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Competing theories of the wage-price spiral and their forecast ability

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Declaration

I declare that this thesis, which I hereby submit for the degree of Doctor of Philosophy (Economics) at the University of the Witwatersrand, Johannesburg, is my own work and has not been submitted by me for any degree or examination at any other University.

Signed :...
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June 2017

Dedication

To my family.

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I would like to thank God, and my supervisor Professor Christopher Malikane for his assiduous efforts in his guidance throughout the process of writing this thesis.

Abstract

This thesis contains three main chapters. The first chapter employs wage-price spirals to generate inflation forecasts for Australia, Canada, France, South Korea, South Africa, United Kingdom and the United States. We use three competing specifications of the wage-price spirals, and test which specification provides the best forecasts of price inflation. For each specification we provide one quarter, four quarter and eight quarter ahead dynamic forecasts of price inflation. The first two wage-price spirals in the first chapter are from the Keynesian tradition from te standpoint of expectations formation. The chapter also considers the New Keynesian wage-price spiral. We use the Root Means Square Error and the Clark and West statistic to compare the performance of inflation forecasts from the three competing wage-price spirals that we consider in the first chapter of the thesis. We find that the New Keynesian wage and price specification suffers from the wrong sign problem, and its forecasts of price inflation generally outperform those from the old Keynesian wage price spiral for the eight quarter ahead time horizon. The usefulness of this finding to the conduct of monetary policy is limited due to the wrong sign problem of the forcing variable in the New Keynesian wage-price spiral. We also find that the Flaschel type specification of price and wage inflation produce four and eight quarter head inflation forecasts that are better than those from the Fair type specification. We further find that the Fair type specification price and wage equation produce the best forecasts of inflation for the one quarter ahead time horizon.

In the second chapter, we estimate natural variables and test their ability to explain the inflation process for the eight countries that we consider. We use the traditional Keynesian wage-price spiral and the triangle system approaches to estimate the NAIRU and potential output. In the case of the traditional Keynesian wage-price spiral, the price Phillips curve, which can be specified as a triangle Phillips curve, features backward looking inflation expectations and nominal wage inflation, the output gap and supply shocks. The nominal wage Phillips curve features inflation expectations and price inflation and the unemployment gap. The presence of price inflation in the nominal wage Phillips curve and the presence of nominal wage inflation in the price Phillips curve leads to the interaction between the two Phillips curves. The separate demand pressure terms allows for their identification since, as

some authors in the literature argue that the goods and labour markets do not move in line with each other. To compute the NAIRU and potential output using the Keynesian approach, we firstly exploit the information contained in vector of unobservable by estimating the wage-price spiral in difference form using the Seemingly Unrelated Regression method. We use this regression method in order to control for any correlation that may exist between errors in the price and wage Phillips curves. This allows us to solve for the vector of potential output and the NAIRU. We then the moving average technique in order to avoid problems associated with the HP filter for smoothing. Due to data availability, use the MA (20) approximation of the low pass filter after padding the endpoints with forecasts from an AR(4) process. We follow a similar procedure in the estimation of the estimation of the NAIRU and potential output for the triangle system approach. To test which method produces the best natural variables, we fit the gaps that are computed from the NAIRU and potential output in a simple single equation price Phillips curve. To test which specification produces the best natural varibles we use a simple single equation triangle price Phillips curve. We find that the output gaps computed from the two competing approaches are significantly correlated, the same applies to the unemployment gaps computed from the two approaches. We find that the quality of unemployment rate gaps computed from the Keynesian and triangle system approach to produce similar quality of results when fitted to a single equation triangle price Phillips curve. The Keynesian approach slightly outperforms the triangle systems approach in the when considering the output gap as a proxy for the demand pressure. These results indicate that the wage-price spiral still remains an important tool in the determination of the dynamics inflation.

In the third chapter, we analyze the relationship between monetary policy and natural variables for Australia, Canada, France, South Korea, South Africa, United Kingdom and the United States. We do this by specifying a relationship between natural rates and the real interest rate. The theoretical relationship between the two variables is positive in the case of the NAIRU and negative through Okun's law in the case of potential output. We regress the natural variable against a constant and the MA(8) of the real interest rate. We find that the parameter of the real interest rate generally has a correct sign when considering the Keynesian approach computed NAIRU's, with only four being significant. In the case of the triangle system approach NAIRU, we find that the real interest rate parameter has a correct sign and

significant four countries. We find that NAIRUs computed using different methodologies can produce a different reference point for policy makers. We then introduce hysteresis in the relationship between monetary policy and the NAIRU. We then find that the interest rate parameter generally has a incorrect sign across the three approaches. The HP filtering approach which we include in our study for comparison purposes produces incorrect correlation for all the countries, while the Keynesian approach negative correlation for seven countries, and the triangle system approach in six countries. In the case of the relationship between monetary policy and potential output, we find that the real interest rate parameter has an incorrect sign. When introducing hysteresis in the relationship between monetary policy and potential we find that, unlike in the case of the NAIRU this plays significant role in the relationship.

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1 Introduction

1.1 Background of the study

The interaction of price inflation and wage inflation is often called a wage-price spiral. This is represented by a separate price Phillips curve and wage Phillips curve that are related. Wage-price spirals have over time emerged as an important tool in the determination of inflation dynamics. Smets and Wouters (2003) use the wage-price spiral to explain the inflation process within a New Keynesian School of thought. The use of the wage-price spiral also finds its roots in the old Keynesian literature that seeks to explain the dynamics of inflation. For instance, Fair (2008) uses an old Keynesian wage-price spiral to explain inflation dynamics, old from the standpoint of backwards expectations formation. He, however, argues that separate wage and price equations outperform single equation Phillips curves including the New Keynesian price Phillips curve in explaining the dynamics of inflation. He finds that the wage-price spiral outperforms the New Keynesian Phillips curve in explaining the dynamics of price inflation. He however does not compare the traditional backward looking wage-price spiral with the rational expectation formation New Keynesian wage-price spiral.

It is important to note that a theoretically sound process that best explain the dynamics of inflation is the most important for the conduct of monetary policy. This places the wage-price spiral in an important position in the determination of the inflation process. This debate can also be extended to the estimation of natural variables, which as argued by Ball and Mankiw (2002) are an important reference point for the conduct of monetary policy. In this instance, a separate specification of the price and wage equation or a systems approach has been argued by Apel and Jansson (1999) to contain more information that is useful in the estimation of natural variables. There has also been a long running debate in the literature that is often not prominent around the orthogonality of monetary policy and natural variables. Where the monetarist view from Friedman (1968) and Phelps (1968) is that monetary policy does not drive natural rates in the longrun. There is also a view from Blanchard (2003) that monetary policy does have a longrun impact on natural variables.

1.2 Motivation of the study

This study is motivated by the lack of consensus in the literature on which wage-price spiral best forecasts inflation. The debate on which wage-price spiral between the Keynesian and New Keynesian specification provides the best inflation forecast has not been settled in the literature. Yet, the determination of inflation process is central in the present day conduct of monetary policy. The second motivation of the study emanates from the fact it is important to compare natural variables from a wage-price spiral and a triangle system Phillips curve, this seems to be a sticky point in the literature. Gordon (1997) uses his triangle Phillips curve model to estimate a time varying NAIRU, while Apel and Jansson (1999) find that there is important information contained in a systems based approach of estimating the NAIRU and potential output. Similarly, the wage-price spiral contains more information than a single equation triangle Phillips curve that can be incorporated in the price equation of the wage-price spiral.

This ties in with the first motivation outlined in the relationship between natural variables and inflation forecasts in the conduct of monetary policy as pointed out in Gordon (1997). This brings us to the last part of our motivation, the raging debate in the literature regarding the relationship between monetary policy and the natural variables. The debate around whether monetary policy determines natural variables is still ongoing since Friedman (1968). The three sets of motivations shape the objectives of the study. We conduct this study for Australia, Canada, France, South Korea, South Africa, United Kingdom and the United States. This diverse group of countries from the standpoint of different levels of development, the fact that and their central banks consider price stability as an important part of their conduct of monetary policy places the computation of inflation expectations, the computation of natural variables as a reference for monetary policy, and whether the natural variables are orthogonal to monetary policy or not.

1.3 Objectives of the study

The objective of this study is to revisit the usefulness of wage-price spirals. We revisit their usefulness in three ways. Firstly, we study the usefulness of wage-price spirals in forecasting price inflation. As pointed out by Ball and Mankiw (2002) central banks target inflation expectations when trying to manage prices. It then becomes important to know which wage-price spiral best forecasts inflation. This knowledge ensure the minimization of policy errors from the standpoint of monetary policy. Secondly, we study whether wage-price spiral provides better estimates of natural rates compared to a triangle system based Phillips curve.

As pointed out by Ball and Mankiw (2002), natural rates should be used as reference points for the conduct of monetary policy in the management of aggregate demand. Thirdly, we study the relationship between natural rates and monetary policy. There are two main competing views in the literature on this issue. The first relates to the monetarist view that monetary policy does not have an impact on natural variables since they are longrun levels. The second view rests on the Keynesian view that monetary policy does affect longrun variables in both the short and longrun for instance Blanchard (2003). This leads use to the last objective of the study, which is to test whether monetary policy determines longrun variables.

1.4 Research problem

The research problem in this study emanates from the work of Fair (2008). He finds that the wage-price spiral outperforms the single equation New Keynesian Phillips curve in explaining the inflation process. On the other hand, Gordon (2011) finds that the backward looking triangle Phillips curve outperforms the New Keynesian Phillips curve in explaining inflation dynamics. The implications of the finding in Fair (2008) is that the wage-price spiral should be used to forecast price inflation, and that the literature is not using the best models in studying the inflation process. The argument of this study is that wage-price spirals should be used to forecast inflation and to estimate proxies of natural variables. This is because of the information benefit of having a separate wage and price equations compared to reduced form equations.

1.5 Research questions

The following research problem poses the following three main question:

i) Which wage-price spiral best forecasts inflation?
ii) Which model between the Keynesian wage-price spiral and the triangle system produces natural variables that best explain inflation?
iii) Does monetary policy determine natural rates?

1.6 Contribution of the study

Firstly, the study compares the performance of competing wage price spiral in forecasting inflation to test which specification produces the best forecasts of price inflation one, four and eight quarter ahead, respectively. This has important implication for the conduct of monetary policy given that there are competing specifications of forecasting price inflation. Secondly, the study estimates potential output and the NAIRU using two competing methodologies, the Keynesian wage-price spiral approach similar to Flaschel et al. (2007) and a triangle system approach of Apel and Jansson (1999). Thirdly, the study builds on the work of Semmler and Zhang (2004) and introduces hysteresis to test if monetary policy significantly determines natural variables.

2 Competing Theories of the Wage-Price Spiral and Their Forecasting Ability of Price Inflation

2.1 Introduction

This chapter estimates three competing wage-price spiral specifications and compares their price inflation forecasts. Wage and price equations are used for forecasting the inflation process and in studying income distribution. For instance, Fair (2008) uses wage and price equations to forecast wage and price inflation. He finds that the separate specification of wage and price equations provide good forecasts of the inflation process. As pointed out by Fair (2008), the study of price equations is perhaps the most important task in macroeconomics. This importance arises from their use in the conduct of monetary policy. On the other hand, Flaschel (2009) uses wage and price equations to study the dynamics of income distribution. As noted by Franke et al. (2006), income distribution plays an important role in the determination of nominal and real economic variables like consumption and investment.

The significance of this chapter is that it tests the forecast ability of three competing wage and price equation specifications. There has been a longstanding debate in the literature of the Phillips curve regarding which specification best explains the inflation process. The study of price equations as pointed out by Fair (2008) is informed by estimating the best forecasts of prices for purposes of the conduct of monetary policy. This paper attempts to determine which specification of the wage and price equations best explains the inflation process. As pointed out by Bernanke and Woodford (1997), a central bank that targets inflation effectively targets inflation expectations. The study of wage and price equations provides a way of extracting inflation forecasts.

The gap that exists in the literature is that the competing specifications of the wage and price equations have not been tested together. Flaschel et al. (2007) find that the separate specification of the wage and price equation by Fair (2000) produces better estimates compared to the New Keynesian Phillips curve. They point out that the New Keynesian Phillips curve only comprises of one equation based on the labour market equilibrium. They do not however test the forecast ability of their specification to that of the New Keynesian approach. This paper tests the forecast ability of an old

Keynesian wage and price equation and the New Keynesian specification. The New Keynesian specification that we consider in this paper has separate wage and price equations.

The contribution of this chapter is to test the forecast ability of three specifications of the wage-price spirals found in Fair (2008), Flaschel et al. (2007) and a Keynesian specification. We use two methods of evaluation to test the forecast ability of the three competing wage and price specifications. This test is performed on the dynamically simulated forecasts from the three competing wage and price specifications. The first method computes the standard deviation of the forecasts from actuals for the respective time horizons. The wage and price specification that produces the lowest standard deviation is interpreted to have superior forecast ability. The second method of evaluation that we use is similar to that found in Clark and West (2007). Unlike the first method, the second method of evaluation tests forecast ability between forecasts from competing wage and price specifications.

The structure of the chapter is as follows: Section 2.2 provides a review of the literature, Section 2.3 outlines the competing wage and price equations. Section 2.4 provides data, estimation strategy and empirical results of the three competing specifications in the form of parameter estimates and the evaluation of dynamically simulated forecasts. Section 2.5 provides forecast evaluation and Section 2.6 concludes.

2.2 Review of Literature

There has been renewed interest in the ability of wage and price specification explaining inflation dynamics. As pointed out by Fair (2008), the dominant approach since Gordon (1980) has been the use of reduced form Phillips curves as opposed to separate wage and price equation in studying inflation dynamics. However, Fair (2000) finds that a reduced form Phillips curve specification produces higher Root Mean Square Errors (RMSE) compared to forecasts from the separate specification of the wage and price equations. Fair (2008) also finds that the separate specification of the wage and price equations dominate the reduced form specification in explaining inflation dynamics. As argued by Flaschel et. al. (2007), separate wage and price equations improve the understanding of the impact of the labour and product markets on the macroeconomy.

There is also ongoing debate in the literature regarding the impact of the formulation of Phillips curves on inflation forecasts, and the theoretical validity of competing specifications. The debate can be summarized into three areas of focus. The first area of interest is around the wrong sign and significance of variables that explain the dynamics of inflation as found in Rudd and Whelan (2005, 2007). The second area of interest relates to the forecast ability of price equations. As pointed out by Svensson (2000) monetary policy authorities that target inflation actually target inflation expectations. The last area of focus that we consider in the literature is the debate around the specification of excess demand.

The microfoundations of the New Keynesian specification of the Phillips curve have provided grounds for policy makers to use it over the traditional Keynesian specification. The New Keynesian specification has however been beset by empirical validity problems. As reported in Rudd and Whelan (2005, 2006), Abbas and Sgro (2011), Mazumder (2010, 2011) the sign of the demand pressure variable has been found to be either negative or insignificant. The New Keynesian literature specifies the demand pressure variable as the labour share or the output gap for example as in Gali and Gertler (1999) and Gali et. al (2001). The negative sign problem for the demand pressure variable in the traditional Keynesian specification is absent. Fair (2008) and Flaschel et. al. (2007) find the demand pressure variable to have a correct sign and to be significant.

Fair (2008) incorporates supply shocks in his separate wage and price equations building on the triangle single equation specification of Gordon (1997). He finds that the demand pressure variable proxied by the unemployment rate to be highly significant. He, however, finds the demand pressure variable proxied by the output gap for the New Keynesian single equation price Phillips curve to be insignificant for the US. This finding contradicts a finding by Lindé (2005) of a significant demand pressure variable proxied by output. Mehra (2004) finds that the wrong sign problem of the output gap in the New Keynesian Phillips curve is due to the exclusion of lags of inflation and supply shocks. This shows that there is still an empirical problem around the demand pressure term for the New Keynesian model. As found in Mazumder (2010, 2011) the labour share as a proxy for demand pressure is either insignificant and has a wrong sign.

The insignificance of the expectations parameter in the New Keynesian specification has received notable attention in the literature. Gali et al. (2001) find that under rational expectations the expectations parameter is significant. This has also been an area of debate that produces contradicting results on the sign of the variable for the New Keynesian specification. Furher (1997) finds that the empirical validity of the importance of future expectations in price equations is relatively weak. This view is supported by the insignificance finding on the future expectations by Rudd and Whelan (2005, 2006, 2007). However, Lindé (2005) finds that future expectations play a significant role in the inflation process.

The finding in Fair (2008) demonstrate that the traditional Keynesian specification of the price and wage equations does not suffer from insignificance or incorrect sign problems. As also demonstrated by Flaschel et. al. (2007), the separate wage and price equations specification improves the predictive accuracy of inflation. As pointed out by Flaschel et. al (2007), the New Keynesian approach generally uses the price Phillips curve in modelling inflation dynamics. Flaschel et. al (2007) notes from the work of Blanchard and Katz (1999) that the single equation approach of the New Keynesian tradition might be based on mark up pricing theory.

A New Keynesian critique by Flaschel et. al. (2007) of the absence of separate wage and price equations is addressed by Malikane (2013). This contribution derives separate wage and price equations that have a forward term on the right hand sight for both the wage and price equations. It also addresses problems raised by Flaschel et. al. (2007) and Mehra (2005), as argued by Gordon (1998) that supply shocks are important in the determination of inflation. The contribution by Malikane (2013) addresses the single reduced form equation short coming of the New Keynesian literature and presents an opportunity to compare the separate wage and price equations with those of the traditional Keynesian specification.

2.3 Outline of the Competing Wage-Price Phillips curve specifications

In this section, we start by outlining the wage price spiral by Fair (2008). This is followed by the wage price spiral similar to that of Chiarella and Flaschel (2000), Fair (2000), Flaschel et al. (2001), Asada et. al. (2006) and Flaschel et al. (2007). The remaining part of this section outlines the New Keynesian wage price spiral that takes into consideration supply side shocks found in Malikane (2013) where the non-labour inputs into production are supply side shocks.

