DOCUMENTO DE TRABAJO N° 384

THE NEW KEYNESIAN FRAMEWORK FOR A SMALL OPEN ECONOMY WITH STRUCTURAL BREAKS: EMPIRICAL EVIDENCE FROM PERU

Walter Bazán-Palomino y Gabriel Rodríguez

DEPARTAMENTO DE ECONOMÍA

PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

DOCUMENTO DE TRABAJO N° 384

THE NEW KEYNESIAN FRAMEWORK FOR A SMALL OPEN ECONOMY WITH STRUCTURAL BREAKS: EMPIRICAL EVIDENCE FROM PERU

Walter Bazán-Palomino y Gabriel Rodríguez

Noviembre, 2014

DEPARTAMENTO
DE **ECONOMÍA**

DOCUMENTO DE TRABAJO 384
http://files.pucp.edu.pe/departamento/economia/DDD384.pdf

Av. Universitaria 1801, Lima 32 – Perú.
Teléfono: (51-1) 626-2000 anexos 4950 - 4951
Fax: (51-1) 626-2874
econo@pucp.edu.pe
www.pucp.edu.pe/departamento/economia/

Encargado de la Serie: Jorge Rojas Rojas
Departamento de Economía – Pontificia Universidad Católica del Perú,
jorge.rojas@pucp.edu.pe

Walter Bazán-Palomino y Gabriel Rodríguez

The New Keynesian Framework for a Small Open Economy with Structural Breaks: Empirical Evidence from Peru.
Lima, Departamento de Economía, 2014
(Documento de Trabajo 384)

PALABRAS CLAVE: Quiebres Estructurales, Curva de Philips Neokeynesiana, IS Dinámica, Regla de Taylor.

Hecho el Depósito Legal en la Biblioteca Nacional del Perú Nº 2014-17234.
ISSN 2079-8466 (Impresa)
ISSN 2079-8474 (En línea)

Impreso en Cartolán Editora y Comercializadora E.I.R.L.
Pasaje Atlántida 113, Lima 1, Perú.
Tiraje: 100 ejemplares

The New Keynesian Framework for a Small Open Economy with Structural Breaks: Empirical Evidence from Peru

Walter Bazán-Palomino
Pontificia Universidad Católica del Perú
Rutgers University

Gabriel Rodríguez
Pontificia Universidad Católica del Perú

Abstract

We present evidence from Peru that The New Keynesian Phillips Curve, Dynamic IS and Taylor Rule derived by Galí and Monacelli (2005) are unstable. The results from methodology of Bai and Perron (2003) suggest that the change of the policy rule (January-2006 and May-2009) induces a break in the inflation process (January-2008) and in the market equation (October-2008); the latter due to the existence of nominal frictions and incomplete information in the Peruvian economy. Moreover, Qu and Perron (2007) estimation reaffirms that there are breaks in the entire reduced system (May-2008 and May-2010). In both cases, the channel of expectations is strengthened since 2008 and it is related to changes in the monetary policy during those years.

JEL Classification: C32, C51, E31.

Keywords: Structural Breaks, New Keynesian Phillips Curve, Dynamic IS, Taylor Rule.

Resumen

En este documento se presenta evidencia para Perú de que la curva de Phillips Neokeynesiana, la IS Dinámica y la Regla de Taylor derivadas por Galí y Monacelli (2005) son inestables. Los resultados de la metodología de Bai y Perron (2003) sugieren que el cambio de la regla de política (Enero-2006 y Mayo-2009) induce una interrupción en el proceso de inflación (Enero-2008) y en la ecuación del mercado (Octubre-2008); este último debido a la existencia de fricciones nominales y la información incompleta en la economía Peruana. Por otra parte, las estimaciones usando el método de Qu y Perron (2007) reafirma que hay interrupciones en todo el sistema en forma reducida (Mayo-2008 y Mayo-2010). En ambos casos, el canal de expectativas se fortalece desde el año 2008 y está relacionado con los cambios en la política monetaria durante esos años.

Classificación JEL: C32, C51, E31

Palabras Claves: Quiebres Estructurales, Curva de Philips Neokeynesiana, IS Dinámica, Regla de Taylor.

The New Keynesian Framework for a Small Open Economy with Structural Breaks: Empirical Evidence from Peru[1]

Walter Bazán-Palomino
Pontificia Universidad Católica del Perú
Rutgers University

Gabriel Rodríguez[2]
Pontificia Universidad Católica del Perú

1 Introduction

Two of the most important lessons of the New Keynesian (NK) framework are the nominal rigidities as the main source of monetary policy non-neutrality and the gains from commitment due to the role of expectations (Galí and Gertler (1999); Clarida, Galí and Gertler (1999); Galí, Gertler and Lopez-Salido (2001, 2005)). Because of the nature of the forward-looking agents in this model, anticipated policy actions will have an influence on current outcomes and it is considered immune to the Lucas critique. Moreover, NK framework is a very flexible tool, capable of including in the basic model many issues with empirical evidence, for our purpose, open economy factors as Clarida, Galí and Gertler (2001), Galí and Monacelli (2005) and Monacelli (2005) approaches.

