With or without productivity gap, an increase in the import price always raises inflation in all the countries except Germany where it is highly significant. The effect is especially significant in the OECD and the US.

Finally, the coefficients on unemployment and on lagged changed inflation are virtually unchanged across two supply shock models in the OECD and the U.S. This implies that the inflation and unemployment relation is quite stable across different models in both countries. However, this relation is not so stable in the UK and Germany where productivity gap and supply shocks interacted with the coefficients on lagged inflation and unemployment. This suggests that the productivity gap model is less robust to misspecification in the case of the UK and Germany than in the case of the US.

Figure 6 provides the inflation forecast results from the supply shock model with and without productivity gap, together with the actual inflation rate. Including productivity gap does not make the supply shock model forecast inflation more precisely in the OECD. From figure 6, we can see that, for the OECD overall, the predicted inflation generated by the supply shock model with productivity gap is further from actual

inflation than those produced without productivity gap. The forecast result in the U.S. has different implications. Adding productivity gap pushes the predicted inflation close to the actual value. Furthermore, the model with all the variables provides the most precise forecast inflation, compared with other models, which indicates productivity gap does explain a moderate part of performance of inflation and unemployment in the 1990s of the U.S.[12] In the UK, the supply shock model with or without productivity gap still over predicts inflation in late 1990s. In Germany, the supply shock model without productivity gap gives the most precise forecast result. However, this improvement is slight, as traditional model does not over predict inflation by much.

6. Time-Varying NAIRU and Productivity Gap

Up to now, all the models we analyzed are based on an assumption that the NAIRU is a constant through time. However, the NAIRU could be time varying. Gordon (1997) argues that the fall in the NAIRU allowed unemployment to stay low in the late 1990s without the danger of rising inflation. In order to check the robustness of the effect of productivity gap, we incorporate the time-varying NAIRU into the productivity Phillips Curve model. But we are not going to estimate the NAIRU in this section, instead, we use time – varying potential output to replace the time – varying NAIRU in the Phillips Curve model. In other words, we estimate a Phillips Curve relation between inflation

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[12] Also, supply shock may play a role during the same period in the U.S.

and output. The potential output data is available in OECD database. The variation of

potential output should illustrate the same characteristics as the time-varying NAIRU.

The potential output Phillips Curve with productivity is:

$$\Delta \pi_t = \alpha(L)\Delta \pi_{t-1} + \beta(L)outputgap_t + \gamma(L)(\vartheta - A)_t + \varepsilon_t \qquad (7)$$

where output gap = actual output – potential output.

We estimate two potential output models in this section, one model with productivity

gap such as (7), the other one without. Table 6 gives the estimation results for both

models. Similar to the previous model, an insignificant coefficient on productivity gap is

shown clearly in all the countries. The hypothesis test result shows that it is not

significantly different from that of the productivity model of section three.[13] The output

gap has positive coefficients in all the countries, which indicates that a positive output

gap generates the inflationary pressure. This effect is significant in the OECD, the U.S.

and Germany and quite stable across both output models.[14] Lagged change of inflation

has the similar effect on inflation in both models in all the countries.

Figure 7 shows actual inflation and predicted inflation from two potential output

models, one with productivity gap, and one without. Considering time – varying

potential output and productivity gap together, productivity gap appears less important.

From the figure, we see that, adding output gap makes the model forecast inflation

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[13] P-value of F test of the hypothesis that coefficient on $\theta - A$ equals that in the productivity model is: OECD:0. 251, US: 0.683, UK: 0.983, Germany:0. 268.

[14] Hypothesis that the coefficient on output gap is same in the output model with and without $\theta - A$ cannot be rejected at any significant level for all the countries. P value of the test is: OECD: 0.933, US: 0.918, UK: 0.816 and Germany: 0.777.

more precisely than all the previous models in the OECD. Although the inclusion of productivity gap in the output gap model generates predicted inflation closer to the actual values, this improvement is smaller than that from including the time-varying output gap. In the U.S, the effect of productivity gap on inflation is to generate a more precise forecast result. Therefore, the acceleration of productivity growth in the late 1990s could explain the decline of inflation and the unemployment rate in the U.S. i.e. as suggested by Ball and Moffitt (2001). In the UK, adding the productivity gap actually reduces the quality of the forecast from the potential output model. In Germany, the model with the productivity gap cannot forecast inflation any better than the traditional Phillips Curve.

