USING A FORWARD-LOOKING PHILLIPS CURVE TO ESTIMATE THE OUTPUT GAP IN PERU

Gabriel Rodríguez[*]

Abstract: This paper identifies the output gap using the theoretical definition of the gap within a Phillips curve in the spirit of the New Keynesian framework. Using Peruvian data for the period 1980:1-2005:4, the results indicate a very flat slope of the Phillips curve but the output gap is large and persistent. Furthermore, the output gap is not correlated with the stochastic trend which is similar to the assumption used in the unobserved components model. The forward-looking component is estimated at 39% indicating a key role of this component in the inflation for a emerging country like Peru which is an economy partially dollarized using an inflation targeting scheme. The model is extended to include information coming from the unemployment rate but the results are very similar indicating poor additional information in the unemployment rate to identify the output gap. In order to compare, other estimations of the output gap are performed. The results show strong differences and the closer measure is the one obtained using the unobserved component model and the model with simple quadratic trend.

JEL Classifications: C22, C52, E31, E32.

Keywords: Phillips Curve, Output Gap, Inflation, Unemployment, Filters.

INTRODUCTION

The literature related to the estimation of the output gap (and potential output) is very extensive but it may be categorized into two groups: statistical and economic. In the statistical approach there are two sub-categories. The first sub-category imposes smoothness on either the trend or the cycle and the simplest widely used method is to fit a polynomial in time to output, the residuals being the estimated cycle. Another very used method is the filter of Hodrick and Prescott (1997) which imposes smoothness but not determinism on the trend. A similar approach extracts an estimate of the cycle by passing the data through a filter that pre-specifies the relevant frequencies for the cycle. Examples are the filters of Baxter and King (1999) and Christiano and Fitzgerald (2003) where the cycle is defined as having spectral power in the range between 6 and 32 quarters.

The other statistical sub-category does not impose prior smoothness on the trend or cycle. It uses a time series model and requires identification of the stochastic trend component. This is the case of the decomposition of Beveridge and Nelson (1981). Other approaches are the

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[*] Department of Economics, Pontificia Universidad Catolica del Peru, Av. Universitaria 1801, Lima 32, Lima, Peru, E-mail: gabriel.rodriguez@pucp.edu.pe

unobserved components model based on Watson (1986) and Clark (1987). In these cases, the trend is assumed to be a random walk with varying growth rate in some specifications and a restriction between the shocks to the cycle and trend is imposed. In a recent paper, Morley, Nelson and Zivot (2003) show importance of the assumption that trend and cycle shocks are uncorrelated.

In the side of the economic approaches, one way to calculate the output gap is to use an aggregate production function. Another measure is calculated by the Congressional Budget Office (CBO, 1995) using a large-scale multi-sector growth model.

There also are efforts in merging statistical and economic approaches to estimate the output gap. For example, Kuttner (1994) uses a bivariate model of inflation and output, assuming that the transitory component of output is the gap variable in the inflation equation. In this case, standard random walk trend and uncorrelated shocks assumptions from the unobserved-components models are used to complete the model.

In a recent paper, Basistha and Nelson (2007) estimate a hybrid Phillips curve containing both forward-looking and backward-looking components in order to estimate the output gap. Furthermore, the approach allows the gap to differ from cycle, and relaxes the restriction that trend and cycle shocks are uncorrelated. The theoretical support of this work is the New Keynesian framework where estimation of the natural output, expectations and credibility play a central role. In this context and unlike previous frameworks, the extraction of the output gap affects inflation and expectations through the Phillips curve. The forward-looking nature of price setting implies that inflation and output gap depend not only on the current value of their driving variables but also on their anticipated future values and therefore, inflation and output gap are forward-looking variables. As a result, anticipated policy actions will have an influence on current outcomes and thus the Central Bank may benefit from being able to influence related expectations.