In spite of the quantitative analysis that can be done by Central Banks and other institutions (whether aimed at policy simulation, estimation or forecasts), here is still debate about the role of the econometric specification and the analysis of the stability of the vector of parameters of the specified model. The Central Bank must take into account that modeling and predicting are two different processes, but they are both affected by the shift in the parameters. In particular, long-term memory and/or non-stationarity of some variables in the model can be confused with their respective structural breaks. Even if it had the correct specification, a very common result is the low efficiency in the prediction. The theoretical and practical experience show that the failure of the prediction is due to changes in the parameters, specifically, the change in the relationship of the equilibrium and the change in the rate of growth of the exogenous variables.

Empirically, it is not clear whether the NK framework -regardless for a closed or an open economy- is stable. This means that the relationship between the variables could change over time, especially when policymakers try to exploit the trade-off between prices and unemployment or/and when the monetary regime shifts. Furthermore, if the parameters of the system reflect the optimal behavior of agents, it is natural to expect a change in this vector through time (Lucas (1976)).

In this regard, a change in the monetary target has two main consequences. According to Cogley and Sbordone (2008), shifts in the Central Bank's inflation objective can affect the persistence of the inflation rate. Another possible consequence is through the real market equation and following Lucas (1976) it is expected to induce a lagged break due to some nominal frictions and incomplete information. Also a change in the monetary instrument can induce a break in the whole system and

[1]This paper is drawn from the Master Thesis of Walter Bazán (2013), Department of Economics, Pontificia Universidad Católica del Perú. We thank useful comments of Todd Keister (Rutgers University), Paul Castillo and Marco Vega (Central Bank of Peru).

[2]Address for Correspondence: Gabriel Rodríguez, Department of Economics, Pontificia Universidad Católica del Perú, Av. Universitaria 1801, Lima 32, Lima, Perú, Telephone: +511-626-2000 (4998), Fax: +511-626-2874. E-Mail Address: gabriel.rodriguez@pucp.edu.pe.

it can be understood as necessary overreaction to ensure new equilibrium[3]; see Bardsen, Jansen and Nymoen (2004).

It is clear for policy makers to have a reliable and robust estimation of the NK framework considering structural breaks. The related literature to the estimation of the first equation of the system, the New Keynesian Phillips Curve (NKPC), is abundant. However, there is not a conclusive statement if the inflation process can be specified with the NKPC equation. Recent studies such as Galí and Gertler (1999); Clarida, Galí and Gertler (1999); Sbordone (2002); McAdam and Willman (2004); Gertler and Lopez-Salido (2001, 2005); and Nelson and Lee (2007) find considerable support for the NKPC using European and United States data. On the other hand, the contributions of Fuhrer (1997); Matheron and Maury (2004); Roberts (2005) and Juselius (2008) are less favorable.

In addition, some investigations that include open economy find some empirical support for the NKPC. For instance, using the Galí and Monacelli (2005) model, Mihailov, Rumler and Scharler (2008) find in a group of countries of OECD that the NKPC has a good performance in both an open and a close economy, regardless if it is pure or hybrid. Leith and Malley (2007) make a similar analysis for some of the G7 economies and find that the terms of trade and the marginal cost drive the inflation dynamics. In the same way, Rumler (2007) finds for the European Union that the degree of substitutability (imperfect) of intermediate goods between domestic and foreign has effects on inflation through the change in the probability of adjusting-prices decision of the firms.

On the sidelines of the debate on NKPC about the best fit of forward-looking, backward-looking or hybrid version, there is very few work studying its stability. For instance, Alogoskoufis and Smith (1991) find a structural break in 1968 for the U.K. and the U.S. which is attributed to the end of Bretton Woods system; Bai and Perron (2003) show two structural breaks in the U.K. which occurred in 1967 and in 1975; Perron and Yamamoto (2009) find one break in the hybrid version for U.S. in 1991; and Hasanov, Arac and Telatar (2010) find some non-linearities and instability in Turkey.

In contrast, the second equation of the model, the Dynamic IS (DIS) equation has not had the same attention as the NKPC and it is very rare to find some evidence of break within. Hence, the discussion focus on an appropriate estimation of the DIS. Supporting the relevance of forward-looking components in the determination of the current output, Furhrer and Rudebusch (2004) find evidence for the U.S. economy using GMM as same as Kara and Nelson (2004) for the U.K. and Australia using maximum likelihood. The latter authors not only show that the optimizing DIS equations for these countries are considerably more stable and interpretable than the backward-looking alternatives, they also split the sample according to the prevailing monetary policy regime but the difference with the full-sample estimate is not statistically significant. In the same spirit, trying to evaluate the stability of this equation for the U.S., Estrella and Furher (2003) implement a set of tests finding that the forward-looking version is less stable than their better-fitting backward-looking counterparts and Fuhrer (2000) shows a weak evidence in favor of the forward-looking DIS using a habit formation function for consumers.