7. Conclusion

This paper set out to examine a productivity theory presented by Ball and Moffitt (2001) within the OECD countries. That theory implies that workers' wage aspirations adjust slowly to the unexpected productivity growth. Any temporary gap between productivity and wage aspirations would disturb the traditional relationship between inflation and the unemployment rate. Following Ball and Moffitt (2001), we include the new variable – the gap between productivity and wage aspirations -- into the traditional Phillips Curve model. Then the new model is applied to the OECD as a whole and to three countries individually (US, UK and Germany).

Our results confirm the role of the gap between productivity and wage aspirations in

the double decline of inflation and unemployment in the U.S., which was the focus of Ball and Moffitt (2001). We showed that this result was robust to specification changes: specifically we found that the productivity gap was an important aspect to US disinflation even when we allow for other supply shocks and a time-varying NAIRU.

In contrast, the role of productivity gap is not robust across countries. Our results suggest that the positive gap between productivity and wage aspirations was not an important aspect of the deflation within the OECD during the 1990s. On the contrary, the time – varying NAIRU explains most of the economic performance across the OECD in the late 1990s. This implies that there have been some positive structural changes in the labour market within the OECD since 1990s.

In addition Ball and Moffitt (2001) result does not extend to two major OECD countries. In the UK, the change of the structure of the labour market (resulting in the change of the NAIRU) seemed the key; and in Germany, traditional Phillips Curve model still kept its power in the late 1990s.

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Table 1. Definitions of Variables

Definition	Code
$Inflation = \log(CPI_t - CPI_{t-1})$	CPI: consumer price index (IFS)
The unemployment rate = (LF – ET)/LF	LF: labour force; ET: total employed (EO)
Change of import price $= \log(PMG_t) - \log(PMG_{t-1})$	PMG: import price goods, local currency, custom basis l (EO)
Output gap = GDPV/GDPVIR – 1	GDPV: gross domestic product, volume GDPVIR: potential gross domestic produc (EO)
Output per worker = (GDPV/ET)/ GDPV (overall base year)/ET(overall base year)	GDPV, GDPVIR and ET same as above (EO)
Real wage = WRMAN / PGDP	WRMAN: wage rate, manufacturing PGDP: deflator for GDP at market deflator(EO)
Weekly work hours = (average actual annu hours worked per person in employment) /	Data source: labour market statistics, OECD

Table 2

Traditional Phillips Curve Model
(1961-1995)
(Dependent Variable: $\Delta\pi$ **)**

	CD	US	Germany

	OE		UK		
	Pooled	Within			
Constant	0.006	0.012	0.031	0.018	0.005
	(0.001)*		(0.030)	(0.115)	(0.108)
Lagged change of Inflation	-0.278	-0.318	-0.090	-0.371	0.256
	(0.000)	(0.000)	(0.716)	(0.184)	(0.260)
Unemployment	-0.086	-0.204	-0.485	-0.243	-0.071
	(0.000)	(0.000)	(0.031)	(0.155)	(0.283)
Sacrifice Ratio**	11.67	4.90	2.18	4.12	14.08
NAIRU*	0.070	0.059	0.064	0.074	0.070
Forecast Error (%)		0.633	3.25	3.18	-1.24
Standard Deviation (%)		1.42	1.45	3.09	1.06
Adjusted R^2	0.088	0.083	0.492	0.244	0.359

*The number in parentheses is p value of F-test for the hypothesis that the sum of coefficients of a variable is zero.

*The NAIRU is calculated from the constant above, since it is assumed that $C = -\beta(1)U*$

** Sacrifice Ratio $= 1/\sum_{i=0}^{2} \beta(L)$

Table 3

Productivity Phillips Curve Model
(1961 – 2000)
(Dependent Variable: $\Delta\pi$)

	OECD (Within)	US	UK	Germany
Constant	0.013	0.025	0.048	0.001
		(0.095)*	(0.155)	(0.947)

	OECD	US	UK	Germany
Lagged change of inflation	-0.250	-0.008	-0.207	0.342
	(0.002)	(0.980)	(0.806)	(0196)
Unemployment	-0.197	-0.389	-0.189	-0.0062
	(0.000)	(0.095)	(0.626)	(0.964)
Productivity gap	-0.048	-0.279	-0.097	-0.079
	(0.202)	(0.397)	(0.300)	(0.598)
Sacrifice Ratio*	5.08	2.571	5.29	161.29
NARIU*	0.066	0.064	0.254	0.161
Forecast error (%)	1.09	2.17	3.88	-2.28
Standard deviation (%)	1.33	1.56	3.40	1.20
Adjusted R^2	0.221	0.493	0.501	0.297

* The number in parentheses is p value of F test for the hypothesis that the sum of coefficient of a variable is zero.