Equations (1) and (2) below outline the price and wage Phillips curve specifications similar to that found in Fair (2008):

$$\begin{aligned} p_t &= \alpha_\pi + \beta_\pi p_{t-1} + \gamma_\pi w_t + \delta_\pi p_t^m + \rho_\pi u_t + \vartheta_\pi t + \varepsilon_t, \quad (1) \\ w_t &= \alpha_w + \beta_w w_{t-1} + \gamma_w p_t + \theta_w p_{t-1} + \rho_w u_t + \vartheta_w t + \mu_t, \quad (2) \end{aligned}$$

where p_t is the log of the actual price level, w_t the log of the nominal wage rate, p_t^m the log of import prices, u_t is the unemployment rate, t is the time trend as noted by Fair (2004, 2008) included to capture relative changes between wages and prices, and ε_t and μ_t are error terms. Following the Fair (2008) specification for the wage equation $\theta_w = \left[\frac{\beta_\pi}{1-\gamma_\pi}\right](1-\gamma_w) - \beta_w$. This restriction as explained in Fair (2004) captures the fact that wages are a function of their own lagged value and other terms. As pointed out by Fair (2004) import prices are excluded in the wage equation since together with the unemployment rate since their influence is captured in the price equation, thereby eliminating identification problems. The formulation avoids problems associated with the introduction of instruments in the estimation of the wage-price spiral.

In formulating his wage price spiral, Fair (2008) uses the triangle model formulation for the determinants of the price equation from Gordon (1997), this formulation models inflation as a function of lagged inflation which captures the persistence of inflation, the demand side pressure which can be captured by either the unemployment rate or output, and supply side shocks. In addition to these terms, Fair (2008) adds the time trend to capture any trend effects that might not be captured by the persistence, demand pressure or supply shocks on the price level or inflation. We note the exclusion of the unemployment rate in the wage equation by Fair (2008), and explicitly introduce it in the wage equation since its exclusion was based purely based on the empirical finding for the US that the unemployment rate for the country has a wrong sign but is insignificant.

Equations (3) and (4) below outline the traditional Keynesian type price and wage specifications similar to Flaschel et. al. (2007):

$$\pi_t = \alpha_0 + \beta_0 \hat{\pi}_t + (1-\beta_0)\hat{w}_{t-1} + \rho_0 \hat{y}_{t-1} + \delta_0 \widetilde{\pi}^m_{t-1} + \theta_0 \widetilde{\pi}^f_{t-1} + \vartheta_0 \widetilde{\pi}^e_{t-1} + \epsilon_{\pi t}, \quad (3)$$

$$\hat{w}_t = \alpha_1 + \beta_1 \hat{\pi}_t + (1-\beta_1)\pi_{t-1} + \rho_1 \hat{u}_{t-1} + \epsilon_{\Delta wt}, \quad (4)$$

where π_t is the inflation rate, $\hat{w}_t$ is wage inflation, $\hat{\pi}_t = \frac{1}{4}\sum_{j=1}^{4} \pi_{t-j}$ is the autoregressive inflation rule of thumb as explained in Kuester et al. (2009), and following Smets and Wouters (2003) and Christiano et al. (2005) we formulate the rule of thumb as a four quarter moving average of price inflation. For Eq. (3) the demand pressure in the price equation is captured by the output gap denoted by $\hat{y}_t$, $\widetilde{\pi}^m_t$ is import inflation, π^f_t is food price inflation, π^e_t energy price inflation, $\hat{u}_t$ is the unemployment rate gap, and $\epsilon_{\pi t}$ and $\epsilon_{\Delta wt}$ are error terms, respectively.

The rule of thumb formulation in Eq. (3) and (4) addresses the problem raised by Zhang and Clovis (2010) of one lag not being sufficient in addressing serial correlation. The inclusion of supply side shocks captures the nonlabour input in the microfoundations of the traditional Keynesian backward looking Phillips curve provided by Malikane (2012). The microfoundations for the price equation leads to a term that captures demand pressures in the form of the output gap, past inflation captured by an autoregressive rule of thumb that captures the persistence of inflation and supply side shocks. This formulation has some similarities with that of Gordon (1997) triangle formulation of the price Phillips curve.

Equations (5) and (6) below outline the New Keynesian price and wage specifications similar to that of Malikane (2013):

$$\begin{aligned} \pi_t &= \alpha_p E_t \pi_{t+1} + \beta_p \pi_{t-1} + \gamma_p \widehat{w}_t + \rho_p y_t + \delta_p \widetilde{\pi}^m_{t-1} + \theta_p \pi^f_t + \vartheta_p \pi^e_t + \varepsilon_{\pi t}, &(5) \\ \widehat{w}_t &= \alpha_{\widehat{w}} E_t \widehat{w}_{t+1} + \beta_{\widehat{w}} \pi_t + \theta_{\widehat{w}} \pi_{t-1} + \gamma_{\widehat{w}} \widehat{w}_{t-1} + \rho_{\widehat{w}} \hat{y}_t + \sigma_{\widehat{w}} \hat{y}_{t-1} + \mu_{\widehat{w}t}, &(6) \end{aligned}$$

where $\pi_t$is the inflation rate, $\widehat{w}_t$ is the labour share which as shown by Malikane (2013) is a portion of the marginal cost that captures the labour input in the production process, as pointed out by Gali and Gertler (1999) the labour share is an appropriate proxy for wage inflation, E_t is the expectations operator, $\varepsilon_{\pi t}$ and $\mu_{\widehat{w}t}$ are error terms. Other variables are as explained above. The specification of the price equation includes the demand pressure term in the form of the output gap, the persistence of inflation and supply side shocks in the form of import prices, food prices and energy prices. The inclusion of supply side shocks in the price equation is also supported by Kuester et al. (2009), who find that the US New Keynesian Phillips curve is flat and attributes this to the misspecification of the marginal cost due to the fact that the labour input is too restrictive a measure to capture marginal cost due to the fact that production processes use more than one input. This specification derived by Malikane (2013), creates a hybrid of the New Keynesian Phillips curve and the triangle model of Gordon (1997).

2.4 Parameter Estimates and Forecasts Evaluation

The study uses quarterly data collected from the International Financial Statistics (IFS) database of the International Monetary Fund (IMF). We also source data from individual country central bank databases. We include the following countries in our study: Australia, Canada, France, Germany, South Korea, South Africa, United Kingdom and the United States. The choice of the countries is diverse so that we have a representation of highly developed countries and developing countries. There has been empirical work done in the literature in relation to developed countries like the United Kingdom and the United States on some of the specification that we consider in this paper. This provides us with an opportunity to contribute to the literature by highlighting which specification of the wage-price spiral produces the best forecast of inflation for different time horizons. There has however been limited work done for countries like South African and South Korea in the specifications of the wage-price spirals that we consider in this study.

The countries that we consider in this study also have central banks that consider price stability as an important part of a successful conduct of monetary policy. Understanding which wage-price spiral produces the best inflation forecasts for different time horizons is important for central banks in these countries. Data availability of the variables that we use in the study also played a role in the choice of the countries. To proxy the general price level we use the consumer price index (CPI). For wages, we use either the Nominal Unit Labour Cost (NULC) or the labour share depending on the specification of the model. For the New Keynesian specification, we use the labour share to proxy wages. While for the traditional Keynesian specification we use the NULC for the traditional specification as proxies for wages. To capture the demand pressure on prices we use either the output gap or the unemployment rate gap or unemployment rate depending on the wage and price specification of interest. For supply side shocks we use the CPI of imports, food and energy, respectively.

We use the log of consumer price index for the price level and the log of nominal unit labour cost for the wage to measure prices and wages, respectively in the estimation of the Fair (2008) wage and price equations. For the demand pressure we, use the unemployment rate following Fair (2008). Following Fair (2008), we also include the linear time trend to capture relative wage and price changes. To estimate the Fair (2008) wage-price spiral outlined in Eqs. (1) and (2) we use two stage least squares. We start by estimating the price equation, then the estimated parameters for the log of lagged price level and log of wages are used in the restriction of the log of lagged price level when estimating the wage equation outlined in Eq. (2). This specification preserves the theoretical restriction of the impact of current prices on wages as explained in Fair (2004, 2008).

To estimate the traditional Keynesian wage and price equations, for inflation we use the growth rate of consumer price index and for wage inflation the growth rate of the nominal unit labour cost. For the demand pressure term on the price equation we use the output gap. While in the wage equation the demand pressure variable is measured by the unemployment rate gap.

For supply shocks, import prices are measured by the real growth rates of import consumer price index, food consumer price index and energy price index. The autoregressive rule of thumb in Eq. (3) and (4) is measured by the four quarter moving average following Malikane (2012) of the price and wage inflation, respectively. We also use two stage ordinary least squares to estimate the price and wage equations (Eq. (3) and (4)).

To estimate the New Keynesian wage and price equations (Eq. (5) and (6)), for inflation we use the growth rate of consumer price index and for wage inflation we use the labour share gap. For the demand pressure term following Gali et. al. (2001) and Malikane (2013) on both the price and wage equations we use the output gap. Supply side shock are measured the same as in the traditional Keynesian wage-price spiral case. We use ordinary two stage least squares to estimate the New Keynesian wage and price equations similar to Fair (2008), it should be noted this method avoids the instrument choice problem associated with estimation techniques like the GMM estimation technique. For the expected price and wage inflation, we estimate a first stage equation with four lagged instruments of explanatory variables. We then extract fitted value that we use in the second stage estimation of the wage and price equations respectively to proxy future expected price and wage inflation.

We ran a total of 628 wage-price spirals for the eight countries that we consider. For the seven of the eight countries that we consider, we started in 1989Q4 until 2011Q4. This was based on the fact that this period signalled the emergence of the importance of the focus on price stability and understanding the dynamics of inflation expectations for central banks. For South Korea we started in 2001Q1 until 2011Q due to the data starting later for this country. This means that for each of the seven countries that we consider except South Korea we ran 84 wage-price spiral estimations, and for South Korea we similarly ran 40 of the same estimations starting in 2001 in this instance.

For example, starting in 1989Q4, we estimate the wage-price spiral and generate simulations that forecast one, four and eight quarter ahead forecasts, respectively. We then increase the sample size by including 1990Q1 and estimate the wage price spiral and then generate the one, four quarter ahead forecasts of inflation, respectively. We repeat this process until the sample is exhausted. This results in 1884 dynamic simulations for the eight countries that we consider in this paper based on the 628 estimated wage-price spiral to generate one, four and eight quarter ahead price inflation forecasts, respectively. This was done for the three competing wage and price specifications given by equations (1 and 2), (3 and 4) and (5 and 6). For all of the eight countries except for South Korea, we generated the respective forecasts from 1990 to 2011, this produced 1764 dynamic simulations. In the case of South Korea we ran 120 dynamic simulations to generate price forecasts from 2001 to 2011.

There are two methods of evaluations that we employ when comparing price and wage forecasts. The first considers the forecast ability between of different specifications to the actuals. The second method of evaluation tests forecast ability between competing wage and price specifications. This type of forecast ability evaluation is similar to that of Clark and West (2007). For the first method of evaluation, we compute the difference between the actual and the forecast captured by the following equation:

$$\varepsilon_{m1} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(\pi_{t+j} - \pi^{f}_{t+j})^2}, \tag{7}$$

where π_t is actual inflation and π^f_t is the forecast, and ε_{m1} the standard deviation of the forecast errors for model one. The same evaluation is done for wages, where w_t and w^f_t replace π_t and π^f_t in Eq. (7), respectively. Forecasts form a wage and price equation specification that produces the lowest standard deviation of errors (ε_{m1}) is interpreted to have superior forecast ability. For the second method of evaluation, the first step of evaluating the forecast ability of competing wage and price equations is already outlined in Eq. (7). Once we have calculated the standard deviation of forecasts from competing models using Eq. (7), we then take the difference between the standard deviations of two models that are being compared. This difference is captured by Eq. (8) below:

$$\varepsilon_{deff} = \varepsilon_{m1} - \varepsilon_{m2}, \tag{8}$$

where ε_{deff} is the difference of the standard deviation of the model one forecast errors (ε_{m1}) and model two forecast errors (ε_{m2}), respectively. In the next step of the process of evaluation, we run a regression of the difference of the standard deviation against a constant. This is captured by Eq. (9) below:

$$\varepsilon_{deff} = c_0 + \eta_t, \tag{9}$$

where c_0 and η_t is the constant and error term, respectively. Eq. (9) above is the final step of the second method evaluation used in this paper. The interpretation of Eq. (9) is that if the constant (c_0) is negative and significant, then model one (ε_{m1}) produces forecasts that are better than the forecasts from model two (ε_{m2}). Since forecast errors of model one are better than forecasts errors of model two. Results from Eq. (9) establishes whether forecasts from competing models or wage-price specification in our case are statistically different from one another or not. Even if we know from Eq. (8) that a model may have a lower standard deviation from the next, Eq. (9) establishes whether the difference is significant or not. This adds useful information about the forecast accuracy of a model or wage-price spiral compared to competing specifications. We now turn our attention to the results of the first wage-price spiral that we consider. Table 1 below presents estimated results for the second stage Fair (2008) wage-price spiral.

Table 1: Estimated Parameters of the Fair (2008) model

	Aus.	Can.	Fra.	Ger.	S. Kor.	S. Afr.	US.	UK.
$p_t = \alpha_\pi + \beta_\pi p_{t-1} + \gamma_\pi w_t + \delta_\pi p_t^m + \rho_\pi u_t + \vartheta_\pi t + \varepsilon_t,$								
α_π	-0.00	-0.02^{**}	0.18^*	0.13^*	0.47^*	0.004	0.08^*	0.05^*
	(0.02)	(0.01)	(0.03)	(0.04)	(0.13)	(0.00)	(0.01)	(0.01)
β_π	0.92^*	0.87^*	0.93^*	0.85^*	0.84^*	0.93^*	0.87^*	0.81^*
	(0.02)	(0.01)	(0.02)	(0.03)	(0.05)	(0.02)	(0.03)	(0.02)
γ_π	0.06^*	0.10^*	0.01	0.08^*	0.04	0.03^{**}	0.06^{**}	0.13^*
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
δ_π	0.02^*	0.03^*	0.01^*	0.03^*	0.01	0.05^*	0.04^*	0.05^*
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
ρ_π	-0.24^*	-0.17^*	-0.02	-0.08^*	-0.03	0.01	-0.17^*	-0.15^*
	(0.05)	(0.04)	(0.03)	(0.04)	(0.08)	(0.04)	(0.03)	(0.05)
ϑ_π	-0.00	0.00	0.00^*	0.00^*	0.00^*	-0.00^*	0.00^*	-0.00^{**}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
$S.E.$	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
$w_t = \alpha_w + \beta_w w_{t-1} + \gamma_w p_t + \theta_w p_{t-1} + \rho_w u_t + \vartheta_w t + \mu_t$								
α_w	0.11^*	0.04^*	0.18^*	0.15^*	0.18^{**}	0.03	0.07^*	0.02
	(0.03)	(0.01)	(0.08)	(0.03)	(0.11)	(0.01)	(0.01)	(0.02)
β_w	0.91^*	0.99^*	0.14^*	1.01^*	0.96^*	0.75^*	0.91^*	0.90^*
	(0.03)	(0.02)	(0.03)	(0.02)	(0.04)	(0.05)	(0.05)	(0.03)
γ_w	0.26	0.73^*	1.31^*	0.45^*	0.68^*	0.25	0.81^*	0.84^*
	(0.16)	(0.08)	(0.33)	(0.12)	(0.21)	(0.21)	(0.06)	(0.07)
ρ_w	-0.21^*	-0.10^*	-0.67^*	-0.05	-0.34^*	-0.47^*	0.003	-0.07
	(0.08)	(0.04)	(0.07)	(0.05)	(0.13)	(0.12)	(0.04)	(0.06)
ϑ_w	-0.00	0.00	-0.00^*	0.00^*	0.00	0.00^*	0.00	0.00^*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
$S.E.$	0.01	0.01	0.02	0.01	0.01	0.03	0.01	0.01

*Significant at 5%, **significant at 10%, std. errors in parentheses.

The results of the estimated parameters of Eq. (1) and (2) are presented in Table 1. The demand pressure in the price equation for the Fair (2008) specification has a correct sign for all countries that we consider except for South Africa, and largely significant across countries. Our finding on the demand pressure variable for the US is consistent with that in Fair (2008). We also find that import prices largely have a significant impact on the inflation process. The policy implication of this finding is that the conduct of monetary policy should pay particular attention to the movement of import prices, since import prices significantly explain the dynamics of inflation for seven of the eight countries that we consider. This is particularly important for South Africa that imports a sizable amount of inputs into their production processes. For the demand pressure term on the wage equation we find an incorrect sign but insignificant for the US, which explains why for the US, Fair (2008) excludes the variable in his wage-price spiral that best explains inflation dynamics for US. We also find that the trend term parameter to be small but significant, this finding is inline with Fair (2008). Table 2 below presents estimated results for the Flaschel et al. (2007) type wage-price spiral.