The last equation of the NK system is the Taylor Rule (TR) which is used by the Central Bank as a reasonable rule to follow in order to stabilize the economy (Clarida, Galí and Gertler (1999, 2001)). Macroeconomists have been interested in analyzing this linear-reaction function because it reveals

[3]In a system where some of the characteristic roots are inside and other outside the unity circle, would exist a saddle path. For the purpose of our case the change in some coefficients can be understood as instantaneous overreaction in order to ensure initial conditions which guarantee a convergence path. Moreover, the dynamic equilibrium of inflation and output gap are determined dependently of monetary policy and the latter changes across regimes.

the preference of the monetary authority and it can provide a basis for forecasting changes in the monetary policy instrument. Unlike the other equations, the TR has more evidence of instability; at least in the U.S. For instance, Judd and Rudebusch (1998) find the TR vary across time in such a way that is consistent with a policy regime; Taylor (1999) quantifies the cost of deviating from this rule in terms of deviations from the product to its trend; Rudebusch and Svensson (1999) show the coefficients of the different rules change for different periods and for different rules; and Taylor (2010) states that in the past decade, the fact that interest rate was below the level that the rule suggests, it is an evidence for another change in the monetary regime.

Few econometricians have been focused on potential structural breaks in the interest rate. In this sense, Garcia and Perron (1996) evaluate the U.S. ex-post real interest rate and find two breaks (1973 and 1981) using the Markov Switching approach and Bai and Perron (2003) find three breaks (1966, 1972 and 1980) applying their own procedure.

The previous literature has tested if each of the equations is stable. Also, it has been assumed that the break date is known. Given that the literature regarding unknown structural breaks in the NK model is relatively sparse, the main aim of this paper is twofold. First, we evaluate the stability of the New Keynesian framework for an open economy developed by Galí and Monacelli (2005) using Peruvian monthly data from 2003:M8 to 2012:M2. Second, the method allows us to identify the unknown break dates and to test if each of the equations and the entire system are subject to structural changes. The latter is crucial for our interest because the literature has not studied structural changes in the whole system. We have the need to highlight that the endogenous and simultaneous estimation of the shift in the vector of parameters and the break dates are our primary interests.

Since 2003, Peru has gone through many changes: the signing of international commercial treaties which expose domestic firms to fiercer competition; the change in the monetary regime (change in the policy instrument in 2003) which generated an increase in the credibility of the Central Bank; and the output grew up more than its capacity constraint (above the trend). However, in 2009 Peru underwent a severe economic slowdown and the government implemented both lax fiscal and monetary policies[4] to mitigate the effects of the crisis and consequently the recovery was fast. Therefore, Peru presents the appropriate conditions to explore possible structural breaks in the Galí and Monacelli (2005) framework.

In the case of Peru, the literature has not considered structural changes as a major problem of research within the NK model; nor to theoretical or empirical grounds[5]. However, the theoretical framework has served as a motivation to answer another type of questions; mainly the quantification of the Central Bank's preferences to respond to changes in inflation and output gap. Using GMM to estimate this system of equations, Rodríguez (2010a) finds that the preferences on the gap between the expected inflation and the inflation target and on the output gap change across regimes. Moreover, regardless of the type of filter applied, the estimates associated with aggregate demand factors are more favorable than those associated with the aggregate supply factors. In the same sense, Llosa and Tuesta (2007) evaluate the stability of different rules for monetary policy and argue that the cost channel modifies the standard conditions for the stability of the system.

With non-observable components models, Llosa and Miller (2005) improve the measurement of

[4]The Peruvian Government increased its expenditure and the Central Bank provided enough liquidity to the financial sector as same as reduced the interest rate.

[5]Bazán (2011) makes an analysis of non-linearities in the peruvian banking credit and finds potential structural changes in this series.

the output gap and identify the periods of inflationary demand pressure; and Rodríguez (2010b) uses the NKPC to estimate the NAIRU and finds that the inflation has relevant information to estimate the output gap[6]. Finally, Montoro (2007) extends the NK monetary model including a committee of policymakers instead of a single agent in order to strengthen mild changes in the interest rate. Nevertheless, none of them considers some algorithm to estimate some structural break endogenously either in a single equation or system.

In order to examine potential instabilities and/or breaks in the system, we start the analysis with a GMM estimation in order to have a benchmark model for comparing structural breaks results. Then, we apply two types of methodologies which allow us to estimate simultaneously the vector of parameters and the unknown structural break dates. The first is Bai and Perron (2003) technique which is used to estimate each equation of the pseudo-structural model and dynamic equilibrium system, resulting in different set of parameters for each regime and their corresponding shift dates. The second is Qu and Perron (2007) approach that help us to evaluate the stability of the entire system (dynamic equilibrium). Finally, we use the estimated-break dates to evaluate the stability of the entire pseudo-structural model via GMM approach.

Our results using the method of Bai and Perron (2003) evidence changes in TR (January-2006 and May-2009), followed by the NKPC (January-2008) and subsequently in the DIS (October-2008). This issue shows that the parameters for each of the equations in the system has a lagged shift, in other words, none of the equations experiment a change on the same date. In addition, the variables with rational expectations take greater explanatory power in the period that the Peruvian economy contracted and had greater uncertainty (since October-2008 until May-2009). The preferences of the Central Bank change after each break, thus the channel of expectations is strengthened, and a conventional policy rule can be used to react to the evolution of domestic inflation and output gap in each regime.