I follow Basistha and Nelson (2007) to estimate output gap using Peruvian quarterly data for the period 1980:1-2005:4. I consider that Peruvian time series data offer an interesting environment to analyze theoretical and practical performance of the New Keynesian approach in order to estimate output gap. Unlike all other Latin American countries (and except Chile), Peruvian economy has experimented strong modifications in its structure. It is around 1992 where government started a process of structural reforms addressed to obtain commercial openness, larger development of the capital and financial markets, more flexibility in the labor market and more efficiency of the monetary and fiscal policy. Furthermore in 2002 a fully-fledged-inflation targeting regime was officially adopted[1]. All these measures implied reduction in volatility of nominal variables, a change in the correlation between growth rate of money and inflation, a reduction of levels of inflation and nominal interest rate, and high growth rates of real output.

Unlike data used in Basistha and Nelson (2007), Peruvian data belongs to the class of emerging countries. These economies are characterized for a larger exposition to changes in its economic structure and consequently there is less stability in its economic cycles. In addition, Peruvian economy is partially dollarized in its financial sector. This characteristic jointly with the use of an inflation targeting regime allows to emerge a particular case of study.

A further interesting characteristic of the Peruvian economy is its desinflationary process arrived since Central Bank announced inflation target in 1994. From the perspective of the New Keynesian framework the component forward-looking in inflation plays a key role during periods of disinflation[2].

Empirical literature related to the output gap in Peru is scarce. Miller (2003) presents a detailed survey about the different techniques applied to estimate output gap in a set of Latin American economies for the period 1994:01-2002:12. The survey indicates that most used methods are the function of production, the filter of Hodrick and Prescott (1997), structural vector autoregressive models, segmented trend models and the decomposition of Beveridge and Nelson (1981). On another side, Llosa and Miller (2005) use an unobserved multivariate components model in order to estimate the output gap. Unlike the approach used in this paper, Llosa and Miller (2005) calibrate their model and they assume that the slope of the Phillips curve is 0.7 which seems to be excessive. In addition, they consider backward and forward-looking magnitudes relatively different to the ones used in the standard literature.

This paper contributes to the scarce literature of output gap in Peru with new and different estimates more in agreement with the characteristics of the Peruvian economy. Our results suggest a very flat Phillips curve with around 40% and 60% of forward and backward-looking components, respectively. Comparing our results with Basistha and Nelson (2007), our Phillips curve is more flat and they suggest that forward-looking components are less important in Peruvian economy. Our results strongly suggest that the calibrated values assumed by Llosa and Miller (2005) are very far from reality. In a recent research, Salas (2009) uses a semi-structural model with around 31 equations and he concludes that the slope of the Phillips curve is between 0.05-0.20 which is also very different to Llosa and Miller (2005) but in agreement with our results. Furthermore, using a multi-country forecasting model, Canales et al. (2008) found close results to our estimates.

The document has the following sections. In Section 2, the model is presented. Section 3 discusses the estimates. Section 4 presents the augmented model introducing the unemployment rate. Section 5 discusses the results. Finally, Section 6 concludes.

THE MODEL

The forward-looking New Keynesian Phillips curve may be derived based on the type of pricing model suggested by Calvo (1983). In this framework, the forward-looking New Keynesian Phillips curve is based on optimizing behavior by forward-looking and monopolistically competitive producers. See also Galí and Gertler (1999), Sbordone (2002), Goodfriend and King (1997), Rothemberg and Woodford (1997), and Yun (1996). This curve takes the following specification:

$$\pi_t = \beta E_t \, \pi_{t+1} + \delta c_t + z_t, \tag{1}$$

where π_t is the inflation rate, c_t is the output gap due to nominal rigidities, z_t is a supply shock to inflation rate, and $E_t \pi_{t+1}$ is the (unobservable) aggregate expectation of inflation rate at the period t+1 based on information at period t. In empirical research lagged inflation rate has been added to these models because it has considerable explanatory power. It is named a hybrid Phillips curve because there are backward-looking and forward-looking behaviors.