Table 2: Estimated Parameters of the Flaschel et al. (2007) model

	Aus.	Can.	Fra.	Ger.	S. Korea	S. Africa	US.	UK.
$\pi_t = \alpha_0 + \beta_0 \widehat{\pi}_{t-4} + (1-\beta_0)\hat{w}_{t-1} + \rho_0 \hat{y}_{t-1} + \delta_0 \widetilde{\pi}^m_{t-1} + \theta_0 \widetilde{\pi}^f_{t-1} + \vartheta_0 \widetilde{\pi}^e_{t-1} + \epsilon_{\pi t}$								
α_0	0.001	0.001	0.003	0.001**	0.001	0.001	0.001**	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
β_0	0.96*	0.96*	0.72*	0.97*	1.04*	0.99*	0.90*	0.86*
	(0.03)	(0.03)	(0.09)	(0.02)	(0.04)	(0.03)	(0.05)	(0.03)
ρ_0	0.20*	0.07*	−0.23	0.06*	0.15*	0.18*	0.14*	0.23*
	(0.05)	(0.04)	(0.09)	(0.03)	(0.04)	(0.06)	(0.04)	(0.06)
δ_0	0.01		0.10*	0.02*	0.03*	0.08*	0.05*	0.04*
	(0.01)		(0.03)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
θ_0		0.07*	−0.06		−0.06	0.03	0.09*	0.09*
		(0.02)	(0.07)		(0.04)	(0.03)	(0.02)	(0.04)
ϑ_0	0.02	−1.26*	−0.18	−1.90*	−1.94*	−1.26*	−0.20**	−2.92*
	(0.00)	(0.19)	(0.11)	(0.24)	(0.37)	(0.33)	(0.12)	(0.27)
R^2	0.94	0.95	0.98	0.95	0.76	0.92	0.95	0.96
$S.E$	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
$\hat{w}_t = \alpha_1 + \beta_1 \widehat{\pi}_{t-4} + (1-\beta_1)\pi_{t-1} + \rho_1 \hat{u}_{t-1} + \epsilon_{\Delta wt}$								
α_1	0.001	−0.002	−0.01*	−0.02*	−0.01*	0.03	−0.01*	0.01*
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
β_1	0.72**	1.80*	0.67*	1.84*	−0.14	0.88*	0.86*	0.88*
	(0.38)	(0.32)	(0.33)	(0.48)	(0.57)	(0.34)	(0.20)	(0.28)
ρ_1	0.002	−1.26*	−0.18	−1.90*	−1.94*	−1.26*	−0.20**	−2.92*
	(0.00)	(0.19)	(0.11)	(0.37)	(0.37)	(0.33)	(0.12)	(0.27)
R^2	0.43	0.80	0.87	0.71	0.50	0.65	0.85	0.90
$S.E$	0.03	0.02	0.01	0.02	0.03	0.03	0.01	0.01

*Significant at 5%, **significant at 10%, std. errors in parentheses.

All countries except for France exhibit a positive and significant result for the output gap. We also find that the restricted parameter on the labour share has a correct sign for all the countries that we consider except for South Korea. The autoregressive rule of thumb on both the price and wage equations plays an important role in the inflation process for all eight countries in our sample, indicating the importance of the persistence of past inflation in determining current inflation. We also find that import prices play an important role in significantly determining inflation in six of the eight countries that we consider. The demand pressure measure in the wage equation of the traditional Keynesian Phillips curve specification has a correct sign and is significant for all but one of the eight countries that we consider. Results from Table 2 above show that the traditional Keynesian Phillips curve like the Fair (2008) specification fits the data well. Table 3 below presents estimated results for the Malikane (2013) wage-price spiral.

Table 3: Estimated Parameters of the Malikane (2013) model

	Aus.	Can.	Fra.	Ger.	S. Korea	S. Africa	US.	UK.
$\pi_t = \alpha_p E_t\pi_{t+1} + \beta_p\pi_{t-1} + \gamma_p\widehat{w}_t + \rho_p\hat{y}_t + \delta_p\widehat{m}_t + \theta_p\pi_t^{food} + \vartheta_p\pi_t^{energy} + \varepsilon_{\pi t}$								
α_p	0.43*	0.49*	0.62*	0.55*	0.46*	0.41*	0.54*	0.52*
	(0.84)	(0.08)	(0.07)	(0.89)	(0.09)	(0.07)	(0.04)	(0.06)
β_p	0.56*	0.50*	0.38*	0.45*	0.55*	0.59*	0.46*	0.49*
	(0.08)	(0.08)	(0.06)	(0.09)	(0.09)	(0.07)	(0.04)	(0.06)
γ_p	−0.10*	−0.07	0.01	−0.001	−0.01	0.01	−0.02	−0.01
	(0.05)	(0.07)	(0.02)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)
ρ_p	0.02	−0.07	−0.05**	−0.02	0.02	0.02	−0.002	0.02
	(0.05)	(0.05)	(0.03)	(0.03)	(0.05)	(0.07)	(0.03)	(0.05)
δ_p	0.003	0.004	−0.02	0.02	0.02**	0.04**	0.0003	−0.003
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
θ_p	0.02	0.06	0.15*	0.03	0.004	0.01	0.03	0.02
	(0.04)	(0.05)	(0.04)	(0.03)	(0.05)	(0.04)	(0.03)	(0.06)
ϑ_p	0.06*	0.06*	0.06*	0.03**	0.05*	−0.02	0.04*	0.01
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
R^2	0.94	0.86	0.97	0.95	0.81	0.93	0.96	0.97
$S.E$	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
$\widehat{w}_t = \alpha_{\widehat{w}} E_t\widehat{w}_{t+1} + \beta_{\widehat{w}}\pi_t + \theta_{\widehat{w}}\pi_{t-1} + \gamma_{\widehat{w}}\widehat{w}_{t-1} + \rho_{\widehat{w}}\hat{y}_t + \sigma_{\widehat{w}} y_{t-1} + \mu_{\widehat{w}t}$								
$\alpha_{\widehat{w}}$	0.69*	0.34*	−0.41*	0.53**	0.41*	0.55*	0.33*	0.47*
	(0.12)	(0.08)	(0.09)	(0.05)	(0.14)	(0.13)	(0.12)	(0.09)
$\beta_{\widehat{w}}$	−0.26*	−0.25*	−0.10	0.01	−0.25	0.11	0.11	−0.07
	(0.09)	(0.08)	(0.31)	(0.06)	(0.39)	(0.11)	(0.07)	(0.06)
$\theta_{\widehat{w}}$	0.25*	0.24*	0.11	−0.01	0.25	−0.11	−0.11	0.07
	(0.09)	(0.08)	(0.30)	(0.06)	(0.39)	(0.11)	(0.07)	(0.06)
$\gamma_{\widehat{w}}$	0.41*	0.57*	−0.18*	0.51*	0.41*	0.45*	0.49*	0.48*
	(0.07)	(0.06)	(0.09)	(0.05)	(0.12)	(0.09)	(0.07)	(0.08)
$\rho_{\widehat{w}}$	−0.35*	−0.51*	−0.87*	−0.08*	−0.37**	−0.22	−0.57*	−0.31*
	(0.09)	(0.09)	(0.25)	(0.03)	(0.22)	(0.16)	(0.06)	(0.08)
$\sigma_{\widehat{w}}$	0.31*	0.45*	0.63*	0.06**	0.33	0.13	0.55*	0.27
	(0.10)	(0.08)	(0.25)	(0.03)	(0.24)	(0.16)	(0.08)	(0.08)
R^2	0.73	0.83	0.24	0.91	0.27	0.67	0.67	0.71
$S.E$	0.01	0.01	0.01	0.00	0.03	0.01	0.01	0.01

*Significant at 5%, **significant at 10%. Std. errors in parentheses.

We find that the New Keynesian price equation has a problem of negative sign for the output gap for Canada, France, Germany and the US. This has been a major challenge for the New Keynesian Phillips curve and its central point of criticism. This drawback has not been solved by the contribution of Malikane (2013) that takes into account the impact of the non-labour on the inflation process. Our finding for the negative sign for the US contradicts the finding by Fair (2008) and Fuhrer (1997) of a positive sign for their estimation of the Fuhrer's New Keynesian model. The difference might by due to the fact that Fair (2008) and Fuhrer (1997) used FIML as opposed to our 2SLS. Like Lawless and Whelan (2011) we find that the New Keynesian Phillips curve have a wrong sign problem for the labour share in the price equation. Six of the eight countries that we consider in this study exhibit a wrong sign for the marginal cost variable. These findings confirm the empirical validity problems of the New Keynesian Phillips curve, even when controlling for supply side shocks.

Unlike in Rudd and Whelan (2006, 2007) we find that expectations of future inflation play an important role in the determination of current inflation for the US, and the seven other countries that we consider. Our results on this variable confirm those found in Abbass and Sgro (2011) for Australia, we find for the parameter in question the sign to be correct and significance at 5% level. Our finding of the significance of expected future inflation on current inflation lends support to the view of Gali. et al. (2001) on the importance future expectations formation having an important role in the explanation of the inflation process. We find that a proper formulation of the marginal cost for the New Keynesian Phillips curve resolves the wrong sign problem of the inflation expectation parameter. This is an important step in the New Keynesian literature given the theoretical importance of the impact of future expected inflation on the dynamics of current inflation.

We also find that energy prices, which are a component of the non-labour input, play an important role in explaining the inflation process. This finding lends support to the view that the poor empirical performance of the New Keynesian Phillips curve over time might be due to misspecification of the marginal cost variable. Energy prices have a correct sign and are significant for all countries that we consider except for South Africa which has a wrong sign and the UK which has a correct sing but has an insignificant effect. Import prices in the New Keynesian wage-price spiral have limited significant effect on price inflation with the exception of South Korea and South Africa; the same applies to food prices with only France exhibiting significant effects of food inflation on price inflation. We now turn our attention to the evaluation of the forecast ability of the three competing wage-price specification that we have considered.

2.5 Forecast evaluation

We use two forecast evaluation methods in this paper. The first takes the square difference of the actual and forecast, this method provides use with standard deviation mean errors or simply root means square errors. This is followed by a comparison between the three competing wage-price spirals. For this comparison, we use the Clark and West (2007) forecast evaluation method since we are comparing forecasts from nested models. Figures 1 to 3 provides a graphical representation of actual inflation and 1 quarter, 4 quarter and 8 quarter ahead Inflation forecasts from the three competing specifications that we have considered in this chapter. Table 4 presents standard deviations for the competing specification forecasts that are presented in Figures 1, 2 ans 3.