The results using the method of Qu and Perron (2007) show that the system of the dynamic equilibrium suffered between 2 (May-2008 and may-2010) and 3 (April-2006, May-2008 and May-2010) breaks. The value of coefficients associated with the forward-looking variables raise after the first break, especially those that explain the output gap.

The are two main conjectures based on the empirical results. First, the nature of the "ordered" breaks in the pseudo-structural system suggests that the policy-reaction function induce a lagged break in the other equations of the system. This fact is an evidence of nominal frictions and incomplete information in the Peruvian economy. Second, in both pseudo-structural system and dynamic equilibrium system, the overreaction of the forward-looking variables is in the line of the theoretical model and after 2008, they are the driving forces of the system. There is a sudden shift in the dynamic equilibrium system, although it is possible this is not a necessary overreaction to ensure a new equilibrium.

The paper proceeds as follows. Section 2 presents the theoretical model and the statistical methodology used to estimate endogenously the parameters of the NK framework for an open economy simultaneously with the unknown structural breaks. In Section 3, we discuss the estimated results for the two approaches, emphasizing their implications in terms of policy analysis. Section 4 concludes.

[6] A new research of output gap is Guillén and Rodríguez (2014).

2 The Model and the Estimation Method

In this paper we use monthly data spanning the period 2003:M8–2012:M2 and the series were obtained from the database of the Central Bank of Peru (henceforth, Central Bank). This time period was dictated by data availability of the Non-Tradables Price Index, GDP Index in real terms and the overnight interest rate of the Central Bank for interbank transactions (the discount interest rate), expressed in units of percent per year.

The domestic inflation rate is defined as $\pi_{H,t} = \ln(NTPI_t) - \ln(NTPI_{t-1})$, where $NTPI_t$ is Non-Tradables Price Index at time t and $\ln(NTPI_t)$ is its log transformation without seasonality. In numerous applications the output gap (x_t) at time t is approximated by detrending the not seasonally adjusted log-GDP Index using the filter of Hodrick and Prescott (1997; henceforth HP) and then subtracting it from the not seasonally adjusted log-GDP Index. Finally, the natural interest rate (rr_t)is the not seasonally adjusted overnight interest rate detrended by the filter HP.

Then, following Galí and Gertler (1999) and Galí, Gertler and Lopez-Salido (2001) we replaced the expected domestic inflation rate with the observed future domestic inflation rate; and we use the same approach for the expected output gap. In other words, $E_t\{\pi_{H,t+1}\} = \pi_{H,t+1}$ and $E_t\{x_{t+1}\} = x_{t+1}$ and this practice is justified by the assumption of rational expectations, which implies unbiasedness of the variables expectations since the error of the forecast of $t+1$ is uncorrelated with the information dated t and earlier.

2.1 The Theoretical Model

In the small open economy version of the NK framework develop by Galí and Monacelli (2005), the model is described as follows

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t, \tag{1}$$

$$x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha}(r_t - E_t\{\pi_{H,t+1}\} - rr_t), \tag{2}$$

$$r_t = rr_t + \phi_\pi \pi_{H,t} + \phi_x x_t. \tag{3}$$

Equation (1) is the NKPC and it is one the main consensus of the modern monetary theory to study inflation and the trade-off with unemployment (or level of activity in an economy). The framework is completed with the introduction of Equation (2) which is the DIS and Equation (3) which is the monetary rule of interest rate (r_t) in the sense of Taylor Rule (TR). This is the system of lineal difference equations for theoretical discussion about stability[7].

The equilibrium is analyzed under a simple interest rate rule, i.e., $r_t = \rho + \phi_\pi \pi_{H,t} + \phi_x x_t + v_t$, where ρ is the impatience rate and v_t is an exogenous (possibly stochastic) component with zero mean. Combining (1)-(3) represents the equilibrium conditions by means of the following system of difference equations:

$$\begin{bmatrix} \pi_{H,t} \\ x_t \end{bmatrix} = A_\alpha \begin{bmatrix} E_t\{\pi_{H,t+1}\} \\ E_t\{x_{t+1}\} \end{bmatrix} + B_\alpha(rr_t - \rho - v_t). \tag{4}$$

[7] The preferences and production functions are summarized by behavioral parameters that should change with monetary policy regime. For further details about the deep parameters, see Galí and Monacelli (2005).