In the present framework, expectations of inflation and the output gap are considered as unobserved variables. Therefore each variable is treated as a state variable in a state-space representation of the Phillips curve. The Kalman filter is used to extract the output gap implied by the behavior of the inflation rate. The part of the actual inflation that is not related to the gap is treated as the state variable implicit in the following measurement equation:

$$\pi_t = \tilde{\pi} + \delta c_t. \tag{2}$$

The non-gap part of inflation ($\tilde{\pi}_t$) is partially observable through its linear projection on observable variables, including survey expectations of inflation (see Roberts, 1997) and lagged actual inflation. Therefore, the state equation is

$$\tilde{\pi} = \beta_0 + \beta_1 \pi_t^{se} + \beta_2 \pi_{t-1} + \varepsilon_{\pi t}, \tag{3}$$

where π_t^{se} denotes survey expectations of inflation and $\varepsilon_{\pi t}$ is a composite of both unobserved variables that play a role in expected inflation and z_t, the supply shock. In order to ensure long-run neutrality, we restrict $\beta_1 + \beta_2 = 1$.

Concerning the decomposition of output, I follow conventional specifications. Thus, the output (y_t) consists of two unobserved components. The first one is the permanent component (p_t) which reflects the impact of permanent shocks on the equilibrium level of output. The second component is the transitory component (c_t) which is associated with nominal rigidities in the economy. The measurement equation for output is given by

$$y_t = p_t + c_t. \tag{4}$$

In order to complete the specification of the state variables, the trend component, p_t, is assumed to be a random walk with a constant drift. On the other hand, the transitory component, c_t, is assumed to be an AR(2) process, which is in the tradition of Watson (1986), Clark (1987), and Harvey and Jaeger (1993). Thus, both state equations are given by

$$\begin{aligned} p_t &= \mu + p_{t-1} + \varepsilon_{pt}, \\ c_t &= \phi_{1c} c_{t-1} + \phi_{2c} c_{t-2} + \varepsilon_{ct}, \end{aligned} \tag{5}$$

where $\varepsilon_{pt} \sim N(0, \sigma_p^2)$, and $\varepsilon_{ct} \sim N(0, \sigma_c^2)$.

Therefore, we have three shocks in the system. The generalized variance-covariance matrix to be estimated is then:

$$\text{cov}(\varepsilon_{pt}, \varepsilon_{ct}, \varepsilon_{\pi t}) = \begin{bmatrix} \sigma_p^2 & \sigma_{pc} & \sigma_{p\pi} \\ \sigma_{cp} & \sigma_c^2 & \sigma_{c\pi} \\ \sigma_{\pi p} & \sigma_{\pi c} & \sigma_\pi^2 \end{bmatrix}. \tag{6}$$

In sum, the state-space formulation of the model may be expressed as follows. Equations (2) and (4) are the measurement equations which relate observed inflation and output respectively to state variables. The equations (3) and (5) represent the state equations which establish the

behavior of the unobserved variables. The parameters are estimated using the maximum likelihood method and then I use the Kalman filter to produce filtered and smoothed estimates of the unobserved components.

RESULTS

I follow Basistha and Nelson (2007) to estimate output gap using Peruvian quarterly data for the period 1980:1-2005:4. I consider that Peruvian time series data offer an interesting environment to analyze theoretical and practical performance of the New Keynesian approach in order to estimate output gap. Unlike all other Latin American countries (and except Chile), Peruvian economy has experimented strong modifications in its structure. It is around 1992 where government started a process of structural reforms addressed to obtain commercial openness, larger development of the capital and financial markets, more flexibility in the labor market and more efficiency of the monetary and fiscal policy. Furthermore, in 2002 a fully-fledged-inflation targeting regime was officially adopted. All these measures implied reduction in volatility of nominal variables, a change in the correlation between growth rate of money and inflation, a reduction of levels of inflation and nominal interest rate, and high growth rates of real output.

Furthermore, unlike data used in Basistha and Nelson (2007), Peru is an emerging country which is characterized for a larger exposition to changes in its economic structure and consequently there is less stability in its economic cycles. In addition, Peruvian economy is partially dollarized in its financial sector. This characteristic jointly with the use of an inflation targeting regime allows to emerge a particular case of study.