Figure 1: Actual inflation and one quarter ahead forecasts

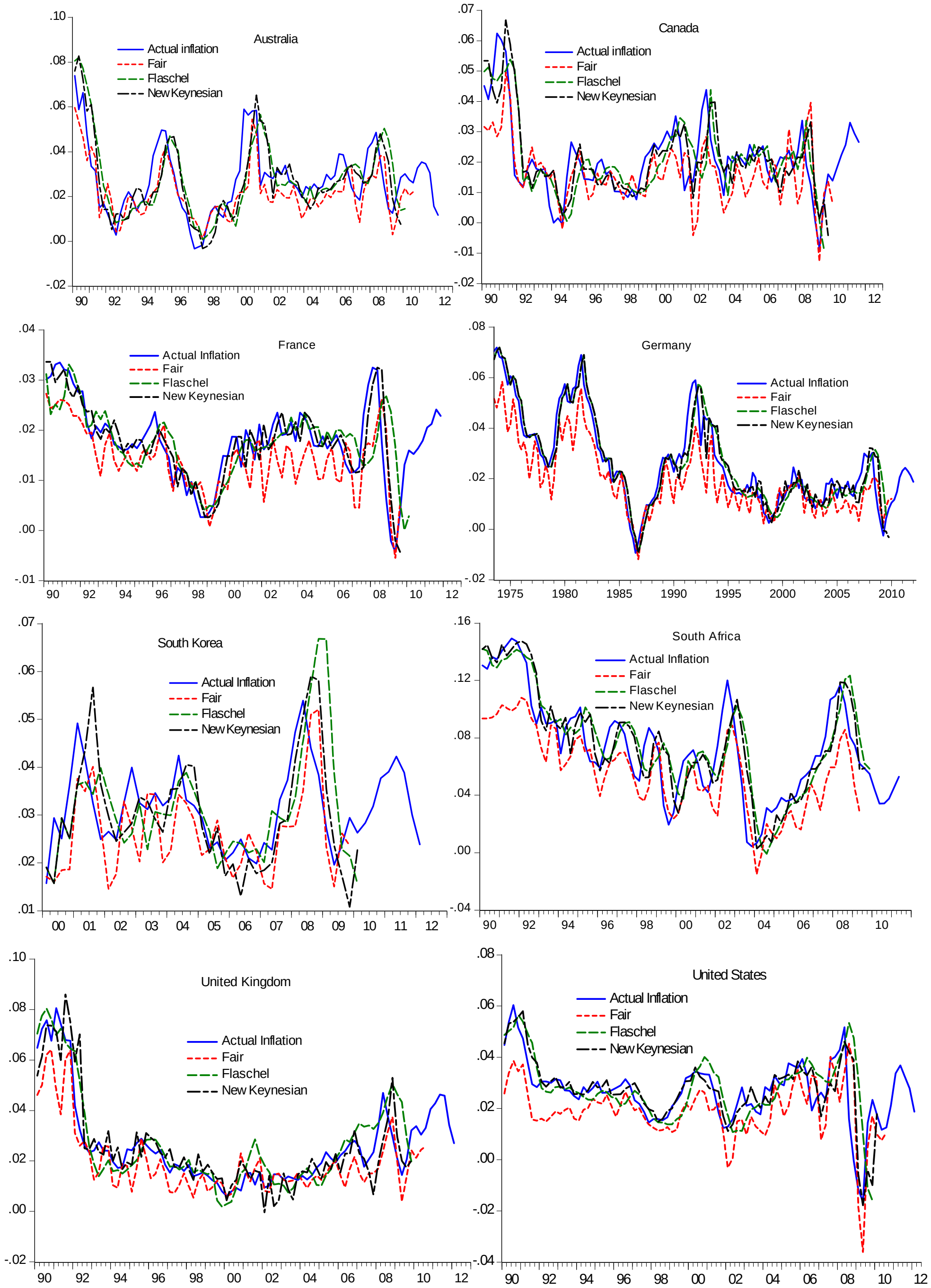

Figure 2: Actual inflation and four quarter ahead forecasts

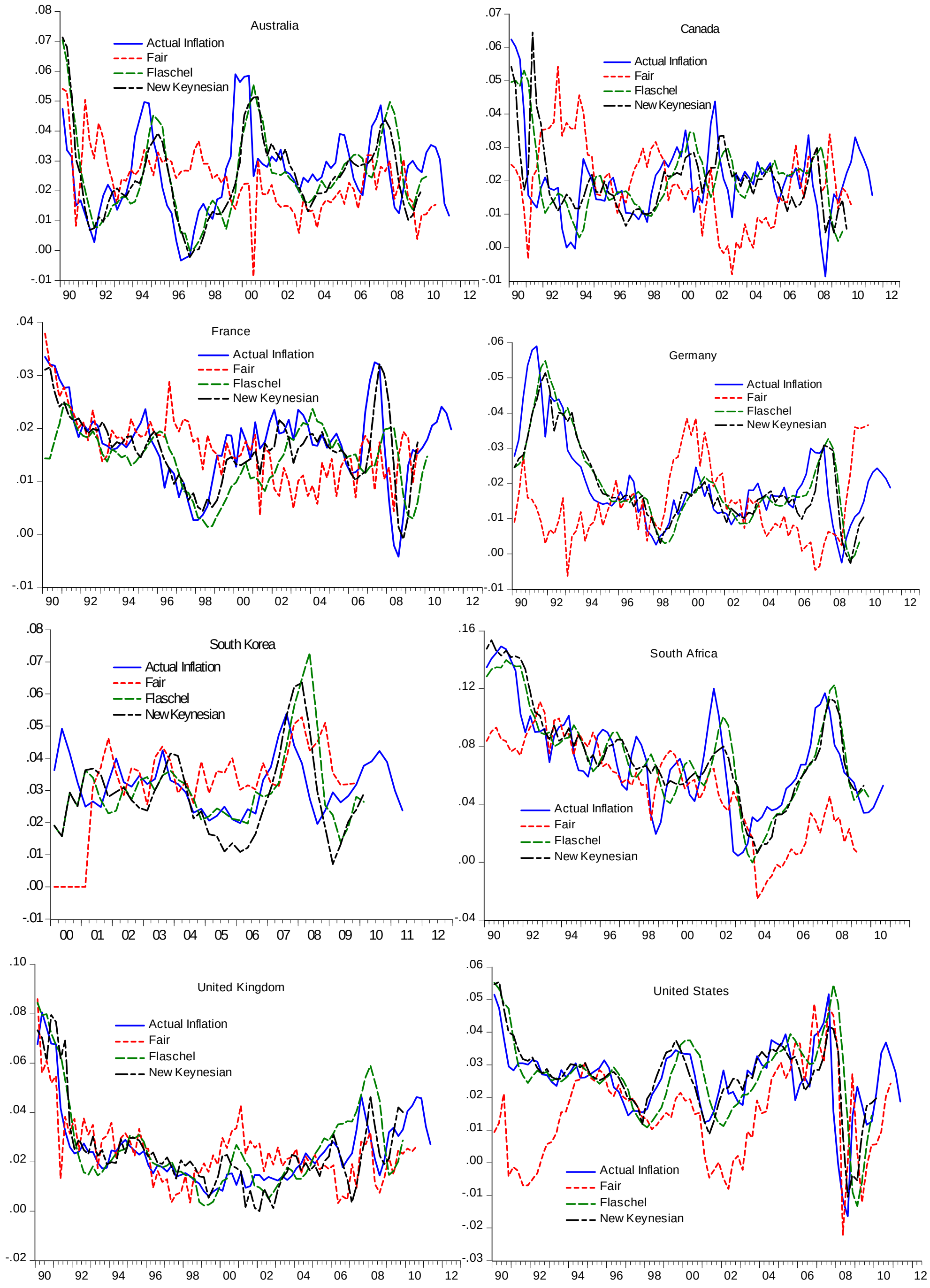

Figure 3: Actual Inflation and eight quarter ahead forecasts

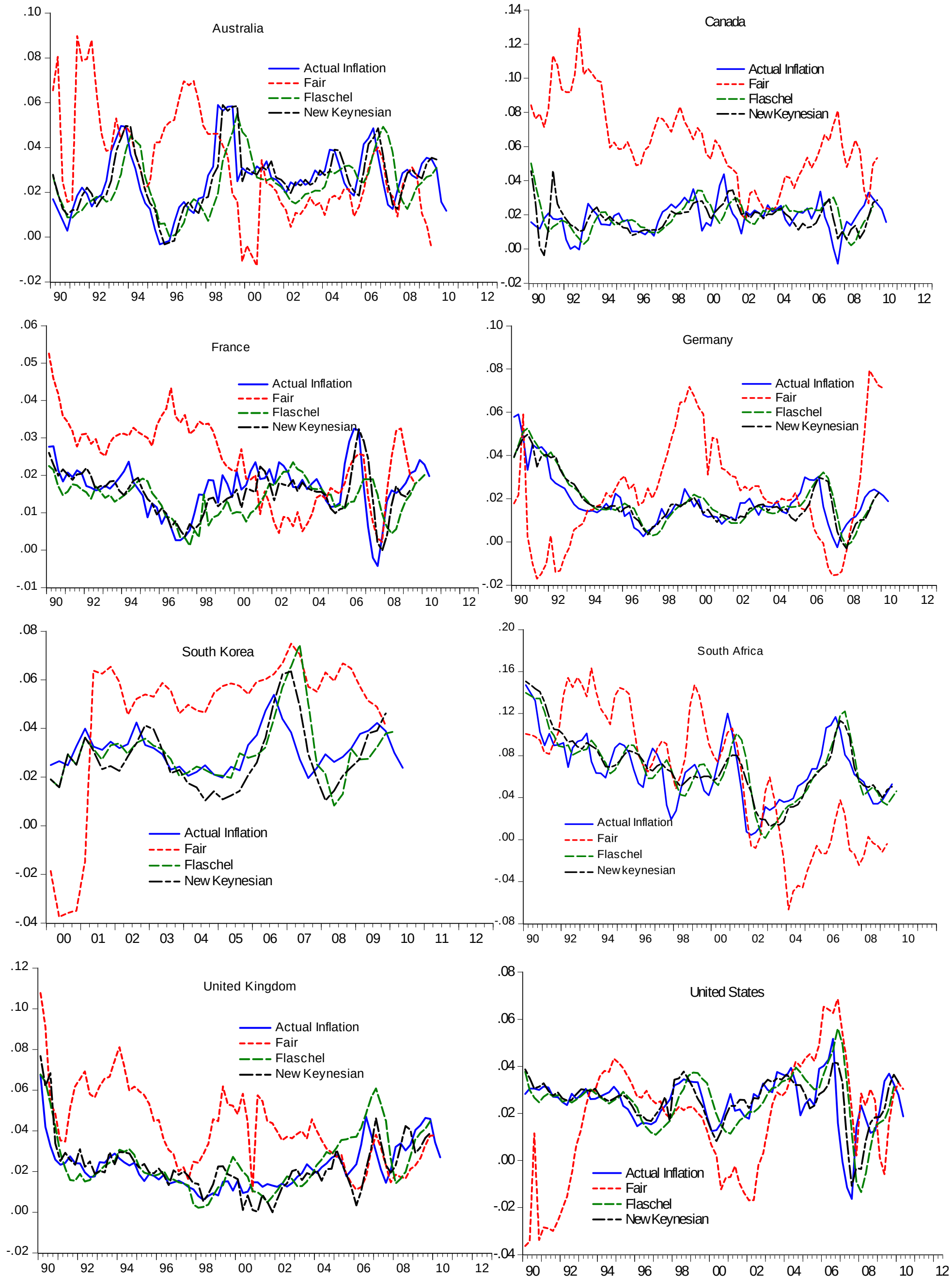

Table 4: Root mean square errors of the model forecasts

	Model	Price Inflation		
Horizon		1	4	8
	Fair	0.02	0.04	0.30
Australia	DK	0.02	0.02	0.02
	NK	0.02	0.03	0.02
	Fair	0.02	0.04	0.18
Canada	DK	0.02	0.02	0.02
	NK	0.02	0.003	0.02
	Fair	0.04	0.01	0.03
France	DK	0.01	0.01	0.01
	NK	0.31	0.54	0.54
	Fair	0.02	0.05	0.10
Germany	DK	0.01	0.01	0.01
	NK	0.07	0.80	0.01
	Fair	0.01	0.04	0.06
S. Korea	DK	0.03	0.04	0.04
	NK	0.01	0.01	0.01
	Fair	0.07	0.16	0.33
S. Africa	DK	0.07	0.07	0.07
	NK	0.05	0.06	0.05
	Fair	0.02	0.04	0.11
United States	DK	0.04	0.04	0.04
	NK	0.02	0.02	0.04
	Fair	0.02	0.02	0.10
United Kingdom	DK	0.01	0.02	0.02
	NK	0.02	0.02	0.02

RMEs in 10^{-2}

The comparison is done over one, four and eight quarter ahead time horizons, respectively. The standard deviation of the forecast errors are computed using the method outlined in Eq. (7). Where a low standard deviation mean superior forecast ability. The Flaschel type (DK) specification generally outperforms the other two specification in forecasting price inflation for Australia, Canada, France, Germany and the United Kingdom for the one, four and eight quarter time horizons. While the New Keynesian type specification outperforms the Flaschel (DK) and Fair (Fa) specifications, respectively, in forecasting price inflation for the respective time horizons for Germany, South African and the UK. Table 5 provides estimates of the Mean Square Errors of the forecast ability of price inflation across the three competing specifications of the wage-price spirals.

Table 5: Forecast performance of competing models

		Price Inflation		
		1	4	8
	DK-Fa	0.001	-0.019^{*}	-0.258^{*}
Australia	DK-NK	0.004^{*}	0.004	-0.010^{*}
	Fa-NK	0.001	0.019^{*}	0.260^{*}
	DK-Fa	0.013^{*}	-0.225^{*}	-0.716^{*}
Canada	DK-NK	0.001	0.001	0.003
	Fa-NK	0.001	0.019^{*}	0.101^{*}
	DK-Fa	0.001	-0.001	-0.180^{*}
France	DK-NK	0.003^{*}	0.004^{*}	0.003^{*}
	Fa-NK	0.001^{*}	0.004^{*}	0.019^{*}
	DK-Fa	-0.003^{**}	-0.090^{*}	-0.067^{*}
Germany	DK-NK	0.001^{**}	0.001	0.001
	Fa-NK	0.005^{*}	0.027^{*}	0.070^{*}
	DK-Fa	0.001	-0.106^{*}	-0.317^{*}
S. Korea	DK-NK	0.005	-0.084^{*}	0.010
	Fa-NK	-0.004	-0.050^{*}	0.319^{*}
	DK-Fa	-0.010	-0.097^{*}	-0.260^{*}
S. Africa	DK-NK	0.011^{*}	0.010	0.012^{*}
	Fa-NK	0.026^{*}	0.105^{*}	0.275^{*}
	DK-Fa	0.000	-0.018^{*}	-0.060^{*}
United States	DK-NK	0.010^{*}	0.010^{*}	-0.011^{**}
	Fa-NK	0.010^{*}	0.027^{*}	0.050^{*}
	DK-Fa	-0.002	0.004^{*}	-0.054^{*}
United Kingdom	DK-NK	-0.000	0.001	0.002
	Fa-NK	0.002	0.010^{*}	0.072^{*}

Figures are10^{-2}

The results in Table 5 above are generated by computing errors from the difference between actuals and individual model forecasts, we then take the difference of the individual square of the errors then run them against a constant. This step is captured by Eq. (8). For instance, DK-Fa in Table 5 captures then the difference of the squared errors from the Flaschel type model and difference of squared errors from the Fair (2008) wage-price model ran against a constant. This is captured by Eq. (9). For instance, the constant parameter reported in Table 5 for Australia is positive for the one step ahead time horizon between the Flaschel type and Fair type comparison. This means that the Fair type specification forecasts outperform by the Flaschel type forecast of inflation one quarter ahead.

The Flaschel type specification forecasts are generally outperformed by those from the other two specifications that we consider for the one quarter ahead forecast of price inflation. This happens for five of the eight countries that we consider. We should however note insignificance of this result for some of the five countries where this is the case. However, for the four quarter ahead price inflation forecast, the Flaschel type specification forecasts generally significantly outperform price inflation forecasts from the Fair type specification for six of the eight countries that we consider. For the eight quarter ahead price inflation forecast, the Flaschel type specification significantly outperforms both the Fair. The Flaschel type specification also significantly outperforms the New Keynesian type for the eight quarter ahead time horizon for Australia, Canada and the US. The New Keynesian type specification forecasts significantly outperform the Flaschel type for only France and South Africa. For the same time horizon, the New Keynesian type specification forecasts significantly outperforms the Fair type forecasts for all the eight countries that we consider.

2.6 Conclusion

We find that specification of the marginal cost of labour and non-labour input to capture the impact of supply side shocks on price inflation does not resolve the negative sign problem on the forcing variable found in the New Keynesian literature for four of the eight countries that we consider. We find that the other two competing specifications of the wage-price spiral do not suffer from such empirical problems. From the Root mean square error method of evaluating inflation we find that the Flaschel type wage and price equations produce forecasts that generally outperform forecasts generated by the Fair and New Keynesian specifications. The Flaschel type (DK) specification generally outperforms the other two specification in forecasting price inflation for Australia, Canada, France, Germany and the United kingdom for the one, four and eight quarter time horizons. While the New Keynesian type specification outperforms the Flaschel (DK) and Fair (Fa) specifications, respectively, in forecasting price inflation for the respective time horizons for Germany, South African and the UK.

From our second method of evaluation, we also find that the Fair type specification generally outperformed by both the Flaschel type and New Keynesian type specifications for all the countries that we consider. For the four quarter ahead price inflation forecast, the Flaschel type specification forecasts generally significantly outperform price inflation forecasts from the Fair type specification for six of the eight countries that we consider. For the eight quarter ahead price inflation forecast, the Flaschel type specification significantly outperforms both the Fair. The Flaschel type specification also significantly outperforms the New Keynesian type for the eight quarter ahead time horizon for Australia, Canada and the US. The New Keynesian type specification forecasts significantly outperform the Flaschel type for only France and South Africa. For the same time horizon, the New Keynesian type specification forecasts significantly outperform the Fair type forecasts for all the eight countries that we consider. The implications of these results is that policymakers need to understand that different wage-price spiral methods of computing inflation forecasts may produce best results for certain time horizons. This means that one type of wage-price spiral may produce the best one quarter ahead forecast of price inflation while a competing specification produces the best four quarter ahead forecast.

3 Systems Approaches to Measuring Natural Rates: A Critical Assessment

3.1 Introduction

The non-accelerating inflation rate of unemployment (NAIRU) and potential output are important reference points for monetary policy and business cycle theory. However, Staiger et al.(1997) find that the NAIRU is imprecisely estimated. Despite this, Ball and Mankiw (2002) maintain that the NAIRU can still be used as a tool to forecast inflation within the framework of the Phillips curve. A number of influential studies, e.g. Gordon (1997), Staiger et al. (1997) and Laubach (2001) estimate the NAIRU using the single-equation backward-looking triangle Phillips curve. Apel and Jansson (1999) extend this approach by formulating a system that features the triangle Phillips curve, Okun's law and a law of motion for the unemployment gap in order to simultaneously estimate the NAIRU and potential output. However, Apel and Jansson do not show whether their systems-based approach significantly performs better than the single-equation approach that is prevalent in the literature.

One of the key features of the system that is proposed by Apel and Jansson (1999) is that it relies on the price Phillips curve in order to exploit the information that is contained in the inflation rate in order to identify the NAIRU. They then simultaneously identify potential output by exploiting the information that is contained in Okun's law. An alternative systems-based approach is to exploit the information that is contained in both the nominal wage and price Phillips curves similar to those proposed by Flaschel et al. (2007). These authors argue that if demand pressure from the goods and labour markets do not move in line with each other, then there is a need to use two measures of excess demand in the wage-price spiral. One measure, the unemployment gap, will feature in the nominal wage Phillips curve and the other measure, the output gap, will feature in the price Phillips curve. Thus, instead of invoking Okun's law to identify potential output, Flaschel et al. propose the use of the price Phillips curve. Furthermore, instead of using the price Phillips curve to identify the NAIRU, Flaschel et al. propose the use of the nominal wage Phillips curve.

This paper contributes to the literature in two ways. Firstly, we use a system composed of the nominal wage and price Phillips curves with separate demand pressures from the goods and labour markets, to estimate potential output and the NAIRU. Our formulation of this system follows Flaschel et al.(2007). Secondly, we then compare the NAIRU and potential output that is derived from the system proposed by Apel and Jansson and the one proposed by Flaschel et al. The aim of this comparison is to ascertain which of these measures contain superior information about the dynamics of price inflation. We use the single-equation specification by Gordon (1997) to test which of these measures better explains the dynamics of price inflation. Gordon's specification of the dynamics of inflation appears to be popular. It has recently been used by Ball and Mazumder (2011) and Watson (2014) to analyze the dynamics of inflation during the Great Recession.

This paper is structured as follows: Section 3.2 provides methodology on systems approaches that we consider in this paper to estimate the NAIRU and potential output. Section 3.3 provides data and estimation strategy followed by section 3.4 which presents the performance evaluation of the estimated output and unemployment gaps computed, and section 3.5 concludes.

3.2 Systems approaches to estimating natural rates

3.2.1 The Keynesian wage-price Phillips curve

The first approach that we consider is based on the work by Flaschel et al. (2007). These authors posit that price and nominal wage inflation are driven by separate demand pressure terms. The price Phillips curve, which can be specified as a triangle Phillips curve similar to Gordon (1997), features inflation expectations and nominal wage inflation, the output gap and supply shocks. The nominal wage Phillips curve features backward looking inflation expectations and price inflation and the unemployment gap. The presence of price inflation in the nominal wage Phillips curve and the presence of nominal wage inflation in the price Phillips curve leads to the interaction between these Phillips curves. The separate demand pressure terms allows for their identification since, as these authors maintain, the goods and labour markets do not move in line with each other.

We, therefore, specify the wage-price Phillips curve system as follows:

$$\begin{bmatrix} \pi_{t+1} \\ \hat{w}_{t+1} \end{bmatrix} = \begin{bmatrix} \kappa_p & 0 \\ 0 & \kappa_w \end{bmatrix} \pi_t^e + \begin{bmatrix} 0 & 1-\kappa_p \\ 1-\kappa_w & 0 \end{bmatrix} \begin{bmatrix} \pi_t \\ \hat{w}_t \end{bmatrix} + \begin{bmatrix} \beta_p & 0 \\ 0 & -\beta_w \end{bmatrix} \begin{bmatrix} y_t - y_t^* \\ u_t - u_t^* \end{bmatrix} + \begin{bmatrix} e_{pt} \\ e_{wt} \end{bmatrix} \tag{1}$$

where π_t is the price inflation rate and $\hat{w}_t$ is nominal unit labour cost inflation. Following Flaschel et al.(2001), we define the expected price inflation rate as $\pi_t^e = \frac{1}{4}\sum_{j=1}^{4} \pi_{t-j}$, y_t denotes the natural log of output and y_t^* the natural log of potential output, u_t is the unemployment rate, u_t^* is the NAIRU, $e_{pt} = \psi_m \widetilde{z}_t^m + \psi_f \widetilde{z}_t^f + \psi_e \widetilde{z}_t^e + \epsilon_{pt}$ is a composite supply shock where $\widetilde{z}_t^m$ is import inflation, $\widetilde{z}_t^f$ is food price inflation, $\widetilde{z}_t^e$ energy price inflation, and e_{wt} is a labour market shock.

As is standard in the literature, we model potential output and the NAIRU as unobserved stochastic processes. The NAIRU is described by a random walk without drift whereas potential output has a drift. Potential output and the NAIRU can thus be written as follows:

$$\begin{bmatrix} y_t^* \\ u_t^* \end{bmatrix} = \begin{bmatrix} \alpha \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ u_{t-1}^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^u \end{bmatrix} \tag{2}$$

Note that in both the price and nominal wage Phillips curves, the output gap and the unemployment gap are not observable. In order to identify these gaps, we construct a vector $\boldsymbol{\xi}$ of the composite error term, which we write as follows:

$$\begin{bmatrix} \xi_{pt} \\ \xi_{wt} \end{bmatrix} = \begin{bmatrix} \beta_p & 0 \\ 0 & -\beta_w \end{bmatrix} \begin{bmatrix} y_t - y_t^* \\ u_t - u_t^* \end{bmatrix} + \begin{bmatrix} e_{pt} \\ e_{wt} \end{bmatrix} \tag{3}$$

The system (3) allows us to write the wage-price system in terms of observable variables as follows:

$$\begin{bmatrix} \pi_{t+1} \\ \hat{w}_{t+1} \end{bmatrix} = \begin{bmatrix} \kappa_p & 0 \\ 0 & \kappa_w \end{bmatrix} \pi_t^e + \begin{bmatrix} 0 & 1-\kappa_p \\ 1-\kappa_w & 0 \end{bmatrix} \begin{bmatrix} \pi_t \\ \hat{w}_t \end{bmatrix} + \begin{bmatrix} \xi_{pt} \\ \xi_{wt} \end{bmatrix} \tag{4}$$

The system (4) allows us to estimate the vector of the unobservable $\boldsymbol{\xi}$. Using system (2), we can write system (3) in difference form to obtain:

$$\begin{bmatrix} \Delta\xi_{pt} \\ \Delta\xi_{wt} \end{bmatrix} = \begin{bmatrix} -\beta_p\alpha \\ 0 \end{bmatrix} + \begin{bmatrix} \beta_p & 0 \\ 0 & -\beta_w \end{bmatrix} \begin{bmatrix} \Delta y_t \\ \Delta u_t \end{bmatrix} + \begin{bmatrix} \zeta_{pt} \\ \zeta_{wt} \end{bmatrix} \tag{5}$$

where $\zeta_{pt} = \Delta e_{pt} - \beta_p \varepsilon_t^y$ and $\zeta_{wt} = \Delta e_{wt} + \beta_w \varepsilon_t^u$. The system (5) allows us to estimate the $\boldsymbol{\beta}$ matrix and to identify the scalar α, which is the growth rate of potential output. It follows that we can rewrite system (1) so that the vector of potential output and the NAIRU is:

$$\begin{aligned} \begin{bmatrix} \widehat{\beta}_p & 0 \\ 0 & -\widehat{\beta}_w \end{bmatrix} \begin{bmatrix} y_t^* \\ u_t^* \end{bmatrix} - \begin{bmatrix} e_{pt} \\ e_{wt} \end{bmatrix} &= \begin{bmatrix} \widehat{\beta}_p & 0 \\ 0 & -\widehat{\beta}_w \end{bmatrix} \begin{bmatrix} y_t \\ u_t \end{bmatrix} - \begin{bmatrix} \pi_{t+1} \\ \hat{w}_{t+1} \end{bmatrix} \\ &+ \begin{bmatrix} \widehat{\kappa}_p & 0 \\ 0 & \widehat{\kappa}_w \end{bmatrix} \pi_t^e \\ &+ \begin{bmatrix} 0 & 1-\widehat{\kappa}_p \\ 1-\widehat{\kappa}_w & 0 \end{bmatrix} \begin{bmatrix} \pi_t \\ \hat{w}_t \end{bmatrix} \end{aligned} \tag{6}$$

The vector $\begin{bmatrix} e_{pt} & e_{wt} \end{bmatrix}'$ introduces noise in system (6). There are various ways in which this noise can be filtered out of the system. Gordon (1997) assumes a size of the standard deviation of the error terms in this vector in order to achieve smoothness of the NAIRU. However the choice of the size of the smoothness parameter appears to be arbitrary. Ball and Mankiw (2002) use the Hodrick-Precott filter. However, Harvey and Jaeger (1993) and Cogley and Nason (1995) among others show that the Hodrick-Prescott filter generates business cycles even if they are not present in the original data. The method by which the noise is filtered out of the system therefore remains an unresolved issue.