Given that both the output gap and domestic inflation are non predetermined variables, the solution to (4) is locally unique, if and only if, A_α has both eigenvalues within the unit circle. The econometric counterpart of equations (1)-(3) is:

$$\begin{aligned} \pi_{H,t} &= \alpha_1 + \alpha_2 \pi_{H,t+1} + \alpha_3 x_t + \varepsilon_{\pi,t} && (5) \\ x_t &= \alpha_4 + \alpha_5 x_{t+1} + \alpha_6 r_t + \alpha_7 \pi_{H,t+1} + \alpha_8 rr_t + \varepsilon_{x,t} && (6) \\ r_t &= \alpha_9 + \alpha_{10} \pi_{H,t} + \alpha_{11} x_t + \varepsilon_{r,t} && (7) \end{aligned}$$

which can be represented as:

$$\begin{bmatrix} \pi_{H,t} \\ x_t \end{bmatrix} = A_T [I, \pi_{H,t+1}, x_{t+1}, rr_t]' + U_T \qquad (8)$$

where A_T is the matrix of coefficients, I is the identity matrix and U_T is the matrix of residuals. The equations (5)-(7), the others specification of the pseudo-structural model as well as each of the rows of equation (8) will be subjected to the evaluation of stability in the parameters.

2.2 The Methodology of Bai and Perron (1998, 2003)

Bai and Perron (2003) consider the estimation of m multiple structural breaks by least squares and the main framework can be described by the following multilinear model

$$y_t = z_t' \delta_j + u_t, \qquad (9)$$

for $j = 1, ..., m+1$, where y_t is a endogenous variable, z_t is a matrix of explanatory variables which register the structural changes, δ_j is the vector of parameters, u_t the error term and $t = T_{j-1}, ..., T_j$ are the break dates which are unknown and are simultaneously estimate with the parameters for T observations.

The first break date is identified as that minimizes the squared sum of residuals and by sup F statistic. At that point, the sample is divided into two segments and in each sub-sample it follows a similar procedure for estimating a new point of structural change; it is a sequential selection procedure. For each partition the estimates of δ_j are estimated by least squares.

Let $\widehat{\delta}(\{T_j\})$ denote the estimates based on the given m-partition $(T_1, ..., T_m)$ denoted $\{T_j\}$. Then the procedure substitutes these in the objective function and denoting the resulting sum of squares residuals as $S_T(T_1, ..., T_m)$, the outcome of the following equation is the estimated break points: $(\hat{T}_1, \hat{T}_2, ..., \hat{T}_m) = \arg\min_{(T_1, T_2, ..., T_m)} S_T(T_1, T_2, ..., T_m)$.

This approach is used to estimate each equation separately. Therefore, we use this method to estimate equation considered in (5)-(7) and also to estimate equation of the system (8).

2.3 The Methodology of Qu and Perron (2007)

This method allows to estimate equations of (8) as a system. Following similar notation as in Qu and Perron (2007), we have the following matrix representation:

$$Y_t = \left(I_n \otimes Z_t'\right) S \beta_j + U_t, \qquad (10)$$

where $n = 2$ is the number of equations, T is the number of observations, $Y_t = [\pi_{H,t}, x_t]$ is the vector of dependent variables at time t, $Z_t = [I, \pi_{H,t+1}, x_{t+1}, rr_t]$ is the vector of independent variables at time t, β_j is the parameters in j regime, $U_t = [U_{1,t}, U_{2,t}]$ is the vector of error terms with zero mean and covariance $\sum_j$, $q = 4$ is the number of the regressors in the system and m is the number of structural breaks. The matrix S is of dimension $(nq) \times (p)$ with full range and it has arbitrary constants with elements 0 and 1, which specify the regressors for each equation in the system. Abusing the notation we are going to denote $X_t = (I \otimes Z_t') \, S$, therefore, we have $Y_t = X_t' \beta_j + U_t$. For a given partition of the sample, using the breaks $(T_1, T_2, ..., T_m)$, we define the partition on the block matrix X_t as $\bar{X}_t = diag(X_{1,t}, X_{2,t}, ..., X_{m+1,t})$ with dimension $(nT) \times (p)(m+1)$ where $X_{j,t}$ $(j = 1, 2, ..., m+1)$ is a subset $(n)(T_j - T_{j-1}) \times (p)$ of X_t (observations in regime j). Then we define the sub vector $U_{j,t}$ of U_t in a similar way. Hence, the equation (10) can be redefine as

$$Y_t = \bar{X}_t \beta + U_t. \tag{11}$$

The approach of Qu and Perron (2007) is based on the sample principle of Bai and Perron (2003) and it is needed a previous step of least-squares estimation. The only difference until this point is that they extend the technique for a system of equations. For each m-partition $(T_1, ..., T_m)$ the estimated $\widehat{\beta}(\{T_j\})$ are obtained from the minimization of the sum of squared residuals and then those values are replaced in the objective function which is equation (10). This algorithm proceeds to search for a estimate that constitutes a global maximization of the likelihood function. Once established the amount of breaks to testing (m) and a minimum number of observations between two structural breaks (h), it searches a regime segment by segment. Then, it calculates the likelihood function for each estimated partition as well as the sum of the estimated likelihood for each of the segments. After that, it chooses the partition which maximizes the likelihood function. Finally, they propose a sup LR statistic in order to test the existence of k structural breaks (null hypothesis). When the likelihood function of the overall estimate by partitions is significantly greater than the function without breaks, they conclude on the existence of structural break and the dating of those breaks is determined by the optimal partitions in the previous step.