* $NAIRU = -C/\beta(1)$;

* Sacrifice Ratio $= 1/\sum_{i=0}^{2}\beta(L)$

Table 4

Productivity Phillips Curve Model

Estimated Coefficient on $(\theta - A)$

Dependent Variable: Δ Inflation

	OECD	US	UK	Germany

Constant	*	*	*	*
Lagged Δ inflation	*	*	*	*
Unemployment	*	*	*	*
$(\theta - A)_t$	-0.159	-0.193	-1.176	0.009
	(0.003)*	(0.126)	(0.007)	(0.889)
$(\theta - A)_{t-1}$	0.083	-0.013	0.0853	-0.059
	(0.096)	(0.943)	(0.836)	(0.445)
$(\theta - A)_{t-2}$	0.028	-0.074	0.994	-0.028
	(0.580)	(0.623)	(0.022)	(0.676)

*We only focus on the coefficient on $(\theta - A)$, other coefficients are ignored here.

* the number in parentheses is p value.

Table 5. Supply Shock Model With and Without $\theta - A$, 1961 – 1995, (Dependent Variable: $\Delta \pi$)

	OECD		US		UK		Germany	
	(Within)	(Within)						
	With	Without	With	Without	With	Without	With	Without
Constant	0.011	0.014	0.018	0.021	0.043	0.013	-0.003	0.005
			(0.086)	(0.029)	(0.254)	(0.173)	(0.751)	(0.751)
Lagged Δ inflation	-0.250	-0.385	-0.126	-0.136	0.069	-0.236	0.354	0.241
	(0.002)	(0.000)	(0.642)	(0.526)	(0.853)	(0.418)	(0.161)	(0.271)
Unemployment	-0.120	-0.201	-0.286	-0.335	-0.184	-0.141	0.044	-0.061
	(0.034)	(0.000)	(0.085)	(0.028)	(0.670)	(0.383)	(0.752)	(0.329)
Productivity gap	-0.039	****	-0.153	****	-0.069	****	-0.128	****
	(0.253)		(0.444)		(0.536)		(0.397)	
Change of import price	0.117	0.119	0.120	0.130	0.071	0.190	-0.006	-0.011
	(0.000)	(0.000)	(0.016)	(0.004)	(0.674)	(0.120)	(0.891)	(0.759)
Sacrifice ratio	8.33	4.98	3.50	2.99	5.43	7.09	-22.73	16.39
NAIRU	0.092	0.070	0.063	0.063	0.234	0.092	0.068	0.082
Forecast error (%)	1.72	1.15	0.06	0.51	4.04	1.88	-2.49	-1.03
Standard deviation (%)	0.96	0.92	0.94	0.86	3.81	2.89	1.16	1.02
Adjusted R^2	0.348	0.014	0.805	0.820	0.403	0.380	0.372	0.419

Table 6. Output Gap Model With and Without $\theta - A$, 1961 – 1995, (Dependent Variable: $\Delta\pi$)

	OECD (Within)		US		UK		Germany	
	With	Without	With	Without	With	Without	With	Without
Lagged Δ inflation	-0.238	-0.142	-0.543	-0.427	-0.299	-0.141	0.088	0.030
	(0.004)*	(0.037)	(0.067)	(0.074)	(0.424)	(0.684)	(0.767)	(0.913)
Output gap	0.266	0.260	0.688	0.707	0.338	0.423	0.381	0.430
	(0.000)	(0.000)	(0.002)	(0.001)	(0.379)	(0.258)	(0.051)	(0.017)
Productivity gap	-0.086	****	-0.386	****	-0.099	****	-0.028	****
	(0.010)		(0.150)		(0.159)		(0.530)	
Sacrifice ratio*	3.76	3.85	1.45	1.41	2.96	2.36	2.62	2.33
Forecast error (%)	-0.14	0.12	0.31	1.18	-3.70	0.99	1.50	1.18
Standard deviation (%)	1.27	1.28	1.27	1.20	3.55	3.34	0.97	0.92
Adjusted R^2	0.230	0.247	0.652	0.650	0.282	0.212	0.385	0.428

* The number in parentheses is p value of F test for the hypothesis that the sum of coefficient of the variable is zero.