Quarterly data for the period 1980:1-2005:4 is obtained from the Statistics of the Central Bank of Peru. Quarterly output is the log of real GDP and quarterly inflation has been computed using the seasonally adjusted CPI data and was annualized. Data for inflationary expectations is not available for the complete sample. Therefore, I use lagged inflation as an approximate measure for inflationary expectations.

Estimates of equations (2)-(5) are presented in Table 1. The estimate of the trend growth rate μ is around 2.2% percent annually. The estimated response of inflation to the gap is only 0.03 indicating a very flat-sloped Phillips curve. Compared with other estimates, it is very small; see Basistha and Nelson (2007), Rudebusch (2002). The estimates also show a negative correlation between the inflation shock and the output-gap shock ($\rho_{\pi c}$), zero correlation between the output-gap shock and shocks to the permanent component (ρ_{pc}), and zero correlation between the permanent shock and the inflation shock ($\rho_{p\pi}$).

Notice that the zero correlation between the trend and cycle components (ρ_{pc}) obtained in the model is consistent with the assumption frequently used in the unobserved component model.

High persistence in output gap dynamics is found. The sum of the autoregressive coefficients is 0.938, whereas the estimate using the approach of Morley, Nelson and Zivot (2003) is only 0.234. Because the approach of Morley, Nelson and Zivot (2003) is univariate, the difference in the estimates suggests the important role of inflation in identifying the persistence of the output gap. It is consistent with the findings of Kuttner (2004), Apel and Jansson (1999), and Roberts (2001).

Table 1
Results

The trend drift, the Phillips curve slope and the autoregressive coefficients					
μ	0.531	(0.194)	$\phi_{1,c}$	1.464	(0.119)
δ	0.029	(0.013)	$\phi_{2,c}$	-0.525	(0.108)
The non-gap coefficients of the Phillips curve					
β_0	0.007	(0.102)			
β_1	0.388	(0.087)			
The standard deviations and the correlations of the shocks					
σ_p	1.171	(0.509)	ρ_{pc}	0.245	(0.615)
σ_c	2.378	(0.709)	$\rho_{p\pi}$	0.236	(0.595)
ρ_π	0.936	(0.069)	$\rho_{\pi c}$	-0.884	(0.092)
Log Likelihood -275.4021					

Standard errors in parenthesis

Although the estimates indicate a high level of backward-looking (0.612) compared with the forward-looking component (0.388), the last component appears to play a key role in the estimation of the output gap.

Empirical literature related to the output gap in Peru is scarce. Miller (2003) presents a detailed survey about the different techniques applied to estimate output gap in a set of Latin American economies for the period 1994:01-2002:12. The survey indicates that most used methods are the function of production, the filter of Hodrick and Prescott (1997), structural vector autoregressive models, segmented trend models and the decomposition of Beveridge and Nelson (1981). On another side, Llosa and Miller (2005) use an unobserved multivariate components model in order to estimate the output gap. The approach is very similar to the one used here, however, Llosa and Miller (2005) calibrate their model. They assume that the slope of the Phillips curve is 0.7 which seems to be excessive. In addition, they consider backward and forward-looking levels relatively different to the ones used in the standard literature.

Our results suggest a very flat Phillips curve with around 40% and 60% of forward and backward-looking components, respectively. Comparing our results with Basistha and Nelson (2007) our Phillips curve is very flat and the forward-looking component is less important. It seems to be coherent for a partially dollarized economy like Peru which is a particular characteristic of this economy compared to other countries in Latin America. Our results strongly suggest that the calibrated values assumed by Llosa and Miller (2005) are very far from reality. In a recent research, Salas (2009) uses Bayesian tools to estimate a semi-structural model with around 31 equations and he concludes that slope of the Phillips curve is between 0.05-0.20 which is also very different to the results of Llosa and Miller (2005) and more in agreement with our results. The estimates of the backward and looking-components are also close to our estimates. Furthermore, using a multi-country forecasting model, Canales et al. (2008) found close results to our estimates and Salas (2009)[3].

Our measure of output gap selects correctly the inflationary and deflationary episodes. The periods detected with inflationary pressures are 1987:1-1990:2 and quarters after 2004. The long deflationary period is detected in 1990:3-1998:4. A neutral period appears to be 1999:1-2003:4.