The advantages of this technique are very wide and it provides tools to carry out the study in three different scenarios: (i) breaks simultaneous in both the regressors as in the covariance matrix, (ii) breaks only in the vector of parameters and (iii) breaks only in the covariance matrix. In this sense, the evidence suggests that the first scenario best fits the series of domestic inflation, output gap and interest rate. But these shifts do not have to occur on the same date and consequently, the number of shifts do not have to be the same. Additionally, it allows to estimate the parameters and break dates with variable with deterministic trend, it does not allow I(1) variables.

3 Empirical Results and Discussion

The different techniques described in the previous section rely on the assumption that both the domestic inflation rate $(\pi_{H,t})$, output gap (x_t) and the interest rate (r_t) are I(0) processes. Hence, prior to apply the different methods of estimation, we tested stationarity of these variables using the GLS-based ADF test and the point optimal test both proposed by Elliott et al. (1996). The results indicate that all series are I(0)[8]. Then, we proceed to model specification.

[8] All results are available upon request.

3.1 Pseudo-Structural Model (GMM estimation)

The Figure 1 shows the evolution of the output gap, domestic inflation and interest rate, respectively. According to Figure 1, in September-2008 the output gap is the first variable to fall, follow by the domestic inflation rate in January-2009 (although the fall is not so pronounced) and finally the interest rate in March-2009. The latter begins to decrease significantly, in relative terms much greater than the other endogenous variables.

In Table 1 we present the results of GMM estimation of the entire system described by the equations (5)-(7) without structural breaks. We use as instrumental variables 9 lags of domestic inflation, output gap, interest rate, salaries gap and exchange rate gap[9]. The policy rule was specified with the natural interest rate (long-term equilibrium) and with a simple policy rule as a function of observable variables, i.e. an intercept in place of the natural interest rate.

Three main findings are observed. The first is related to the value of the coefficients. All parameters are statistically significant and are relevant to explain the whole model. However, the sign of some of them are not as expected. For the NKPC, the intercept has a value very close to zero so that in spite of being statistically significant does not incorporate any pertinent information to explain $\pi_{H,t}$. Also, if we compare the coefficient associated with $\pi_{H,t+1}$ ($\alpha_2 = 0.27$) to the coefficient associated with x_t ($\alpha_3 = 0.07$), we can see that the forward-looking variable has greater power in explaining the dynamic of domestic inflation. As same as NKPC, the DIS has some parameters with contrary signs to those expected and the intercept is close to zero. Moreover, x_{t+1} ($\alpha_5 = 0.57$) and $\pi_{H,t+1}$ ($\alpha_7 = 1.06$) are the variables with better fit in explaining the excess demand equation. Conversely, due to the fact that the interest rate is the price of the money, r_t ($\alpha_6 = 0.27$) and rr_t ($\alpha_8 = -0.23$) have opposite signs. But they share a similar parameter (in line with the theoretical model) thus we can add the coefficients $0.27 - 0.23 = 0.04$, having a value very close to zero. This would indicate that monetary policy has little impact on real activity measured by the output gap variable and therefore, should focus on the control of domestic inflation. If we look at the equation of the monetary instrument the findings are more interesting. The intercept has a value of 0.0342 which theoretically represents the long-term interest rate of the economy or the impatience rate of the society. In addition, it can be seen through the parameters $\alpha_{10} = 1.65$ and $\alpha_{11} = 0.28$ that the Central Bank prefers the stabilization of domestic prices rather than the economic growth.

The second finding is related to the uniqueness of equilibrium. Following Galí and Monacelli (2005), the parameters $\phi_\pi(\alpha_{10})$ and $\phi_x(\alpha_{11})$ can take any positive value describing the strength of the response of the interest rate to changes in $\pi_{H,t}$ and x_t, respectively. Those values are crucial in order to ensure a solution. One possible solution is when we set $x_t = \pi_{H,t} = 0$ (steady state) which are associated to an optimal policy rule; although the solution may not be unique. The latter is guaranteed when $\kappa_\alpha(\phi_\pi - 1) + (1 - \beta)\phi_x > 0$, i.e., this strict inequality must hold (it is necessary and sufficient condition) for uniqueness[10]. If we replace the estimated coefficients $0.06(1.65 - 1) + (1 - 0.275)0.28 > 0$, actually we obtain that the strict inequality holds. Hence the Central Bank can choose a path (or sequence) for the interest rate that ensure a convergent path (or sequence) for the level of prices which is consistent with the inflation targeting.

Taking together the first and the second finding, an interest rate above 3.42% would increase the saving (less consumption and investment) of the economy or stabilize the prices and output.

[9] For a given sample size, we estimated the model with different number of lags of the instrumental variables and for different combinations of them, but we only report the best results .

[10] This implies that the matrix A_α (coefficient matrix of the reduced model) have two eigenvalues within the unit circle, which led to uniqueness of solution and stable path.