3.2.2 The triangle system approach

The second approach that we consider is based on the work by Apel and Jannson (1999). These authors exploit the interdependence of the unemployment gap and the output gap through Okun's law, in order to identify the output gap. Gordon's (1997) triangle Phillips curve is then used to identify the unemployment gap. The system is specified as follows:

$$\begin{bmatrix} \pi_t \\ y_t - y_t^* \\ u_t - u_t^* \end{bmatrix} = \begin{bmatrix} \rho(L) & 0 & \eta(L) \\ 0 & 0 & \phi_l(L) \\ 0 & 0 & \delta_m(L) \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t - y_t^* \\ u_t - u_t^* \end{bmatrix} + \begin{bmatrix} \varepsilon_t^{pc} \\ \varepsilon_t^{ol} \\ \varepsilon_t^{c} \end{bmatrix} \tag{7}$$

where $\varepsilon_t^{pc} = \sum_{k=0}^{p} \omega_k z_{t-k} + \zeta_t^{pc}$ is a linear combination of supply shocks z_t and the error term ζ_t^{pc}. The first row in system (7) is Gordon's (1997) triangle Phillips curve. The second row is Okun's law, which links the output gap and the unemployment gap and the third row is the law of motion for the unemployment gap. According to Apel and Jansson (1999) the use of Okun's law, besides identifying the output gap, also provides additional information about how the NAIRU should behave. It is this additional information that these authors argue is lost when using the single-equation Phillips curve approach. The laws of motion for the NAIRU and potential output are the same as in system (2). We follow the same procedure as in section 3.1 in extracting potential output and the NAIRU.

3.3 Data and estimation strategy

We sourced data from the IMF, OECD, individual country central banks and statistical bureau databases. The frequency of the data is quarterly. For advanced economies, the sample is from 1960 to 2012, whereas for emerging markets it is from 1990 to 2012, due to data availability. Regarding variables, we use the consumer price index to measure prices, nominal unit labour cost to measure nominal wages and output is measures by real GDP. Following Gordon (1997) We use three proxies to measure supply side shocks: the price index for imported goods, consumer price index for energy and consumer price index of food.

To compute the NAIRU and potential output using the Keynesian approach, the first step is to exploit the information contained in system (5) by estimating the wage-price spiral in system (1) in difference form using the Seemingly Unrelated Regression method. We use this regression method in order to control for any correlation that may exist between errors in the price and wage Phillips curves. This allows us to identify the parameter matrix $\begin{bmatrix} \widehat{\beta}_p & 0 \\ 0 & -\widehat{\beta}_w \end{bmatrix}$. We then use system (6) and to solve for the vector of potential output and the NAIRU. At this point we, confront the problem of filtering. In order to avoid problems associated with the HP filter, we use the moving average technique proposed by Stock and Watson (2007). Due to data availability, use the MA (20) approximation of the low pass filter after padding the endpoints with forecasts from an AR(4) process.

Figure 4 illustrates price inflation, the output gap and the unemployment gap. We expect the output gap to be negatively correlated with the unemployment gap because of Okun's law. We observe that the output and unemployment gaps generally move in opposite directions. This holds even when the amplitude of the output gap is higher than that of the unemployment rate gap for instance for Germany, France and South Korea. Generally, positive output gaps are associated with increases in actual inflation, something that is theoretically consistent with the relationship of the two variables from the standpoint of the Phillips curve. We also observe that a negative unemployment gap is associated with a fall in actual inflation for all of the eight countries.

Table 6 presents the estimation results of the wage-price Phillips curves using the derived output and unemployment gaps. We find that the output gap parameter in the price Phillips curve has a correct sign and is significant for all the countries. Our results confirm that supply side shocks play an important role in the determination of inflation as argued by Gordon (1997) and Fair (2008). However, food price shocks are significant in only two countries, while energy price shocks are significant throughout, except for South Africa, where import prices are significant. Import prices are significant for six of the eight countries.

Figure 4: Output and unemployment rate gaps from the Keynesian approach

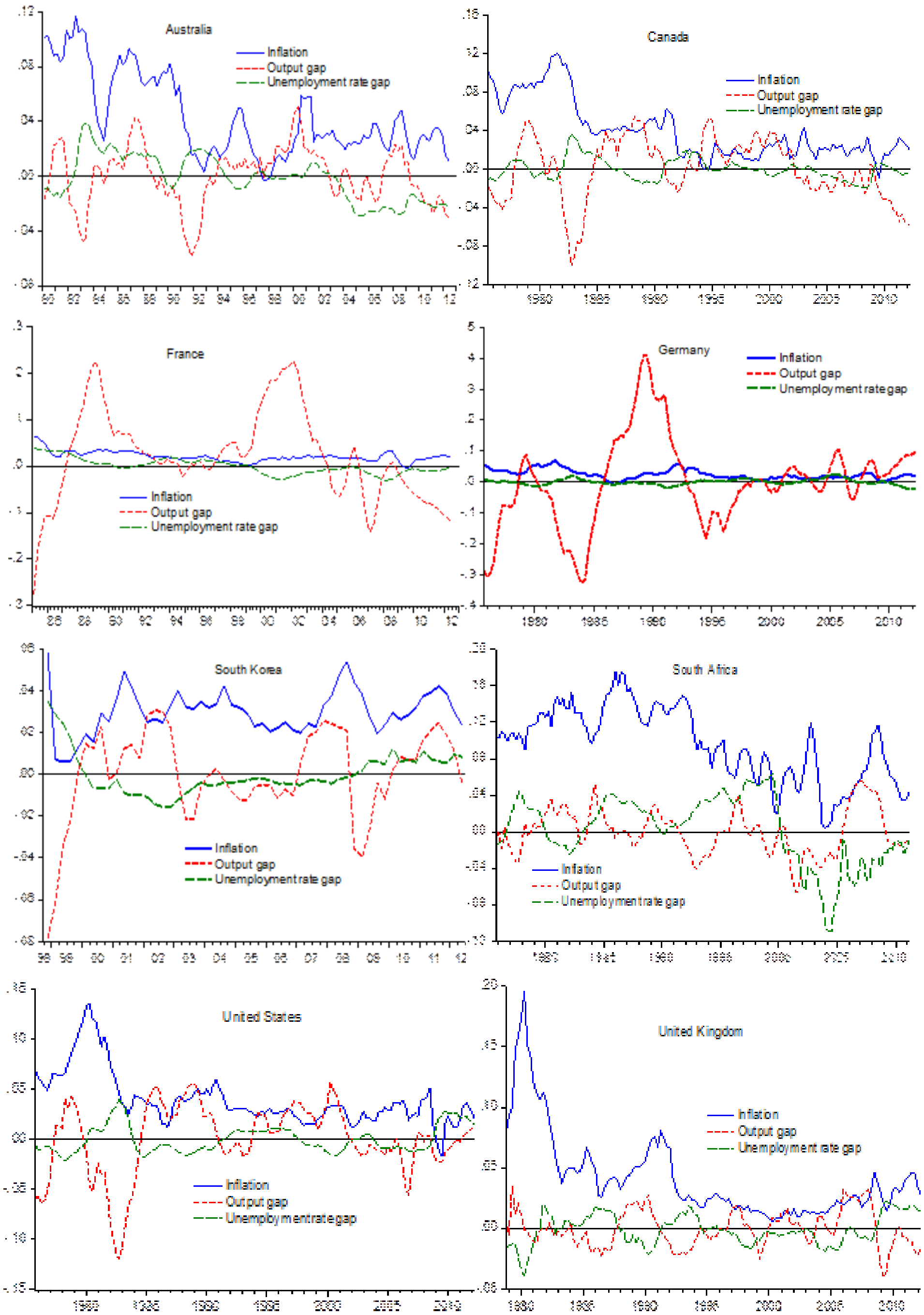

Table 6: Estimated parameters of the Keynesian model

	Aus.	Can.	Fra.	Ger.	S. Kor.	S.Afr.	US.	UK.
				Price Phillips Curve				
κ_p	0.89^* (0.03)	0.85^* (0.03)	0.95^* (0.03)	1.00^* (0.02)	0.88^* (0.02)	0.93^* (0.01)	0.89^* (0.03)	0.76^* (0.03)
β_p	0.08^* (0.03)	0.07^* (0.01)	0.01^* (0.00)	0.02^* (0.00)	0.20^* (0.02)	0.15^* (0.03)	0.09^* (0.01)	0.05^{**} (0.03)
ψ_m	0.02^* (0.01)	-0.002^* (0.01)	0.02^{**} (0.01)	0.04^* (0.01)	0.02^* (0.00)	0.08^* (0.01)	0.06^* (0.01)	0.02 (0.04)
ψ_f	-0.06^* (0.03)	0.88^* (0.02)	-0.01 (0.02)	-0.02 (0.02)	0.04^{**} (0.02)	0.02 (0.02)	0.04 (0.02)	0.06 (0.04)
ψ_e	0.03^* (0.01)	0.05^* (0.00)	0.03^* (0.01)	0.02^* (0.01)	0.08^* (0.01)	-0.01 (0.01)	0.02^* (0.00)	0.03^{**} (0.01)
R^2	0.92	0.96	0.95	0.94	0.88	0.92	0.96	0.93
				Wage Phillips Curve				
κ_w	0.29 (0.20)	0.67^* (0.15)	1.20^* (0.16)	2.34^* (0.32)	-0.24 (0.52)	-0.52^{**} (0.31)	-0.80^* (0.12)	0.04^* (0.14)
β_w	-0.73^* (0.20)	-0.85^* (0.07)	-0.48^* (0.01)	-1.51^* (0.20)	-1.65^* (0.51)	-0.64^* (0.11)	-0.27^* (0.07)	-1.86^* (0.19)
R^2	0.52	0.83	0.24	0.41	0.14	0.34	0.80	0.79

*Significant at 5%, **significant at 10%, std. errors in parentheses.

Table 7: Estimated parameters of Okun's law

	$y_t - y_t^*$	R^2
Aus.	-0.04 (0.07)	-0.002
Can.	-0.11^* (0.03)	0.11
Fra.	-0.06^* (0.01)	0.11
Ger.	-0.03^* (0.00)	0.19
S. Korea	-0.37^* (0.05)	0.35
S. Africa	0.01 (0.12)	-0.00
US.	-0.20^* (0.02)	0.29
UK.	-0.07^* (0.02)	0.10

*significant. at 5%, **significant at 10%, std. errors in parentheses.

We now turn to testing whether the negative relationship between the output and unemployment gaps implied by Okun's law holds. To do this we estimate a simple Okun's law relationship where the unemployment gap is the dependent variable and the output gap the independent variable. Table 7 presents the results. In six of the eight countries, we find a significant relationship between the output and the unemployment gaps. Only in South Africa and Australia do we not find a significant relationship.

As we mentioned before, we follow the same procedure as the Keynesian case in extracting the NAIRU and potential output for the Apel and Jansson (1999) approach. Figure 5 illustrates price inflation, the output gap and the unemployment gap extracted from the triangle system approach. We observe that the output and unemployment gaps extracted from the triangle system approach generally move in opposite directions. We also observe that a negative unemployment gap is associated with a fall in actual inflation for all of the eight countries.

Table 8 presents the estimation results of the triangle system approach using the derived output and unemployment gaps. We find that the unemployment gap parameter in the price Phillips curve has a correct sign and is significant for seven countries. Only in France do we not find the correct sign and significant for the unemployment gap parameter. We also find that import prices play a significant role in the determination of inflation, where they are significant for six of the eight countries. However food price shocks are significant in none of the countries, while energy price shocks are significant only for France. The bottom halve of Table 8 present the results for Okun's law. In six of the eight countries, we find a significant relationship between the output and the unemployment gaps. Only in France and South Korea do we not find a significant relationship.

Figure 5: Output and unemployment rate gaps from the triangle system

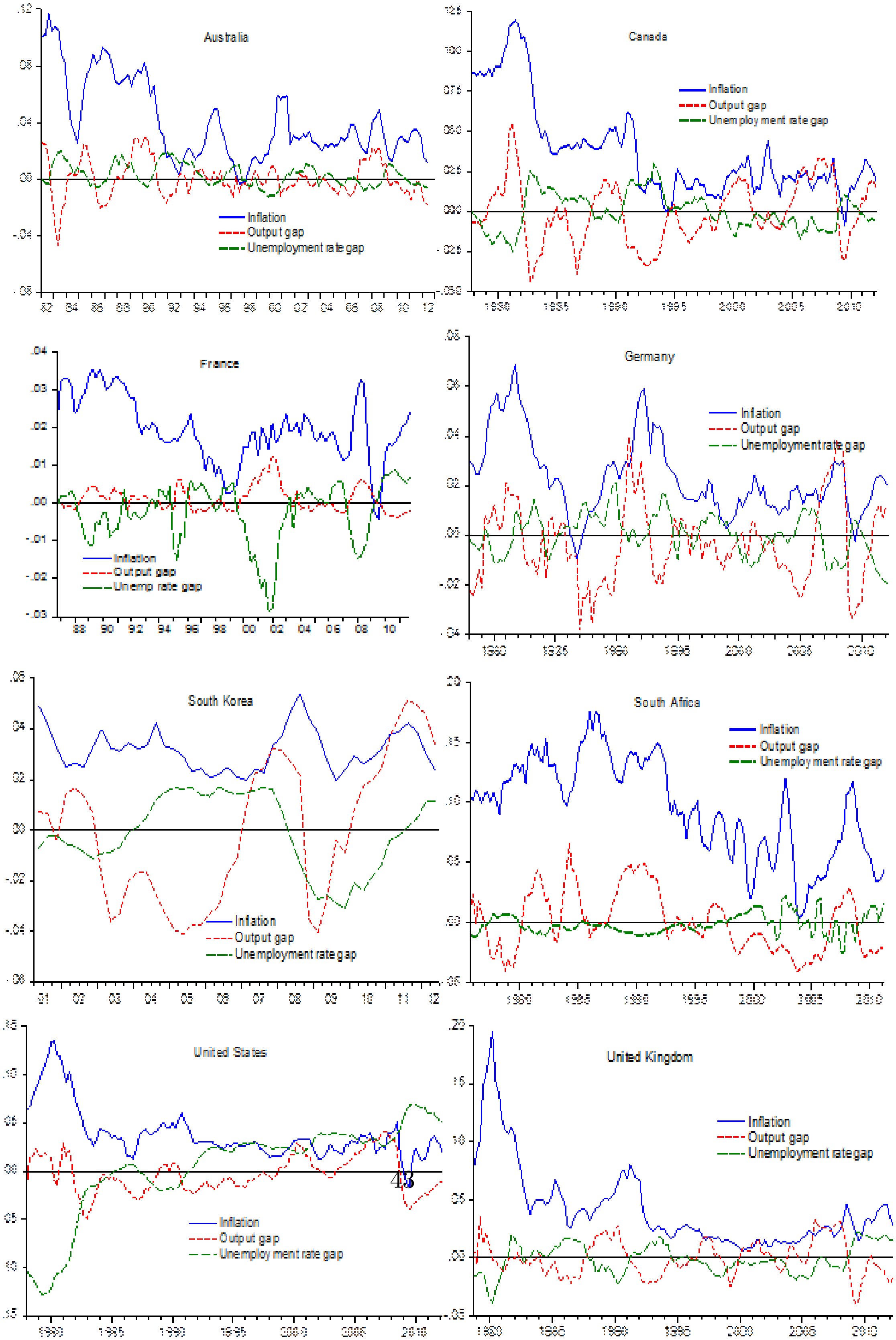

Table 8: Estimates of the triangle system

	Aus.	Can.	Fra.	Ger.	S. Kor.	S.Afr.	US.	UK.
				Price Phillips Curve				
ρ_1	0.98* (0.01)	0.98* (0.01)	0.95* (0.03)	0.96* (0.02)	0.70* (0.08)	0.99* (0.01)	1.00* (0.01)	0.97* (0.01)
η_1	−0.27* (0.09)	−0.21* (0.06)	0.01* (0.00)	−0.10** (0.05)	−0.26* (0.05)	−0.28* (0.12)	−0.11* (0.06)	−0.24* (0.06)
ω_{m1}	−0.003 (0.01)	0.02** (0.01)	0.02** (0.01)	0.02** (0.01)	0.01 (0.01)	0.06* (0.01)	0.06* (0.02)	0.03** (0.02)
ω_{f1}	−0.01 (0.03)	−0.03 (0.03)	−0.01 (0.02)	−0.07* (0.03)	−0.11* (0.04)	0.02 (0.03)	−0.01 (0.03)	0.05 (0.04)
ω_{e1}	−0.02 (0.01)	−0.03* (0.01)	0.03* (0.01)	−0.001* (0.01)	−0.01 (0.02)	−0.28* (0.12)	−0.11* (0.06)	−0.04* (0.02)
R^2	0.92	0.95	0.95	0.91	0.48	0.91	0.92	0.95
				Okuns Law				
ϕ_0	−0.70* (0.14)	−1.28* (0.09)	1.20* (0.16)	−0.86* (0.14)	0.37 (0.86)	−0.77* (0.21)	−1.33* (0.07)	−0.52* (0.08)
ϕ_1			−0.48* (0.01)		−0.38 (0.86)	−0.57* (0.21)		
R^2	0.03	0.61	0.24	0.18	0.004	0.29	0.72	0.23

*Significant at 5%, **significant at 10%, std. errors in parentheses.