* Sacrifice ratio in Table 6 is calculated in terms of the loss of output, i.e. $1/\sum_{i=0}^{2}\beta(L)$, but β is coefficient of output gap in model (7).

Figure 1

OECD inflation and unemployment
(1962 - 2000)
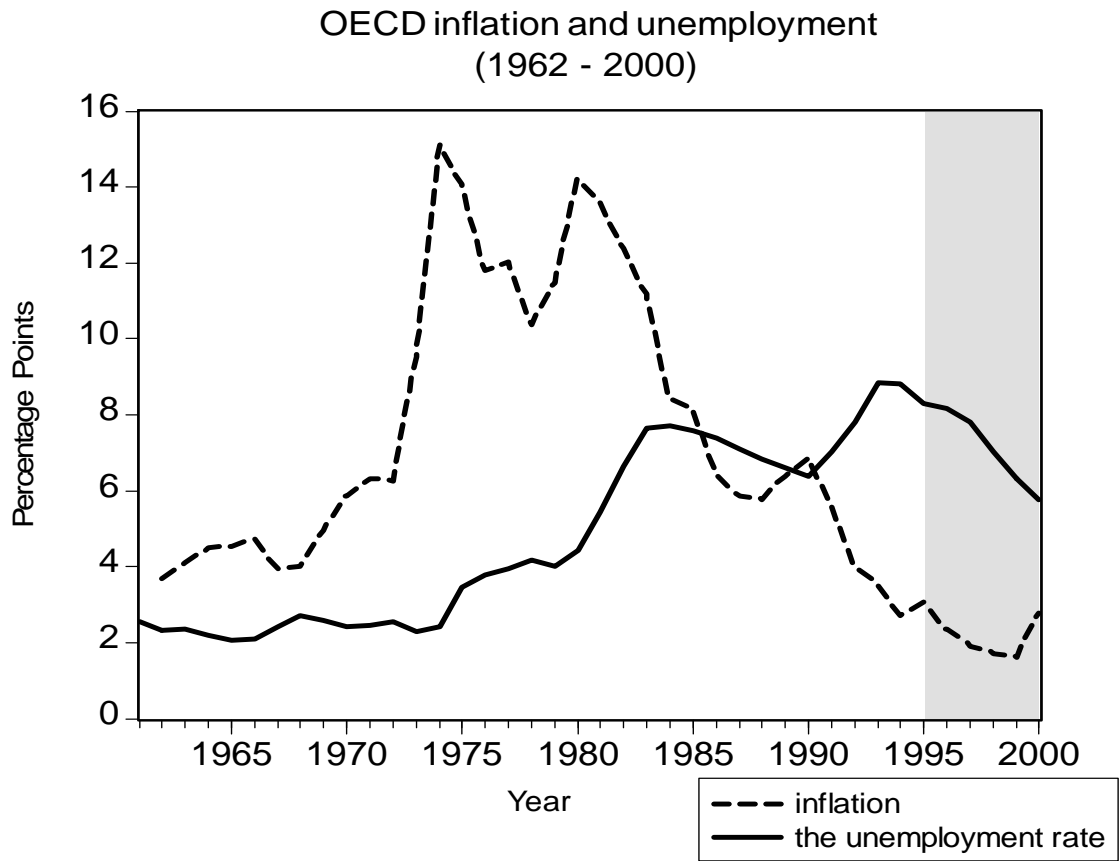
Data Source: OECD Economic Outlook (June, 2000)