From January-2006 (3.50%) to May-2009 (4.00%), the interest rate was higher because the inflation rate was slightly far from the target and the GDP grew above its trend. During June-2009 and February-2011, it was below its long-term level and a possible explanation is that the monetary authority stimulated the economy owing to the slowdown in the GDP growth (below its potential).

The third finding is about the method. GMM estimation is a good approach to estimate the theoretical model and the filtered data present a good performance to measure marginal cost and natural interest rate. Moreover, the J-statistic test does not allow us to reject the null hypothesis which confirms the validity of the included restrictions[11].

3.2 Pseudo-Structural Equations with Breaks

Table 2 shows the estimates of each of the equations of the system (5)-(7) using the approach of Bai and Perron (1998, 2003). We present both the parameters for each regime and the break dates estimated endogenously.

With regard to the NKPC, the break date is January-2008. Similar to GMM results, the intercept is significant in the two regimes with a value very close to zero and after the break date the expected domestic inflation increase its explanatory power. This means that the dynamics of domestic inflation is governed in 28.47% by $\pi_{H,t+1}$ and in 7.42% by x_t. The variables together explain $\pi_{H,t}$ and there is not autocorrelation (Q-statistic). Note that after the break date, the results of Bai and Perron (2003) and GMM approaches are similar.

Other specifications have been estimated. For example, the hybrid NKPC version does not present any break and therefore, the results are not reported. Not the same thing happens with the backward-looking NKPC which has a break in January-2008 (Table 3). After the break date, domestic inflation is explained in 25% by $\pi_{H,t-1}$ and in 8.6% by x_t. As in the forward-looking NKPC specification, the p-values of F-statistic is zero and of Q-statistic is very high.

Concerning the DIS, Table 2 shows October-2008 as the date of break and unlike the NKPC, the variables with expectations have some different issues. In the second regime x_{t+1} takes greater relevance while $\pi_{H,t+1}$ reduces its explanatory power, i.e., α_5 passes from a value of 0.094 to 0.179 while α_7 from a value of 0.920 to 0.545. Regard to the interest rate, α_6 does not have the negative value as we expected although it is statistically significant in the both regimes (different from GMM values). If we make the analysis as a deviation from its natural level, in the first regime has a value of 0.06 $(1.731 - 1.669)$ and in the second regime, this changes to -2.467 $(0.508 - 2.975)$ obtaining an inverse relationship with the output gap. This means that after the break, the monetary policy has an impact in the real economy and it is stronger in the second regime. An interesting and different result from Table 1. Also, in this equation the explanatory variables have good fit and there is no autocorrelation.

As well as with the NKPC, we tried on a different specification only obviating rr_t. According to Table 3, the break dates are June-2007 and May-2010. In the first regime, any parameter is statistically significant. In contrast, in the second regime all parameters are statistically significant and the coefficients associated with the forward-looking variables (α_5 and α_7) significantly explain the behavior of x_t and have the expected signs. In the last regime, the interest rate has an impact of -0.625 at 90% of confidence.

According to Table 2, the monetary policy rule has two breaks: January-2006 and May-2009 which coincide with the increase and the reduction of the interest rate, respectively. After the

[11] The Q-statistic test shows that there is autocorrelation in the DIS and TR, but not in NKPC

first break, all the parameters are statistically significant and the fact that the intercept changes in all the regimes has an interesting interpretation. Before January-2006, the agents perceived improvement in the economy and Peru had a context of sustained growth and low inflation hence it is expected a low impatience rate (2.8%), i.e., agents preferred to postpone present consumption. Conversely, between January-2006 and May-2009 Peru had a period of crises which leads to an increase of the uncertainty and a contraction of the real sector and consequently, the impatience rate raised to 4.7%, preferring current consumption. Finally, after the last break, the confidence of the agents increased and the impatience rate low at 2.7%, similar to the level pre-crisis.

When estimating a smoothing policy rule, Table 3 shows that the dates of break change: May-2006 and November-2008. As in the other estimates, the parameters in the first regime is not relevant to the analysis. In both the second and third regime, the first lag of the interest rate explains at least 90% of the dynamics of the policy rule. After November-2008, when it started the period of uncertainty in the Peruvian economy, the Central Bank increased its preferences in response to changes in $\pi_{H,t}$ and x_t.

Note first that the smoothing policy is defined as $r_t = \alpha'_9 + (1-\rho)(\alpha_{10}\pi_{H,t} + \alpha_{11}x_t) + \rho(r_{t-1}) = \alpha'_9 + \alpha'_{10}\pi_{H,t} + \alpha'_{11}x_t + \alpha_{12}r_{t-1}$ and we focus on α'_{10} and α'_{11}. With this in mind, we can compute the preferences of the Central Bank for the second and the third regime for the reasons explained above. Hence, the preferences in the second regime are $\alpha'_{10} = 0.057 \Rightarrow \alpha_{10} = 1.043$ and $\alpha'_{11} = 0.047$, then $\alpha_{11} = 0.864$ and in the third regime are $\alpha'_{10} = 0.308$, then $\alpha_{10} = 3.397$ and $\alpha'_{11} = 0.204$, the $\alpha_{11} = 2.251$. According to those values, after November-2008 the Central Bank reacted much stronger than before and in relative terms, much higher than the results in Table 2. Thus, the interest rate is extremely procyclical.