Our analysis of whether the gaps from competing methodologies are different starts with graphical representations, followed by correlation tests and fitting the gaps into simple single equation triangle price Phillips curve by Gordon (1997). Figure 6 presents output gaps generated from the Keynesian approach and the triangle system approach. We observe that output gaps generated using the triangle system approach are less volatile compared to the Keynesian approach gaps.

Figure 6: Output gaps from competing methodologies

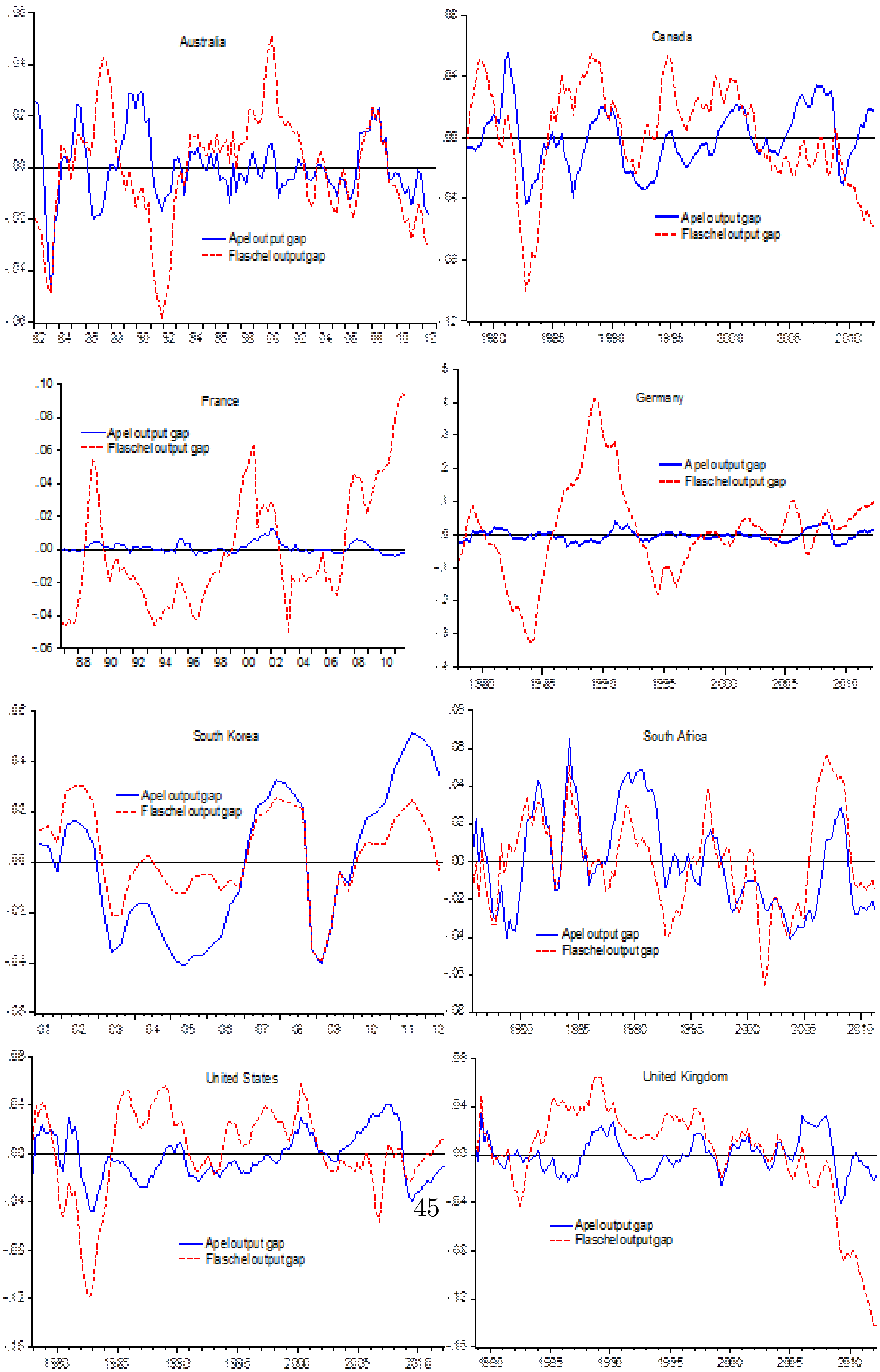

Figure 7 presents unemployment gaps generated from the two approaches. We find that the unemployment gaps generated from the Keynesian approach are generally more volatile than the ones from the triangle system approach. Nevertheless, in some of the countries, the two gaps track each other (Canada, Germany, the US and the UK). In the case of Australia, the two gaps track each other and then diverge in the early 2000s. The deputy governor of the central bank in Australia in his speech in August 2010 attributes to this to the dot-com bubble and that this had a noticeable impact on unemployment. This presents a puzzling result for higher output gap. This may be that the output gap of the triangle system approach has a more pronounce unemployment influence given that the potential output is computed from Okun's law. We now turn to running a correlation test between gaps from the competing methodologies.

Figure 7: Unemployment gaps from the two approaches

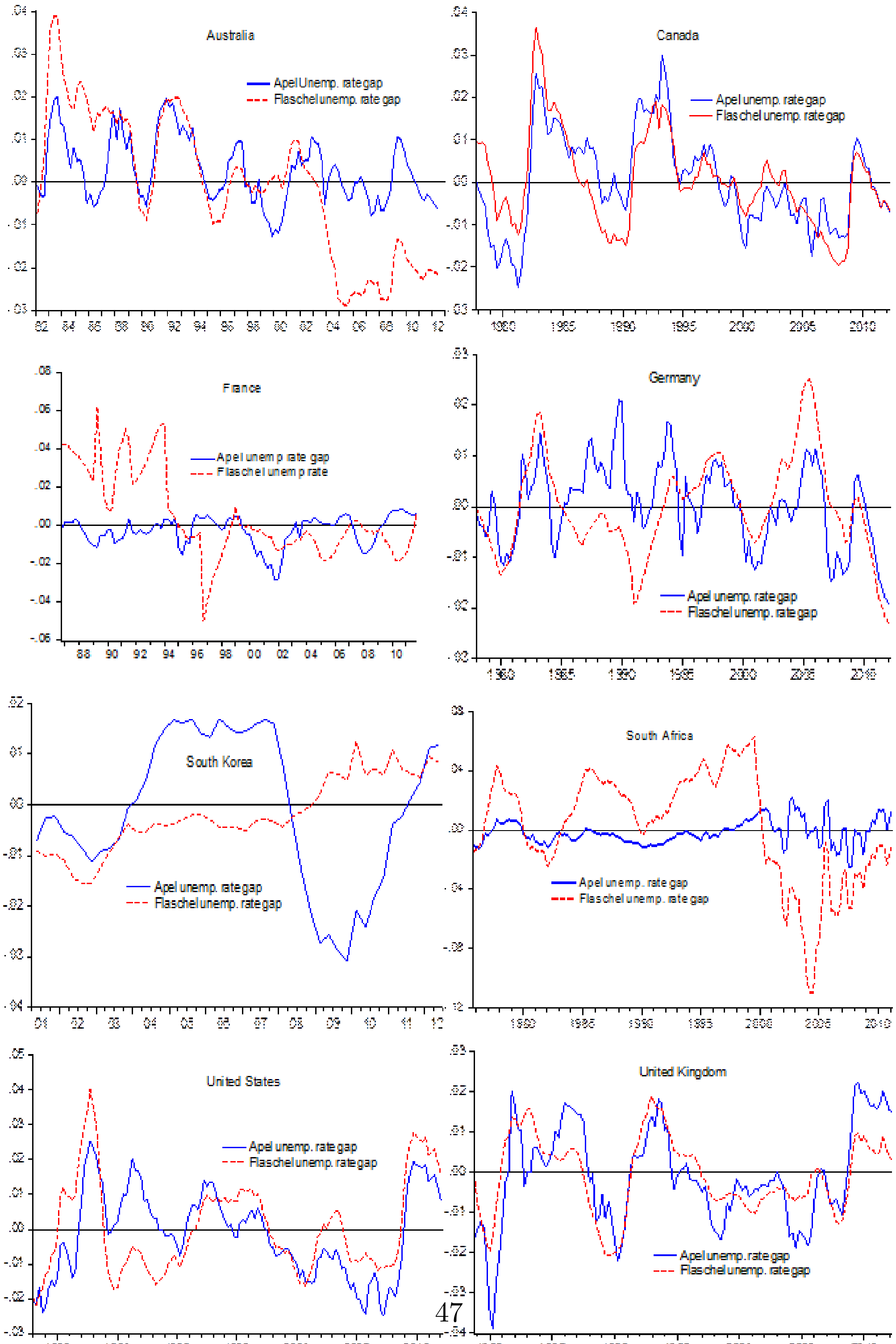

Table 9: Correlation between Gaps

	$y_t - y_t^*$	$u_t - u_t^*$
Aus.	0.98^* (0.01)	0.67 (0.00)
Can.	0.20 (0.02)	0.79 (0.00)
Fra.	0.20 (0.04)	0.74 (0.00)
Ger.	-0.08 (0.32)	0.51 (0.00)
S. Kor.	0.81 (0.00)	-0.22 (0.14)
S. Afr.	0.58 (0.00)	0.21 (0.15)
US.	0.25 (0.00)	0.67 (0.00)
UK.	0.32 (0.00)	0.75 (0.00)

Probability in parentheses, *Significant at 5%, **significant at 10%.

It is important to check the extent to which the output and unemployment gaps from both approaches are correlated. A high correlation would imply that the two gaps may not be significantly different. Table 9 presents correlation test results for the output and unemployment rate gaps generated from the Keynesian and triangle system approaches. We find positive statistically significant correlation for six countries for both the output and unemployment gaps from the competing methodologies. There is an exception of negative correlation of the output gap in Germany, and for the unemployment gap for South Korea. However, in some cases where there is positive correlation, the correlation coefficient is relatively small, e.g. the correlation of output gaps for Canada, France, the US and the UK.

3.4 Evaluation of Gaps from two approaches

To test which gaps are superior, we use a price Phillips curve that is widely accepted in the literature, the triangle Phillips curve by Fuhrer (1995). This Phillips curve features lags of price inflation, the unemployment or output gap and supply shocks. We expect the unemployment gap to have a negative sign and, in the case where the output gap is used, to have a positive sign. Supply shocks are supposed to have positive signs. We write this Phillips curve as follows:

$$\pi_t = \rho_0 \pi_{t-1} + \eta_0 x_{t-1} + \omega_{m0} \widetilde{z}^m_{t-1} + \omega_{f0} \widetilde{z}^f_{t-1} + \omega_{e0} \widetilde{z}^e_{t-1} + \varepsilon_t, \tag{10}$$

where x_{t-1} is the demand pressure that can be proxied by either the unemployment rate gap ($\eta_0 < 0$) or the output gap ($\eta_0 > 0$), and ε_t is the error term. Table 10 presents estimation results. The parameter for the unemployment gap from the Keynesian and triangle system approaches generally have a correct sign and are significant. Only in France and South Korea do we not find correct sign for the unemployment gap parameter. Import prices play an important role in the determination of price inflation in four countries. The results suggest that the quality of the unemployment gaps is not vastly different.

Table 10: Estimates of the triangle model (eq. 10), Unemployemnt rste gaps

	Aus.	Can.	Fra.	Ger.	S. Kor.	S.Afr.	US.	UK.
	Keynesian unemployment gaps							
ρ_0	0.98*	0.99*	1.01*	0.97*	1.00*	0.99*	1.00*	0.99*
	(0.01)	(0.01)	(0.02)	(0.02)	(0.06)	(0.02)	(0.01)	(0.01)
η_0	−0.07	−0.17*	0.10*	−0.12*	0.002	−0.02	−0.08**	−0.26*
	(0.05)	(0.05)	(0.03)	(0.04)	(0.17)	(0.03)	(0.05)	(0.09)
ω_{m0}	0.01	0.00	0.04*	0.02**	−0.01	0.06*	0.05*	0.02
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
ω_{f0}	−0.04	−0.01	−0.11*	−0.05*	−0.05	0.03	0.01	0.05
	(0.04)	(0.03)	(0.03)	(0.03)	(0.05)	(0.03)	(0.04)	(0.04)
ω_{e0}	−0.02	−0.01	−0.04*	0.00	0.01	0.01	−0.04*	−0.03
	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)	(0.02)	(0.01)	(0.02)
R^2	0.91	0.95	0.86	0.91	0.51	0.91	0.93	0.94
	Triangle unemployment gaps							
ρ_0	0.98*	0.98*	0.96*	0.97*	0.87*	0.99*	0.99*	0.98*
	(0.02)	(0.01)	(0.02)	(0.02)	(0.10)	(0.01)	(0.02)	(0.02)
η_0	−0.28*	−0.21*	0.27*	−0.08	−0.10	−0.31*	−0.12*	−0.16*
	(0.10)	(0.06)	(0.06)	(0.06)	(0.07)	(0.12)	(0.06)	(0.07)
ω_{m0}	0.00	0.02	0.04*	0.02**	−0.01	0.06*	0.06*	0.01
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
ω_{f0}	−0.02	−0.02	−0.10*	−0.06*	−0.05	0.03	−0.01	0.07**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
ω_{e0}	−0.02	−0.02*	−0.03*	0.00	0.02	0.01	−0.04*	−0.03
	(0.01)	(0.01)	(0.01)	(0.06)	(0.03)	(0.02)	(0.06)	(0.02)
R^2	0.91	0.95	0.87	0.91	0.54	0.92	0.92	0.94

*Significant at 5%, **significant at 10%, std. errors in parentheses.

Table 11: Estimates of the triangle model (eq. 10), Output gaps

	Aus.	Can.	Fra.	Ger.	S. Kor.	S.Afr.	US.	UK.
	Keynesian output gaps							
ρ_1	0.97*	0.98*	0.98*	0.98*	1.00*	0.98*	1.00*	0.99*
	(0.02)	(0.01)	(0.02)	(0.02)	(0.04)	(0.01)	(0.01)	(0.02)
η_1	0.07**	0.05*	0.01*	0.01*	0.11**	0.14*	0.04*	0.04*
	(0.04)	(0.02)	(0.00)	(0.00)	(0.05)	(0.04)	(0.02)	(0.02)
ω_{m1}	0.00	0.00	0.02	0.03*	−0.01	0.05*	0.05*	0.00
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
ω_{f1}	−0.02	0.02	−0.07*	−0.05**	−0.05	0.03	0.00	0.10*
	(0.01)	(0.03)	(0.03)	(0.02)	(0.04)	(0.03)	(0.04)	(0.04)
ω_{e1}	−0.01	0.00	−0.02**	−0.01	−0.01	0.00	−0.04*	0.00
	(0.01)	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)
R^2	0.91	0.95	0.87	0.92	0.56	0.92	0.93	0.94
	Triangle output gaps							
ρ_1	0.98*	0.99*	0.96*	0.97*	0.79*	0.99*	1.00*	1.00*
	(0.02)	(0.01)	(0.03)	(0.02)	(0.07)	(0.01)	(0.02)	(0.02)
η_1	0.11**	0.09*	0.04*	0.02	0.08	0.12*	0.05*	0.23*
	(0.06)	(0.04)	(0.01)	(0.00)	(0.03)	(0.05)	(0.04)	(0.05)
ω_{m1}	0.00	0.01	0.04*	0.02**	0.00	0.06*	0.05*	0.02
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
ω_{f1}	−0.01	0.00	−0.12*	−0.05**	−0.03	0.03	0.01	0.05
	(0.04)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.04)	(0.04)
ω_{e1}	−0.01	−0.02**	−0.04*	−0.01	0.00	0.00	−0.04*	−0.04*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.02)	(0.06)	(0.02)
R^2	0.91	0.95	0.81	0.91	0.60	0.92	0.93	0.94

*Significant at 5%, **significant at 10%, std. errors in parentheses.

Table 11 presents the results for the output gap as a demand pressure term. The parameter of the output gap that is computed using the Keynesian approach has a correct sign and is significant for all the countries, while the parameter of the output gap that is computed using the triangle approach has a correct sign and significant for six countries. The countries where the triangle output gap is not significant are Germany and South Korea. Import prices consistently play a significant role in the determination of inflation in Germany, South African and the United States.

3.5 Conclusion

We find that demand pressure variables computed from the Keynesian and triangle system approach have a correct and significant sign when fitted in the respective systems that determine inflation. We find that import prices play a more significant role in the determination of general price inflation compared to food and energy prices. We find a strong Okun's law relationship between the output and unemployment gaps computed from the two respective methodologies that we consider in this paper. We find that the output gaps computed from the two competing approaches are significantly correlated, the same applies to the unemployment gaps computed from the two approaches. We find that the quality of unemployment rate gaps computed from the Keynesian and triangle system approach to produce similar quality of results when fitted to a single equation triangle price Phillips curve. The Keynesian approach slightly outperforms the triangle systems approach in the when considering the output gap as a proxy for the demand pressure. These results indicate that the wage-price spiral still remains an important tool in the determination of the dynamics inflation.

4 Are NAIRUs and Potential Output Orthogonal to Monetary Policy Changes?

4.1 Introduction

Friedman (1968) and Phelps (1968) argue that monetary policy does not have an impact on natural variables. Friedman (1968) in particular states that monetary policy cannot peg interest rates and the unemployment rate. If the central bank kept interest rate lower, it would stimulate spending which would ultimately cause inflation to increase. With an increase in inflation, the public will come to expect a further increase in inflation, which, by Fisher's relation, would raise the nominal interest rate. The central bank cannot peg the unemployment rate below the natural rate either, because this would be inflationary, causing the nominal interest rate to rise. In his Nobel lecture Friedman (1977) maintains the view that nominal variables like monetary aggregates cannot determine real variables like the natural rate of unemployment. As Bernanke and Milhov (1998) note, this view about the long run neutrality of monetary policy is widely accepted in the literature and by policymakers.