In order to see how different and good our measure of the output gap is, I calculated other measures of output gap using some well known methods. I calculated output gap using the filter of Hodrick and Prescott (1997), the filter of Baxter and King (1999), the filter of Christiano and Fitzgerald (2003), the decomposition of Beveridge and Nelson (1981), the unobserved component model proposed by Clark (1987), a model with a linear time trend, and a model with quadratic time trend.

The Figure 1 shows the evolution of the different output gap measures. For example, it is easy to observe that our measure is almost completely unrelated with the measure of output gap calculated using the approach of Beveridge and Nelson (1981). The simple correlation is 0.070. Unlike this measure, our measure is large and persistent. Intermediate values of correlations are obtained with the filter of Hodrick and Prescott (0.656), the filter of Baxter and King (0.691) and the unobserved components model (0.523). Our measure presents more similarity with the measures obtained using a simple linear trend (0.932) and a simple quadratic trend (0.856).

Another way to evaluate the different measures is to observe the identification of the inflationary or deflationary pressures along the period of estimation. For example the measure obtained by the decomposition of Beveridge and Nelson (1981) appears to be poor in the identification of the periods. The first above inflationary period is not detected by the decomposition of Beveridge and Nelson (1981) and the unobserved components model. All measures, except our one, indicate that for 2003 until end of the sample there are not inflationary pressures (neutral position). The measure estimated using a quadratic trend appears to be closely related to our measure which is very impressive because is a very simple univariate method.

In summary, our results indicate a very flat slope of the hybrid Phillips curve, around 39% of forward-looking component and a large and persistent measure of output gap. These results are consistent with other Peruvian recent estimates due to Salas (2009). Comparing our estimates with those found by Canales et al. (2008) for a set of Latin-American countries, Peru appears to be a special case. Some explanations for these differences may be the partial dollarization of the economy, a large period using an inflation targeting scheme. Furthermore, the sample covers a period of important and strong structural reforms in many areas of the Peruvian economy.

ADDING THE UNEMPLOYMENT RATE

Following the suggestion of Clark (1987), and in order to exploit potential useful information of the unemployment rate, I extend the previous model adding the unemployment rate. In a similar way as for the output, I define the unemployment rate to be a sum of the natural rate (n_t) and the unemployment gap (c_{ut}):

$$u_t = n_t + c_{ut}. \tag{7}$$

Following the representation of the Okun's Law used by Clark (1987), I assume that the current and lagged output gap affect the unemployment gap:

$$c_{ut} = \gamma_0 c_t + \gamma_1 c_{t-1}. \tag{8}$$

Concerning the natural rate of unemployment (n_t), I assume that it follows a random walk without drift which is in the same spirit as Clark (1987), and Apel and Jansson (1999):