Figure 2. Constructed OECD Productivity Growth

(1961 – 2000)
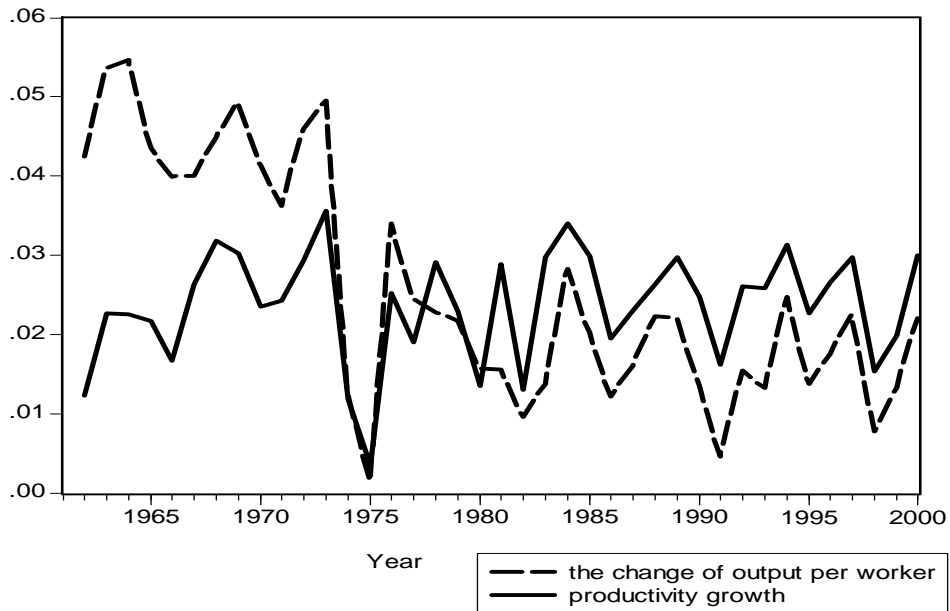
Figure 3. Constructed OECD Wage Aspiration

(1961-2000)