However, the monetary neutrality view has been challenged on several grounds. The first line of the challenge is based on the idea that wage rigidities and indexation play an important role in the transmission of monetary shocks to real variables. For example, Barro (1977) points out that wage stickiness is derived from an insurance element that mutually benefit firms and workers. Gray (1976) argues that monetary supply shocks given rigid wages may cause fluctuation in employment and output. Sargent (1976) estimates a structural macroeconomic model testing the neutrality argument. He finds that the hypothesis that monetary policy causes unemployment cannot be rejected. Fischer (1976) considers three models of wage indexing, and finds that wage indexing stabilizes output. In his later work, Fischer (1977) finds that overlapping labour contracts monetary policy can affect the behavior of output. While Gordon and Leeper (1994) later find that a monetary policy shocks affect output even after three years. Goodfriend and King (1997) monetary policy has an impact on real variables in the context of the New Neoclassical Synthesis models when they control for Keynesian wage rigidity effects.

The second line of challenge against the monetary neutrality view is based on the idea that there is no equilibrium unemployment rate that is independent of the history of the actual unemployment rate–the idea of hysteresis. Tobin

(1980) says that: "It is possible that there is no NAIRU, no natural rate, except one that floats with actual history." This means that the NAIRU may not be independent of the actual unemployment rate. Tobin (1981) further argues that empirically, the monetary neutrality view has a "dismal record" and yet, it has not diminished in policy making circles. Perhaps the most influential paper that has put forward the idea of hysteresis in the unemployment rate is the one by Blanchard and Summers (1986). This paper argues that since monetary policy affects the actual unemployment, and the NAIRU has hysteresis, then monetary policy does determine real variables in both the short and long run.

While Friedman (1968) argued that the natural rate of unemployment "...is the level that would be ground out by the Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of labor and commodity markets, including market imperfections, stochastic variability in demand and supplies, the cost of gathering information about job vacancies and labor availabilities, the cost of mobility and so on." Therefore Ball (1999) in support finds that a sustained monetary policy position drives natural variables. Where disinflation in OECD countries increased the NAIRU overtime. Blanchard (2003) maintains that monetary policy has an impact on real variables, and that the this can last for a period of over ten years. There has been a debate in the literature on whether monetary policy has an impact on long-run variables.

This paper makes an empirical contribution by testing the relationship between longrun variables generated from Keynesian and triangle system approaches and monetary policy using the Semmler and Zhang (2004) methodology. They postulate a positive relationship between NAIRU and monetary policy. They regress the NAIRU against a constant and an eight quarter backward average of the real interest rate. They find a significant positive relationship between the NAIRU and monetary policy. The second contribution that this paper makes relates to the explicit introduction of hysteresis in the relationship between longrun variables and monetary policy. The literature has largely established hysteresis as an important driver of the NAIRU (for example: Ball (1999), Blanchard and Summers (1986), Ball (1997)). We use the IS curve and an equation of motion for the NAIRU to ground this relationship in theory.

This paper is structured as follows: Section 4.2 presents the methodology, Section 4.3 analysis, Section 4.4 robustness checks and Section 4.5 concludes.

4.2 Methodology

To test whether the there is a relationship between the NAIRU and monetary policy, we follow Semmler and Zhang (2004) and use the empirical specification which links the NAIRU and the real interest rate, which we write as follows:

$$u_t^n = \tau_0 + \tau_1 \bar{r}_t + \varepsilon_{nt}, \tag{11}$$

where u_t^n is the NAIRU, $\tau_1 > 0$ and $\bar{r}_t$ is the moving average of the real interest rate, the error term is represented by ε_{nt}. In the case of the relationship between potential output and monetary policy, $\tau_1 < 0$ through Okun's law. As a way to rationalize eq.(1), Blanchard (2003) identifies hysteresis as a phenomenon that brings about a relationship between the NAIRU and monetary policy. The theoretical relationship between these two variables rests on a presupposition that persistently high interest rates lead to a fall in the growth rate. Through Okun's law, the decrease in the growth rate leads to a high actual unemployment rate, which then leads to an increase in the NAIRU.

We explicitly introduce hysteresis by assuming that the change in the NAIRU is determined by the unemployment gap as follows:

$$u_t^n = u_{t-1}^n + \beta(u_{t-1} - u_{t-1}^n), \tag{12}$$

where u_t is the actual unemployment rate and β is the hysteresis parameter. We now introduce a simple IS relation that will assist in grounding the relationship between the real interest rate and the natural rate of unemployment in theory. The simple IS relation is as follows:

$$(y_t - y_t^n) = \gamma_1(y_{t-1} - y_{t-1}^n) + \gamma_2(y_{t-2} - y_{t-2}^n) - \varphi \bar{r}_{t-1} \tag{13}$$

where y_t and y_t^n is actual output and potential output, respectively. Using Okun's law, we can restate the unemployment gap in terms of the output gap as follows:

$$u_t - u_t^n = -\theta(y_t - y_t^n) \tag{14}$$

We can then write eq. (14) as follows:

$$(y_t - y_t^n) = -\rho(u_t - u_t^n) \tag{15}$$

where $\rho = \frac{1}{\theta}$. Substituting eq. (15) into eq. (13) results in the following:

$$(u_t - u_t^n) = \gamma_1(u_{t-1} - u_{t-1}^n) + \gamma_2(u_{t-2} - u_{t-2}^n) + \frac{\varphi}{\rho}\overline{r}_{t-2} \tag{16}$$

Substituting in the lag of the unemployment rate gap given by eq. (16) into the hysteresis eq. (12) results in the following:

$$u_t^n = u_{t-1}^n + \delta_1(u_{t-2} - u_{t-2}^n) + \delta_2(u_{t-3} - u_{t-3}^n) + \delta_3\overline{r}_{t-2} \tag{17}$$

where $\delta_1 = \beta\gamma_1$, $\delta_2 = \beta\gamma_2$ and $\delta_3 = \frac{\beta\varphi}{\rho}$, respectively. Eq. (17) says there is a positive relationship between the natural rate of unemployment and monetary policy, taking into account hysteresis. It is a more general specification that extends the equation proposed by Semmler and Zhang (2004). To investigate the relationship between potential output and monetary policy we start by capturing hysteresis in potential output using eq. (12), this is what Ball (1999) calls "reverse hysteresis". This is then followed by making the output gap the measure of demand pressure in the IS equation. Then substituting eq. (13) in the hysteresis equation in terms of potential output results in the following:

$$\Delta y_t^n = -\beta_0 y_{t-1}^n + \phi_1(y_{t-2} - y_{t-2}^n) + \phi_2(y_{t-3} - y_{t-3}^n) + \phi_3\overline{r}_{t-2} \tag{18}$$

where Δ is the difference operator and y_t^n is the log level of potential output, β_0 is the hysteresis parameter of potential output and $\phi_1 = \beta_0\gamma_1$, $\phi_2 = \beta_0\gamma_2$ and $\phi_3 = -\beta_0\varphi$. Eq. (18) above establishes a negative relationship between the growth rate of potential output and the real interest rate. Since we have accounted for hysteresis from the standpoint of potential output, the theoretical relationship that comes out is one where the second lag of the real interest rate determines the current growth rate of potential output in a negative way.

4.3 Analysis

Table 1 below presents results of the estimation of Eq. (11). We estimate the equation using NAIRUs computed using the Keynesian, triangle system and the HP filter approaches. As pointed out by Harvey and Jaeger (1993) the HP filter has a long tradition of being used to smooth data. This method of smoothing data is not without its problems. However, this method is often used in the literature for bechmarking purposes. We find that the parameter of the real interest rate generally has a correct sign when considering the Keynesian approach computed NAIRU's, with only four being significant.

The results of estimates of eq. (11) using NAIRUs from competing methodologies are presented in Table 12. In the case of the triangle system approach NAIRU, we find that the real interest rate parameter has a correct sign and significant four countries. NAIRUs computed using different methodologies can produce a different reference point for policy makers. For instance, we find that there is a positive relationship between the NAIRU computed from the Keynesian and HP filter approaches for the triangle system and HP filtering approaches. On the other hand, the Keynesian approach NAIRU produces a positive relationship with the real interest rate proxy. The HP approach produces a positive relationship for the same number of countries as the Keynesian approach.

Table 12: Estimates of Eq. (11), NAIRU

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
				Flaschel NAIRUs				
τ_0	0.06* (0.00)	0.07* (0.00)	0.10* (0.00)	0.08* (0.00)	0.02* (0.00)	0.20* (0.01)	0.05* (0.00)	0.07* (0.00)
τ_1	0.01 (0.00)	0.30* (0.00)	−0.27* (0.00)	−0.16* (0.07)	0.44* (0.07)	1.25* (0.16)	0.11* (0.04)	0.30* (0.05)
R^2	0.00	0.62	0.47	0.03	0.48	0.33	0.05	0.19
$Corr.$	0.02	0.79	−0.69	−0.18	0.69	0.58	0.22	0.44
				Apel NAIRUs				
τ_0	0.05* (0.00)	0.08* (0.00)	0.10* (0.00)	0.09* (0.00)	0.07* (0.00)	0.17* (0.00)	0.07* (0.00)	0.07* (0.00)
τ_1	0.34* (0.06)	0.18* (0.03)	−0.06 (0.04)	−0.44* (0.09)	−0.07 (0.21)	1.26* (0.11)	−0.18* (0.04)	0.29* (0.05)
R^2	0.26	0.22	0.02	0.14	0.00	0.53	0.12	0.19
$Corr.$	0.51	0.47	−0.66	−0.37	−0.05	0.73	−0.35	0.44
				HP filter NAIRUs				
τ_0	0.05* (0.00)	0.07* (0.00)	0.09* (0.00)	0.08* (0.00)	0.03* (0.00)	0.17* (0.00)	0.06* (0.00)	0.07* (0.00)
τ_1	0.34* (0.06)	0.43* (0.03)	0.06* (0.03)	−0.12 (0.09)	−0.02* (0.00)	1.28* (0.11)	−0.01 (0.05)	0.22* (0.06)
R^2	0.39	0.58	0.05	0.01	0.19	0.52	0.07$^+$	0.09
$Corr.$	0.50	0.76	0.21	−0.12	0.44	0.72	−0.01	0.62

*Significant at 5%, **significant at 10%, std. errors in parentheses. $^+$ is 10^{-3} and $^\times$ is 10^{-2}

We find that for the majority of countries the correlation between the Keynesian NAIRU and the real interest rate is positive except for France and Germany. We also find a negative correlation for France, Germany, South Korea and the United States. For the HP filtering approach, we find a negative correlation for two countries. The three methodology NAIRUs confirm negative correlation in Germany. Table 13 presents results of the relationship between monetary policy and potential output. We find that the interest rate parameter generally has an incorrect sign across the three approaches. The HP filtering approach produces incorrect correlation for all the countries, while the Keynesian approach negative correlation for seven countries, and the triangle system approach in six countries. We interestingly have cases of expected correlation and a wrong sign problem for the parameter of interest, for example, the triangle system approach for Australia.

Table 13: Estimates of Eq. (11), Potential output

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
	Flaschel Potential Output							
τ_0	$0.41^{\times *}$ (0.00)	$0.31^{\times *}$ (0.05)	$0.36^{\times *}$ (0.00)	$-0.11^{\times}$ (0.00)	$0.36^{\times *}$ (0.00)	$0.18^{\times *}$ (0.00)	$0.35^{\times *}$ (0.00)	$0.38^{\times *}$ (0.00)
τ_1	0.01 (0.01)	-0.01 (0.01)	$0.18^{\times}$ (0.02)	0.16^{*} (0.04)	0.03^{*} (0.02)	$-0.34^{\times}$ (0.00)	0.01 (0.00)	0.01^{*} (0.01)
R^2	0.02	0.02	0.00	0.12	0.09	0.01	0.01	0.01
$Corr.$	-0.76	-0.62	-0.82	-0.50	-0.68	0.37	-0.47	-0.43
	Apel Potential Output							
τ_0	$0.36^{\times *}$ (0.00)	$0.36^{\times *}$ (0.00)	$0.25^{\times *}$ (0.00)	$0.22^{\times *}$ (0.00)	$0.32^{\times *}$ (0.00)	$0.17^{\times *}$ (0.00)	$0.31^{\times *}$ (0.00)	$0.29^{\times *}$ (0.00)
τ_1	0.02^{*} (0.05)	0.02^{*} (0.00)	0.01^{*} (0.00)	0.05^{*} (0.01)	0.04^{*} (0.02)	$0.22^{\times}$ (0.00)	0.03^{*} (0.01)	0.02^{*} (0.00)
R^2	0.35	0.06	0.10	0.21	0.07	0.01	0.19	0.14
$Corr.$	-0.76	-0.47	0.48	-0.50	-0.67	0.37	-0.47	-0.38
	HP filter Potential Output							
τ_0	0.05^{*} (0.00)	0.05^{*} (0.00)	0.04^{*} (0.00)	0.04^{*} (0.00)	0.04^{*} (0.00)	0.02^{*} (0.00)	0.05^{*} (0.00)	0.07^{*} (0.00)
τ_1	0.21^{*} (0.03)	0.04 (0.08)	0.17^{*} (0.04)	0.39^{*} (0.12)	0.41^{*} (0.08)	0.04 (0.03)	0.31^{*} (0.08)	0.22^{*} (0.06)
R^2	0.31	$0.25^{\times}$	0.14	0.07	0.37	0.02	0.09	0.09
$Corr.$	0.56	0.05	0.38	0.27	0.60	0.13	0.30	0.56

*Significant at 5%, **significant at 10%, std. errors in parentheses.$^+$ is 10^{-3} and $^\times$ is 10^{-2}

Table 14: Estimates of Eq. (12)

	Keynesian	R^2	Triangle	R^2	HP filter	R^2
Aus.	0.06^{**} (0.03)	0.66	0.24^{**} (0.08)	0.77	-0.07^{**} (0.04)	0.95
Can.	0.00 (0.02)	0.88	0.01 (0.04)	0.59	-0.09^{*} (0.04)	0.91
Fra.	0.17^{*} (0.02)	0.93	0.53^{*} (0.10)	0.55	-0.08 (0.06)	0.85
Ger.	0.04 (0.04)	0.91	0.39^{*} (0.09)	0.79	-0.11 (0.07)	0.88
S. Korea	0.13^{*} (0.05)	0.90	0.44^{*} (0.14)	0.17	-0.04^{*} (0.01)	0.76
S. Africa	0.38^{*} (0.04)	0.97	-0.44^{*} (0.09)	0.99	-0.10 (0.04)	0.98
US.	0.13^{*} (0.03)	0.73	-0.08^{*} (0.04)	0.72	-0.06 (0.04)	0.91
UK.	0.11^{*} (0.04)	0.91	0.20^{*} (0.06)	0.68	-0.10 (0.09)	0.89

*Significant at 5%, **significant at 10%, std. errors in parentheses.

We now turn our attention to understanding the extent to which the hysteresis parameter is important by estimating eq. (12). Table 14 presents results. We find that in the case of the Keynesian NAIRU, the hysteresis parameter has a correct sign and significant in six countries. In the case of the triangle system approach we find a positive sign and significance for five countries. The triangle system NAIRU has a wrong sign problem that is significant. This produces a counter-intuitive result where a positive unemployment gap reduces the NAIRU. While the HP filter approach produces a wrong sign problem for the parameter for all the countries. Table 15 presents results of the relationship between the NAIRU and monetary policy when taking hysteresis into account.

We find that the parameter of the real interest rate has a correct sign and significant for only two countries for the three approaches. The Keynesian and the HP approaches NAIRUs have an incorrect sign for four countries. While in the case of the triangle system NAIRU, only two countries, the United States and the United Kingdom, have an incorrect sign. We also find that the correlation of the NAIRU and the proxy for the real interest rate when taking hysteresis into account to be consistently negative for both France and Germany for the two approaches. However, the HP filter approach only confirms the same result as the other two approaches for Germany. Table 16 presents results of the relationship between monetary policy and potential output when taking into account hysteresis.