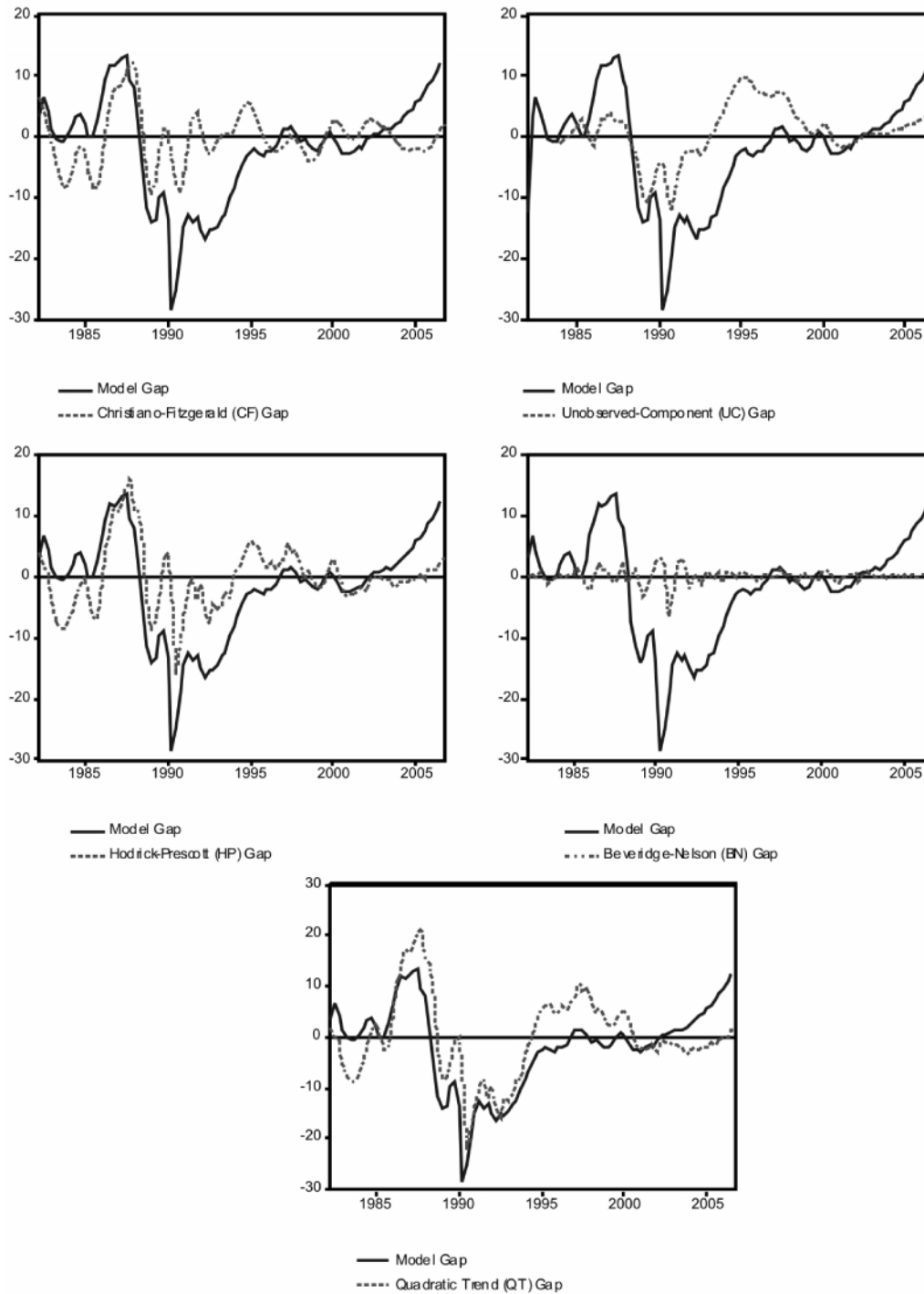$$n_t = n_{t-1} + \varepsilon_{nt}. \tag{9}$$

Figure 1: Estimates of Output Gap

Finally, the variance-covariance matrix of the four shocks is allowed to be completely general:

$$
\text{cov}(\varepsilon_{pt}, \ \varepsilon_{ct}, \ \varepsilon_{\pi t}, \ \varepsilon_{nt}) =
\begin{bmatrix}
\sigma_p^2 & \sigma_{pc} & \sigma_{p\pi} & \sigma_{pn} \\
\sigma_{cp} & \sigma_c^2 & \sigma_{c\pi} & \sigma_{cn} \\
\sigma_{\pi p} & \sigma_{\pi c} & \sigma_\pi^2 & \sigma_{\pi n} \\
\sigma_{np} & \sigma_{nc} & \sigma_{n\pi} & \sigma_n^2
\end{bmatrix}.
\tag{10}
$$

RESULTS

The results of the extended model are presented in Table 2. The estimates of the drift and the slope of the Phillips curve are very similar as those presented in Table 1. The coefficients corresponding to the Okun's Law are not significant. It means absence of persistence in the unemployment gap. The equation related to the inflation shows that the backward-looking component is relatively more important (0.608).