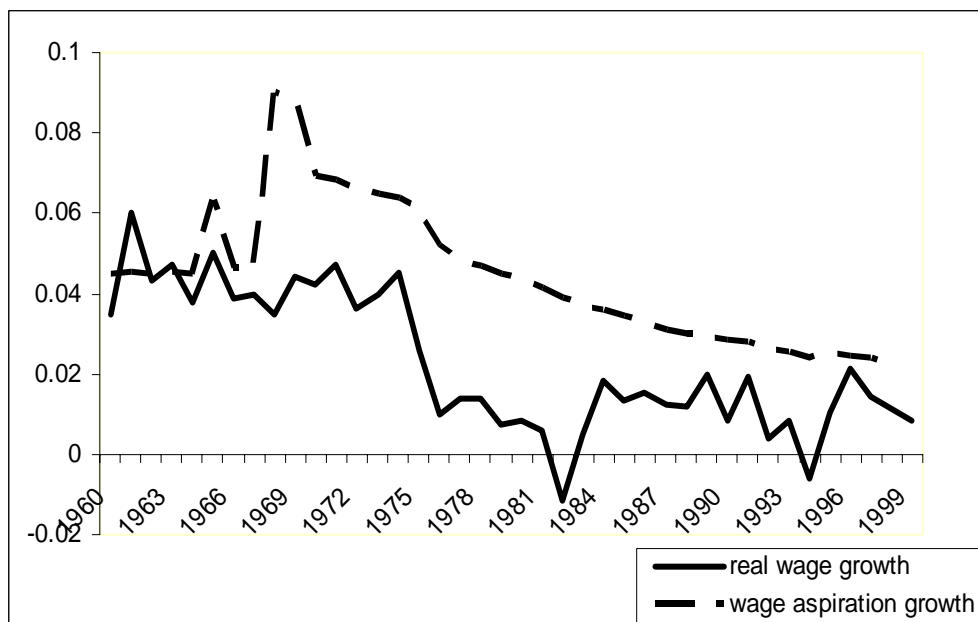
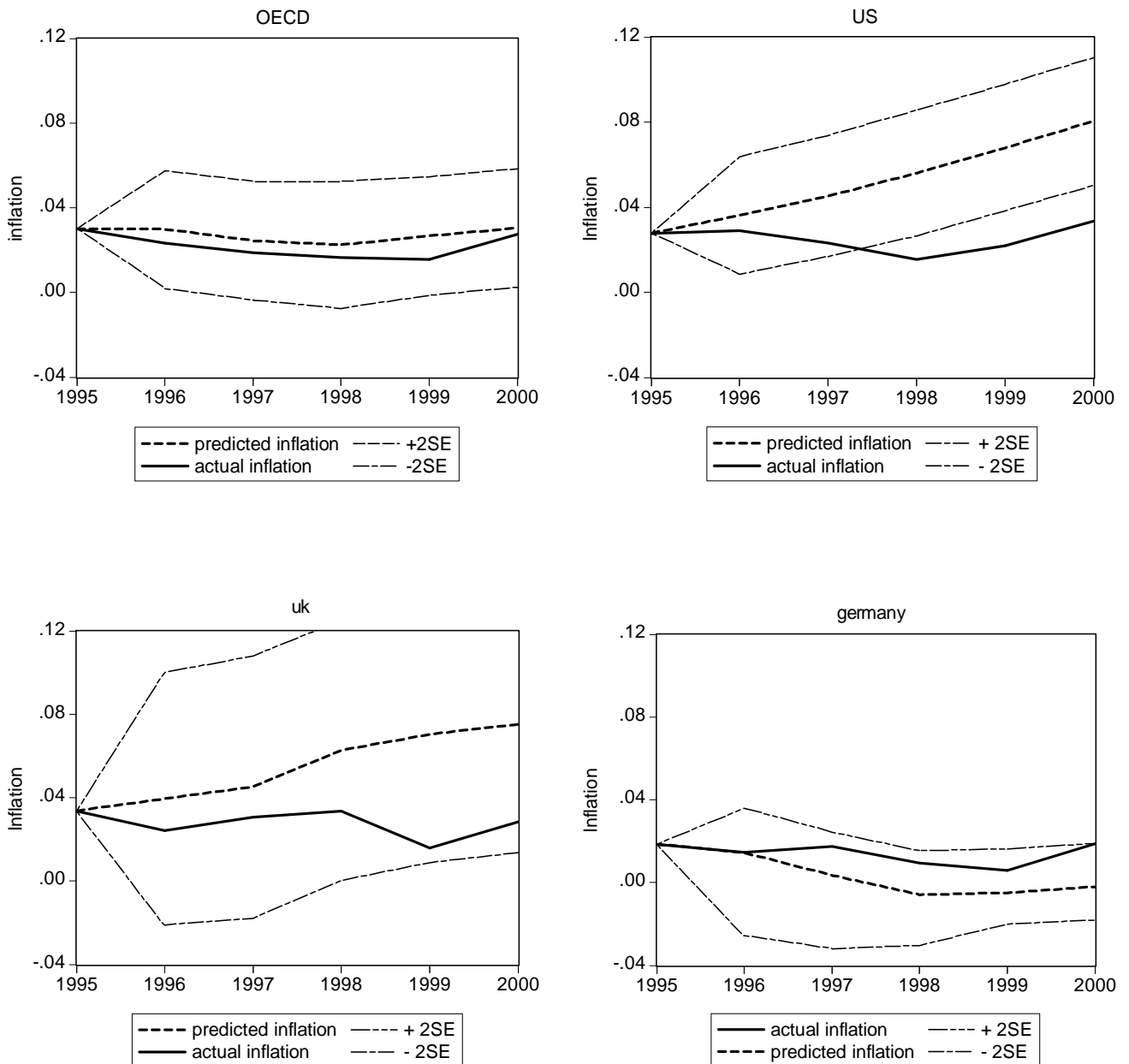**Figure 4. Forecast of Inflation from the Traditional Phillips Curve**