Table 15: Estimates of Eq. (17)

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
				Flaschel NAIRUs				
$cons$	$0.11^{\times}$ (0.00)	0.06^{+} (0.00)	$0.52^{\times *}$ (0.00)	-0.18^{+} (0.00)	-0.60^{+*} (0.00)	$0.16^{\times *}$ (0.00)	-0.52^{+*} (0.00)	0.99^{+*} (0.00)
δ_1	-0.08^{*} (0.00)	0.02 (0.02)	0.01 (0.04)	0.02 (0.04)	$0.22^{\times}$ (0.03)	-0.03 (0.05)	-0.06 (0.04)	0.10^{*} (0.04)
δ_2	0.09^{**} (0.05)	-0.02 (0.02)	0.03 (0.04)	$-0.12^{\times}$ (0.04)	0.01 (0.03)	0.13^{*} (0.05)	0.10^{*} (0.04)	-0.09^{*} (0.04)
δ_3	0.01 (0.01)	-0.95^{+} (0.00)	$-0.17^{\times}$ (0.00)	0.02^{*} (0.01)	0.01 (0.01)	-0.01^{*} (0.01)	0.02^{*} (0.01)	-0.02^{*} (0.00)
R^2	0.97	0.99	0.99	0.99	0.99	0.99	0.98	0.99
$Corr.$	0.05	0.79	-0.68	-0.13	0.70	0.58	0.25	0.42
				Apel NAIRUs				
$cons$	$-0.11^{\times **}$ (0.00)	$0.21^{\times}$ (0.00)	0.65^{+} (0.00)	0.01^{+} (0.00)	$-0.19^{\times *}$ (0.00)	$0.11^{\times *}$ (0.00)	0.04^{+} (0.00)	0.92^{+} (0.00)
δ_1	0.05 (0.06)	0.07 (0.05)	0.16 (0.18)	0.25^{*} (0.08)	-0.41^{*} (0.10)	-0.04 (0.03)	0.05 (0.06)	-0.04 (0.07)
δ_2	$-0.18^{\times}$ (0.07)	-0.06 (0.05)	-0.03 (0.18)	-0.17^{*} (0.08)	0.50^{*} (0.10)	-0.08^{*} (0.03)	-0.07 (0.06)	0.07 (0.07)
δ_3	0.02^{*} (0.01)	0.01 (0.01)	$0.42^{\times}$ (0.01)	0.02 (0.02)	0.09^{*} (0.04)	0.59^{+} (0.00)	$-0.40^{\times}$ (0.00)	-0.02 (0.01)
R^2	0.96	0.92	0.94	0.95	0.96	0.99	0.95	0.95
$Corr.$	0.54	0.46	-0.11	-0.32	0.08	0.73	-0.37	0.40
				HP filter NAIRUs				
$cons$	-0.88^{+*} (0.00)	0.12^{+} (0.00)	0.24^{+*} (0.00)	0.88^{+*} (0.00)	0.05^{+*} (0.00)	$0.14^{\times *}$ (0.00)	0.76^{+*} (0.00)	$0.17^{\times *}$ (0.00)
δ_1	0.05^{**} (0.02)	0.05^{**} (0.02)	0.06^{**} (0.04)	0.05 (0.05)	-0.12^{+} (0.00)	$-0.25^{\times}$ (0.00)	-0.10^{*} (0.02)	0.11^{*} (0.04)
δ_2	-0.05^{*} (0.02)	-0.07^{*} (0.02)	-0.07^{**} (0.18)	-0.04 (0.05)	$-0.88^{\times *}$ (0.00)	$-0.34^{\times}$ (0.00)	-0.03^{*} (0.00)	-0.18^{*} (0.05)
δ_3	0.01^{*} (0.00)	$-0.34^{\times}$ (0.01)	0.01^{*} (0.00)	0.04 (0.01)	$0.11^{\times}$ (0.00)	$-0.37^{\times}$ (0.00)	-0.02^{*} (0.00)	-0.04^{*} (0.00)
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
$Corr.$	0.59	0.77	0.29	-0.03	0.56	0.73	-0.02	0.65

*Significant at 5%, **significant at 10%, std. errors in parentheses. $^{+}$ is 10^{-3} and $^{\times}$ is 10^{-2}

Table 16: Estimates of Eq. (18)

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
				Flaschel Potential Output				
$cons$	0.07^{*}	-0.01	-0.08	0.15^{*}	0.24^{*}	-0.09^{*}	0.15^{*}	0.06^{*}
	(0.01)	(0.01)	(0.09)	(0.03)	(0.01)	(0.02)	(0.01)	(0.01)
β_0	-0.02^{*}	0.04	0.03	-0.05^{*}	-0.09^{*}	0.04^{*}	-0.05^{*}	-0.02^{*}
	(0.00)	(0.01)	(0.04)	(0.01)	(0.01)	(0.08)	(0.00)	(0.00)
ϕ_1	-0.05^{*}	-0.06^{*}	-0.09^{*}	-0.20^{*}	$-0.41^{\times}$	-0.05^{*}	-0.09^{*}	-0.04^{*}
	(0.01)	(0.01)	(0.02)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
ϕ_2	0.08^{*}	0.08^{*}	0.12^{*}	0.21^{*}	-0.74^{+}	0.06^{*}	0.10^{*}	0.06^{*}
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ϕ_3	-0.02^{*}	-0.02^{*}	$0.24^{\times}$	-0.02	-0.04^{*}	-0.01^{**}	-0.04^{*}	-0.04^{*}
	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)	(0.00)	(0.01)	(0.01)
R^2	0.39	0.28	0.49	0.75	0.89	0.24	0.73	0.46
$Corr.$	0.06	-0.15	0.03	0.31	0.22	-0.02	-0.02	0.02
				Apel Potential Output				
$cons$	0.06^{*}	0.13^{*}	0.16^{*}	0.13^{*}	0.32^{*}	0.10^{*}	0.12^{*}	0.10^{*}
	(0.00)	(0.00)	(0.02)	(0.01)	(0.03)	(0.01)	(0.00)	(0.01)
β_0	-0.02^{*}	-0.05^{*}	-0.06^{*}	-0.04^{*}	-0.11^{*}	0.03^{*}	-0.04^{*}	-0.04^{*}
	(0.00)	(0.05)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
ϕ_1	-0.01	-0.01	-0.01^{**}	0.01	-0.02^{*}	0.01	$0.32^{\times}$	0.02^{*}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
ϕ_2	0.01	0.02^{*}	0.02^{**}	-0.01	0.01^{**}	-0.01^{**}	0.01	-0.01^{*}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
ϕ_3	-0.01^{**}	-0.03^{*}	-0.03^{*}	-0.02^{*}	-0.02^{*}	$-0.19^{\times}$	-0.01^{*}	-0.01
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
R^2	0.72	0.93	0.93	0.76	0.89	0.48	0.94	0.76
$Corr.$	0.58	0.14	0.24	0.33	0.41	0.19	0.33	0.32
				HP filter Potential Output				
$cons$	0.22^{*}	0.63^{*}	0.91^{*}	0.70^{*}	0.72^{*}	-0.41^{*}	0.67^{*}	0.48^{*}
	(0.02)	(0.01)	(0.06)	(0.03)	(0.02)	(0.06)	(0.02)	(0.03)
β_0	-0.01^{*}	-0.04^{*}	-0.06^{*}	-0.04^{*}	-0.05^{*}	0.03^{*}	-0.04^{*}	-0.03^{*}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ϕ_1	-0.05	-0.02	-0.23^{*}	0.16	0.02	0.30^{*}	0.11	0.18
	(0.07)	(0.07)	(0.10)	(0.10)	(0.01)	(0.12)	(0.08)	(0.15)
ϕ_2	-0.14^{*}	0.13^{*}	-0.05	-0.08	0.01	-0.26^{*}	-0.09	-0.20
	(0.06)	(0.07)	(0.10)	(0.10)	(0.01)	(0.12)	(0.08)	(0.01)
ϕ_3	-0.02	-0.48^{*}	-0.53^{*}	-0.37^{*}	-0.13^{*}	0.01	-0.19^{*}	0.12^{*}
	(0.03)	(0.03)	(0.06)	(0.07)	(0.01)	(0.02)	(0.03)	(0.05)
R^2	0.56	0.93	0.74	0.77	0.98	0.34	0.91	0.67
$Corr.$	0.51	-0.04	0.32	0.14	0.59	0.20	0.20	0.51

*Significant at 5%, **significant at 10%, std. errors in parentheses. $^{+}$ is 10^{-3} and $^{\times}$ is 10^{-2}

The real interest rate parameter generally has a correct sign when considering the growth rate of potential output computed using the Keynesian approach. We find that monetary policy does have a significant negative relationship with potential output, except for France. We similarly find that, using the triangle system approach and the HP filter approaches, the real interest rate parameter is generally negative and significant. We continue to find positive correlation being accompanied by negative regression relationship between the dependent and independent variable of interest.

We find that the hysteresis parameter β_0, as argued by Blanchard (2003) does indeed play a significant role in the relationship between monetary policy and potential output. We also find that potential computed using the triangle system approach Apel type approach consistently have a positive correlation with the proxy for the real interest rate, which in this case is the second lag as per eq. (18). Given the theoretical relationship between output and the unemployment rate captured by Okun's law, the expectation was a negative correlation between the growth rate of potential output and the real interest rate proxy. The Flaschel type growth rate of potential output as the similar result for the majority of countries that we consider when controlling for hysteresis.

4.4 Robustness checks

We conduct robustness checks in order to test the specification of the relationships outlined in eq. (11). We add two lags of the dependent variables on the right hand side. The two lags capture the fact that we use a traditional Keynesian Phillips curve in the benchmarking process since this type of formulation is the least controversial from the standpoint of theoretical validity as demonstrated in our findings in the second chapter of this thesis. Table 17 presents results for robustness checks for NAIRUs from the three approaches.

Table 17: NAIRU Robustness Estimates of Eq. (11)

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
				Flaschel NAIRUs				
u_{t-1}	1.62*	1.79*	1.76*	1.85*	1.44*	1.67*	1.76*	1.94*
	(0.07)	(0.05)	(0.06)	(0.04)	(0.14)	(0.06)	(0.05)	(0.03)
u_{t-2}	−0.65*	−0.82*	−0.78*	−0.86*	−0.44*	−0.69*	−0.78*	−0.95*
	(0.07)	(0.05)	(0.06)	(0.04)	(0.00)	(0.06)	(0.05)	(0.03)
τ_0	0.00**	0.00*	0.00**	0.00*	−0.00	0.00*	0.001*	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	0.01	0.01*	−0.003	0.002	0.004	0.01	0.01*	0.00
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)
R^2	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99
				Apel NAIRUs				
u_{t-1}	1.05*	1.26*	1.52*	1.13*	1.65*	1.86*	1.11*	1.086*
	(0.09)	(0.08)	(0.09)	(0.08)	(0.10)	(0.04)	(0.08)	(0.09)
u_{t-2}	−0.10**	−0.33*	−0.56*	−0.17*	−0.71*	−0.87*	−0.16**	−0.11
	(0.09)	(0.08)	(0.00)	(0.00)	(0.10)	(0.00)	(0.00)	(0.09)
τ_0	0.00	0.01*	0.00*	0.00	0.00	0.00*	0.003*	0.00
	(0.00)	(0.00)	(0.00)	(0.020)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	0.04*	0.01	0.003	0.007	0.07**	0.00	−0.02	−0.01
	(0.01)	(0.01)	(0.04)	(0.02)	(0.04)	(0.00)	(0.01)	(0.02)
R^2	0.96	0.93	0.96	0.95	0.97	0.99	0.95	0.94
				HP filter NAIRUs				
u_{t-1}	1.96*	1.98*	1.97*	1.97*	1.96*	1.99*	2.01*	1.99*
	(0.00)	(0.00)	(0.00)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
u_{t-2}	−0.97*	−0.99*	−0.98*	−0.98*	−0.97*	−0.99*	−1.02*	−0.99*
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
τ_0	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	0.003	0.004*	0.001*	0.002*	0.00*	−0.00*	0.00	0.001*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.05)
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

*Significant at 5%, **significant at 10%, std. errors in parentheses. $^+$ is 10^{-3} and $^\times$ is 10^{-2}

We find that the lags of the NAIRUs to be generally significant with sum of the fist and second lag parameters being positive. For the Keynesian approach, we find that robustness checks results in only half the number of countries having a correct sign and significant of the initial case. In the case of the triangle system approach, robustness checks yield a correct and significant interest rate parameter for only two countries. For the HP approach, the number of countries with a correct sign and significant for the real interest rate parameter remains the same at five. This finding indicates that results from the three approaches regarding the relationship between the growth rate of potential output and monetary policy is robust to different specifications for the HP approach. The other two approaches experience half the number of countries having a positive and significant sign for the interest rate parameter. This points to the fact that, for the two approaches, the findings are not robust. Table 18 presents robustness checks in relation to the relationship between monetary policy and potential output.

Table 18: Potential output Robustness Estimates of Eq. (11)

	Aus.	Can.	Fra.	Ger.	S.Kor.	S.Afr.	US.	UK.
				Flaschel Potential Output				
Δy^n_{t-1}	1.54^{*}	1.48^{*}	1.49^{*}	1.56^{*}	1.49^{*}	1.51^{*}	1.50^{*}	1.56^{*}
	(0.07)	(0.06)	(0.06)	(0.06)	(0.15)	(0.06)	(0.07)	(0.06)
Δy^n_{t-2}	-0.69^{*}	-0.72^{*}	-0.76^{*}	-0.72^{*}	-0.53^{*}	-0.77^{*}	-0.59^{*}	-0.70^{*}
	(0.07)	(0.06)	(0.06)	(0.05)	(0.15)	(0.05)	(0.07)	(0.06)
τ_0	0.66^{+*}	0.76^{+*}	0.95^{+*}	-0.07^{+}	0.14^{+}	0.45^{+*}	0.31^{+*}	0.46^{+*}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	$0.10^{\times}$	$-0.33^{\times}$	$0.13^{\times}$	0.02^{**}	$0.30^{\times}$	-0.46	0.31^{+}	0.99^{+}
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.91	0.89	0.89	0.92	0.97	0.89	0.93	0.94
				Apel Potential Output				
Δy^n_{t-1}	1.54^{*}	1.73^{*}	1.73^{*}	1.81^{*}	1.75^{*}	1.82^{*}	1.69^{*}	1.47^{*}
	(0.05)	(0.06)	(0.07)	(0.05)	(0.10)	(0.05)	(0.06)	(0.07)
Δy^n_{t-2}	-0.69^{*}	-0.73^{*}	-0.75^{*}	-0.83^{*}	-0.78^{*}	-0.84^{*}	-0.07^{*}	-0.48^{*}
	(0.07)	(0.05)	(0.07)	(0.05)	(0.10)	(0.04)	(0.06)	(0.08)
τ_0	0.66^{+*}	0.02^{+**}	0.05^{+}	0.03^{+**}	0.07^{+*}	0.03^{+*}	0.02^{+**}	0.01^{+}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	0.13^{+*}	0.12	-0.11^{+}	0.41^{+*}	$0.42^{\times **}$	0.25^{+*}	0.02^{+*}	0.02^{+}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.91	0.99	0.99	0.99	0.99	0.99	0.99	0.99
				HP filter Potential Output				
Δy^n_{t-1}	2.02^{*}	1.97^{*}	2.01^{*}	1.96^{*}	2.00^{*}	1.96^{*}	1.97^{*}	1.99^{*}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.08)	(0.01)	(0.01)	(0.01)
Δy^n_{t-2}	-1.03^{*}	-0.97^{*}	-1.02^{*}	-0.96^{*}	-1.01^{*}	-0.97^{*}	-0.97^{*}	-0.99^{*}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.09)	(0.01)	(0.01)	(0.01)
τ_0	0.60^{+*}	0.15^{+*}	0.55^{+*}	0.18^{+*}	0.24^{+}	0.15^{+*}	0.11^{+*}	0.06^{+**}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
τ_1	0.24^{+*}	0.95^{+}	$0.34^{\times *}$	0.86^{+*}	$0.27^{\times *}$	0.19^{+*}	0.36^{+*}	0.34^{+}
	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
R^2	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

*Significant at 5%, **significant at 10%, std. errors in parentheses. $^{+}$ is 10^{-3} and $^{\times}$ is 10^{-2}

As expected, we find that the two lagged variables of the growth rate of potential output are significant. For the Keynesian approach, we find that robustness checks results in only two countries having a correct sign and significant for one country as opposed to three countries in the initial case. In the case of the triangle system approach, robustness checks yield a correct and significant interest rate parameter for five countries. This is one less than in the initial case in the results presented in Table 13. In the case of the HP approach, the number of countries with a correct sign and significant for the real interest rate parameter remains the same at six. This finding indicates that results from the three approaches regarding the relationship between the growth rate of potential output and monetary policy is robust to different specifications.

4.5 Conclusion

We find that monetary policy proxied by the real interest rate does generally determine the NAIRU and potential output. We also hysteresis plays an important role in driving the NAIRU in the case of both the Keynesian and triangle system approaches. We, however, find that hysteresis is only important in the case of this relationship monetary policy and potential output and limited in the case of the monetary policy and the NAIRU.

5 Conclusion

In relation to forecasting inflation, this study finds that the New Keynesian wage-price suffers the same theoretical problem that the single equation NKPC suffers. The wrong sign problem on the forcing variable. The finding that half of the countries that we consider have this problem, places the rational of using the NKPC wage-price for policy purposes on shaky grounds. The finding on the wage-price spirals begs the question why has an empirically dismal formulation of the inflation process has gained such traction in the literature and policymaking circles.

We find that the traditional Keynesian wage-price spiral of Fair (2008) from the standpoint of root mean square errors outperforms the Flaschel type and New Keynesian specifications. We also find that this result is consistent when considering the Clark and West (2007) statistic of evaluating forecasts across models. This wrong sign problem finding on the forcing variable is a major setback for the NKPC literature in the studying the dynamics of inflation. It simply means that there was no need for a move away from the old Keynesian wage-price spiral in the determination of inflation. This finding means that there no meaningful progress that can is useful for policy purposes. Since there is little value to a forecasting tool that is theoretically invalid. This means that policymakers should go back to using the old Keynesian wage-price in studying the inflation process.

In relation to the estimation of the NAIRU and potential output, this study finds that the output and unemployment gaps from Keynesian and triangle system are significantly correlated. We importantly find that the unemployment rate gaps from the Keynesian and the triangle system approaches produce similar results when fitted to a single triangle price Phillips curve. We also find that in the case of the output gaps, the Keynesian generated gap slightly outperforms that of the triangle system. The results indicate that a fairly recent method of computing natural rates fails to outperform an old Keynesian specification of the wage-price spiral. This finding once again cements the place of the Keynesian wage-price spiral in studying the dynamics of inflation. This shows that information that in contained in the wage equation of the wage-price spiral is slightly more important we find compared to the one contained in Okun's law in explaining inflation dynamics.

In relation to the relationship between monetary policy and natural variables, we find that monetary policy does in some instances determine the NAIRU and potential output. This finding is consistent with the argument by Blanchard (2003). A significant relationship between monetary policy and potential variables presents a challenge in the conduct of monetary policy since as argued by Ball and Mankiw (2002) and Gordon (1997) these variable are supposed to serve as a reference point around which actual variables should be managed. This finding rejects the monetarist view that monetary policy does not have a significant impact on longrun variables.

This means that central banks cannot religiously assume that their monetary policy positions do not have an impact on longrun variables. We also find that hysteresis is important in the context of the relationship between monetary policy and potential output, and not monetary policy and the NAIRU as argued in Blanchard (2003). This means when trying to understand the impact of monetary policy on the two natural variables, monetary policy authorities need to understand that the hysteresis argument in the natural variables cannot be blindly applied.

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