Table 2
Results

The trend drift, the Phillips curve slope and the Okun's law coefficients					
μ	0.417	(0.161)	γ_0	-0.088	(0.109)
δ	0.023	(0.011)	γ_1	-0.012	(0.053)
The autoregressive coefficients and the non-gap coefficients of Phillips curve					
$\phi_{1,c}$	1.456	(0.102)	β_0	0.066	(0.071)
$\phi_{2,c}$	-0.501	(0.102)	β_1	0.392	(0.083)
The standard deviations of the shocks					
σ_p	1.136	(0.475)	σ_π	0.931	(0.067)
σ_c	2.493	(0.623)	σ_n	0.742	(0.073)
The correlations of the shocks					
ρ_{pc}	0.122	(0.512)	ρ_{pn}	0.307	(0.457)
$\rho_{p\pi}$	0.318	(0.484)	ρ_{cn}	-0.069	(0.309)
$\rho_{\pi c}$	-0.858	(0.099)	$\rho_{\pi n}$	-0.074	(0.297)

Standard errors in parenthesis

The cyclical component presents high persistence as shown by the sum of the autoregressive coefficients which is 0.955. The correlation between the shocks of the trend and cyclical components is not significant. It is the same result as in the Section 3 indicating that the assumption of the unobserved components model is not rejected.

The correlation of our measure of output gap with other measures is similar to those obtained before. Higher correlations are obtained with the quadratic and linear methods to calculate the output gap. The correlation with the reduced model (Sections 2 and 3) is 0.968; see Figure 2.

All results indicate that unemployment rate does not contain useful information in the estimation of the output gap. Our conjecture is related on the poor quality of this variable.
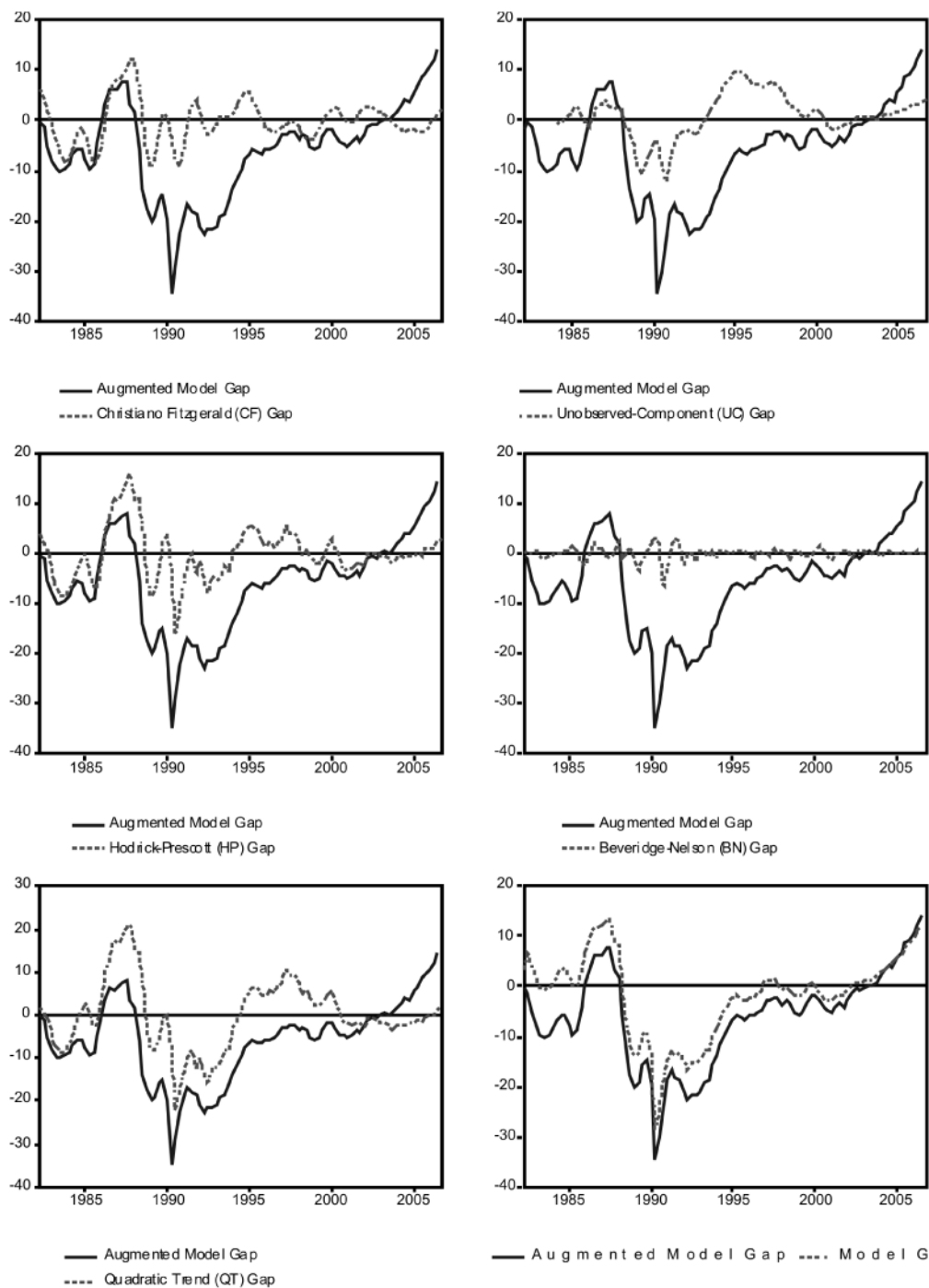
Figure 2: Estimates of Output Gap (Augmented Model)