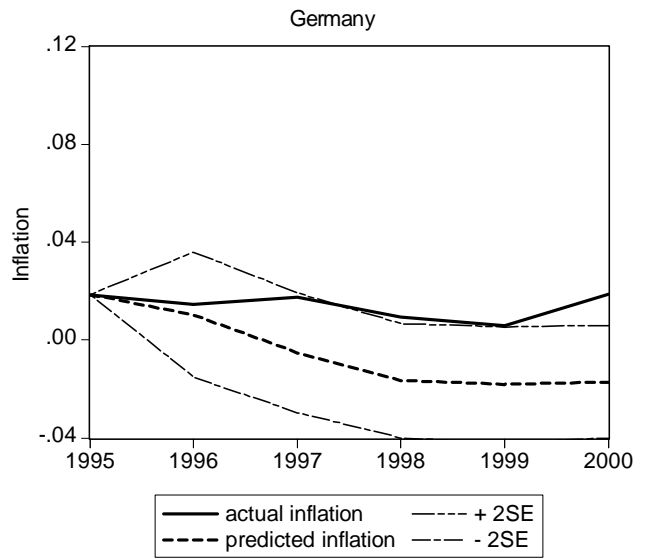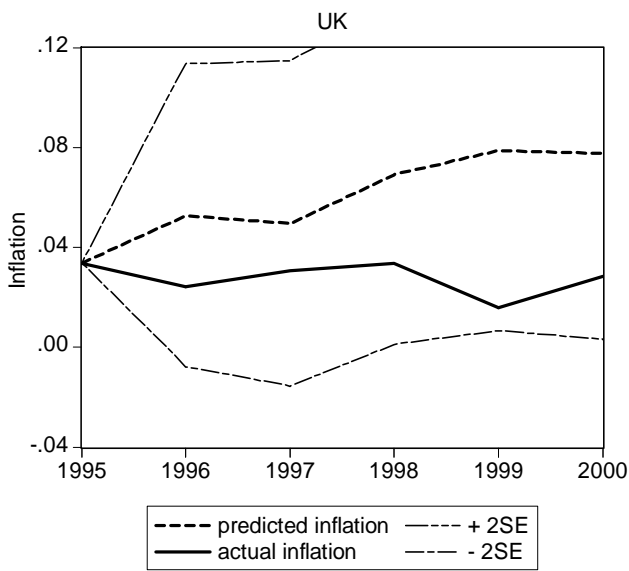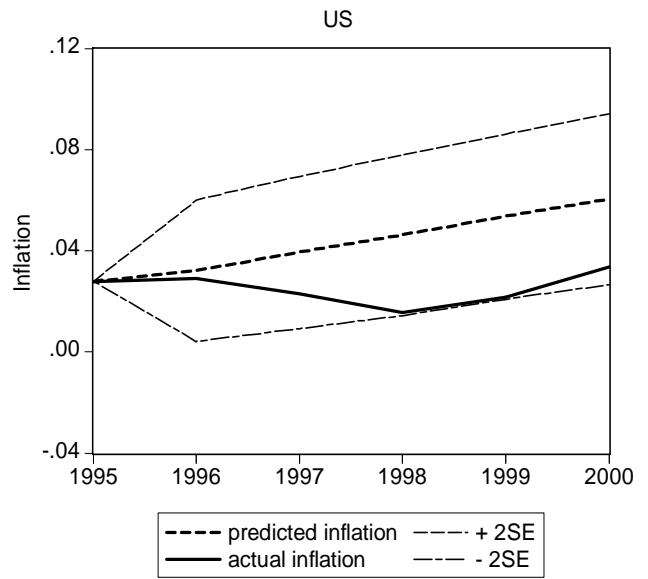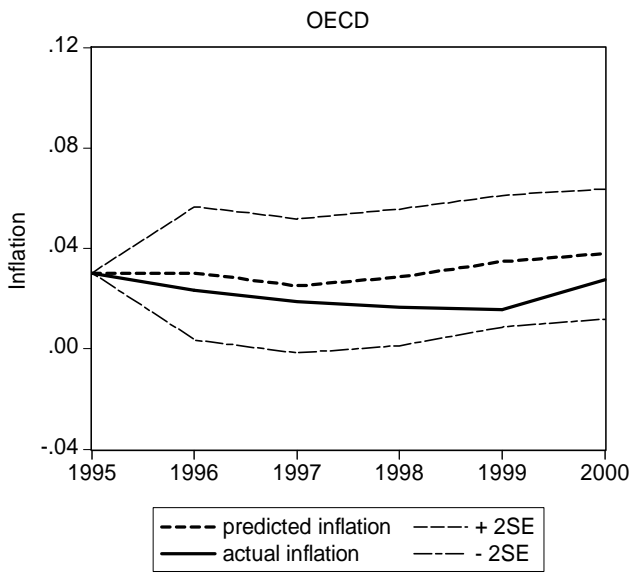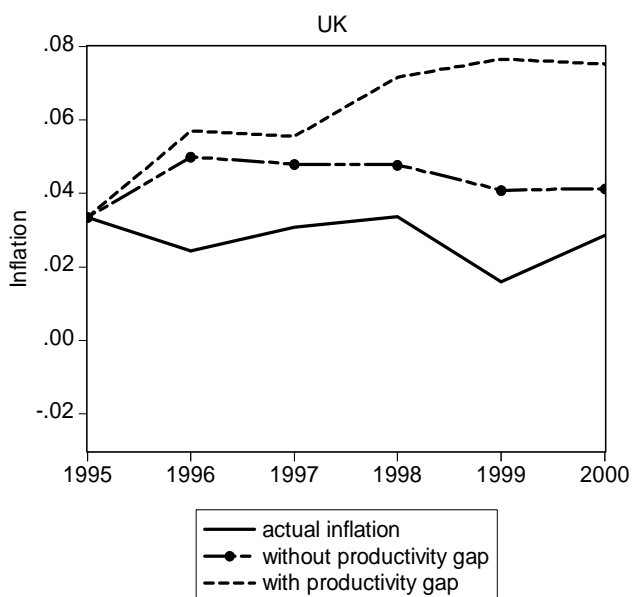# Figure 5. Forecast of Inflation from the Productivity Model