CONCLUSIONS

This paper identifies the output gap using the New Keynesian framework theoretical definition of gap within a Phillips curve. This approach allows the gap to differ from the cycle and relaxes the restriction that the trend and cycles are uncorrelated.

The results show that the output gap is large and persistent. Furthermore, the output gap is not correlated with the stochastic trend which is similar to the assumption used in the unobserved components model. The model has been extended to include information coming from the unemployment rate. The results are very similar to those obtained without this variable indicating poor useful additional information in the unemployment rate to identify the output gap.

Empirical literature related to the output gap in Peru is scarce. Miller (2003) presents a detailed survey about the different techniques applied to estimate output gap in a set of Latin American economies. The survey indicates that most used methods are the function of production, the filter of Hodrick and Prescott (1997), structural vector autoregressive models, segmented trend models and the decomposition of Beveridge and Nelson (1981). On another side, Llosa and Miller (2005) use an unobserved components multivariate model in order to estimate the output gap. The approach is very similar to the one used here, however, Llosa and Miller (2005) calibrate their model. They assume that the slope of the Phillips curve is 0.7 which seems to be excessive. In addition, they consider backward and forward-looking levels relatively different to the ones used in the standard literature.

Our results suggest a very flat Phillips curve with around 40% and 60% of forward and backward looking components, respectively. Comparing our results with Basistha and Nelson (2007) our Phillips curve is very flat and the forward-looking component is less important. It seems to be coherent given the fact that Peru is a partially dollarized economy. Our results strongly suggest that the calibrated values assumed by Llosa and Miller (2005) are very far from reality. In a recent research, Salas (2009) uses Bayesian techniques to estimate a semi-structural model with around 31 equations and he concludes that slope of the Phillips curve is between 0.05-0.20 which is also very different to results of Llosa and Miller (2005) and more in agreement with our results. Furthermore, using a multi-country forecasting model, Canales et al. (2008) found close results to our estimates.

For comparison, I have tried with other estimations of output gap. I used the procedures of Hodrick and Prescott (1997), Baxter and King (1999), Beveridge and Nelson (1981), the unobserved components model and a simple quadratic trend to obtain the output gap. The results show strong differences between our measure of output gap and other measures. The closer measure is the one obtained using the unobserved component model and the simple quadratic trend.

Notes

1.   It is worth to say that Peru was announcing targets for inflation since 1994.

2. In many empirical works it is assumed backward-looking expectations which imply that output gap has permanent effects on the level of inflation rate. Furthermore, this structure implies that level of inflation rate is unpredictable which is contradictory with inflation target policies.

3. It is worth to mention that Salas (2009) and Canales et al. (2008) use lagged output gap in the hybrid Phillips curve. I use contemporaneous output gap.

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