Figure 6. Forecast of Inflation from Supply Shock Models
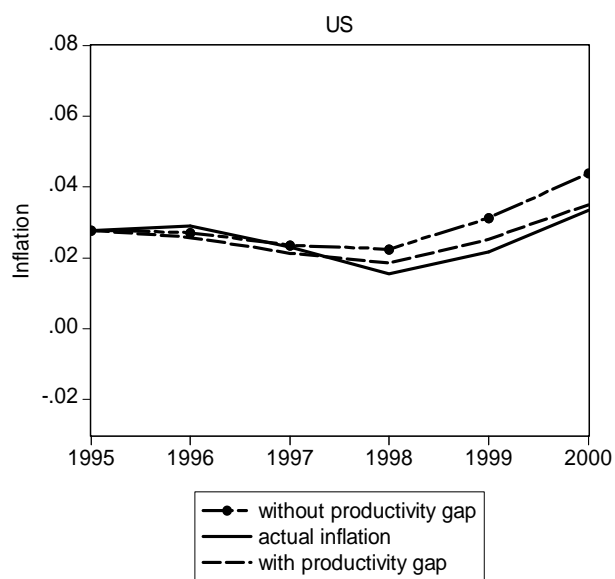
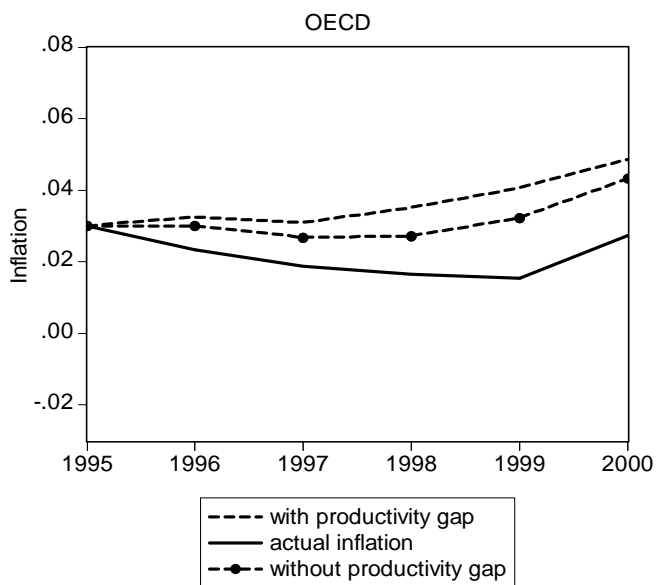**(with and without $\theta - A$)**
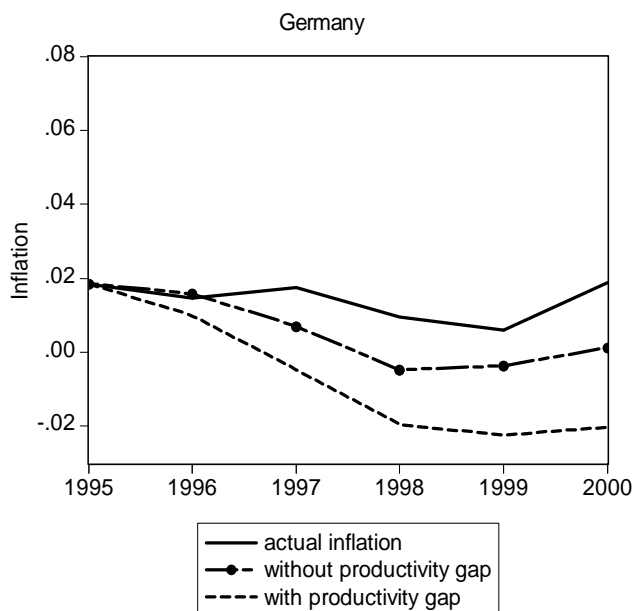
Figure 7. Forecast of Inflation from Potential Output Models

(with and without $\theta - A$)