The results shown above evidence some structural breaks in the equations of the NK framework for an open economy. If it is the case, it is natural to expect that the model of the dynamic equilibrium has also experimented some shifts. Hence, the endogenous estimation of the parameters and the break dates is necessary.

3.3 Dynamic Equilibrium with Breaks

Table 4 shows the results of Bai and Perron (2003) specification for each of the equations of the system (8). We can see that there are not structural breaks in the dynamic equilibrium of the domestic inflation. On the other hand, the output gap equation presents some interesting findings. Between, June-2007 and February-2008, the forward-looking variables (γ_6 and γ_7) are the main source of variability of x_t; in other words, the output gap is governed in 1.77% by $\pi_{H,t+1}$ and in 0.47% by x_{t+1}. Nevertheless, in the third regime these coefficients are not significant and their values are reduced. Regard to the natural interest rate, its coefficient has a value of 1.173 in the second regime whereas it has a value of -2.594 in the third regime.

Finally, we also estimate the dynamic equilibrium as a complete system using Qu and Perron (2007) technique which is presented in Table 5. The analysis was carried out by allowing two and three possible breaks. In the first case, the dates of breaks are May-2008 and May-2010; while in the second case are February-2006, April-2008 and February-2010. The results of the second case are not reported because they do not incorporate any relevant information to the analysis and are not better than those obtained with two breaks. However, it is useful when we are only interested in knowing the dates of the shifts.

In Table 5 can be seen that for the equation of the domestic inflation, the only variable which has a break is x_{t+1} because γ_3 has a value of 0.068 until May-2010 and then it has a value of -0.107. The negative sign in the third regime may be due to the fact that in that period, the Peruvian economy was affected by shocks of aggregate supply which dominate aggregate demand shocks. Something to be said, from that date onwards there was positive domestic inflation and the output gap was close to zero or even negative.

For its part, the equation of the output gap has more changes in the parameters. For instance, $\pi_{H,t+1}$ has a greater impact on x_t in the first two regimes than in the last whereas x_{t+1} has a better explanatory power in the last two regimes than in the first one. If we check the third regime, the long-term interest rate drives the output gap dynamics ($\gamma_8 = -2.276$). It should be noted that the goodness of fit is not very high and none of these two equations present autocorrelation.

The theoretical model predicts that $\pi_{H,t}$ and x_t are jumping variables and this fact is consistent with the results shown in Table 5. The system of difference equations has at least two breaks and this feature could be understand as the equilibrium conditions are subject to the prevailing regime or the parameters are conditioned to the economic conditions. Also, this instantaneous change in the parameters is possible only if all agents act simultaneously and in the same direction.

An important finding remains to be seen if these results are contrasted with those shown in Table 2. When we allow 3 breaks, the first date is February-2006 which coincides with the first shift of the policy rule. Then, the second break is between April-2008 and May-2008 which is in line with the shift in the NKPC in January-2008. Finally, the third break date is May-2010, one year after the second change in the policy rule (May-2009) which could give an indication of a lagged effect on the formation of expectations of the agents.

3.4 Pseudo-Structural Model with Breaks

After knowing the break dates and with enough evidence to think that the interest rate is driving the changes in the other equations of the model, we decide to test three types of potential shifts in the pseudo-structural model. All of them has a better performance in terms of efficiency and accuracy. This fact reflects the better fitness of the specification when it is estimated the whole system with breaks rather than a particular equation.

Table 6a presents results when it is used the break dates of the TR ($\widehat{\tau}_1$ =Jan06, $\widehat{\tau}_2$ =May09) for the estimation. It shows that there is a general improvement with respect of Table 1 (GMM without breaks) and Table 2 (independent estimation of breaks dates and parameters in each equation). For example, it can be seen that in the second and third regime almost all parameters are statistically significant and in relative terms of Table 2, there are considerable gains in the results. Even if Table 6.a is compared to Table 3, the accuracy of the estimation increases when the system includes the other equations.

When we allow shift in the system using the break dates of the DIS ($\widehat{\tau}_3$ =Oct08), Table 6b presents that the only delicate issue is the TR in the second regime. Finally, Table 6c combines the two previous cases with a particular fact, the NKPC is not subject to breaks. Thus, we do not have regimes but it is allowed shifts in the DIS ($\widehat{\tau}_3$ =Oct08) and TR ($\widehat{\tau}_1$ =Jan06, $\widehat{\tau}_2$ =May09). As we expect, the NKPC is similar to Table 1, the DIS is similar to Table 6b and TR is similar to Table 6a. Again, in terms of efficiency and accuracy the results are better than Table 2 and other single-equation estimations. A very important observation is about the uniqueness of equilibrium which is satisfied in all regimes (Tables 6a and 6b).

3.5 Discussion

In this part of the document we discuss the main results of the different approaches that we used. The first finding is related to the slope of the NKPC. Regardless the estimation of pseudo-structural model with or without breaks, κ_α has a value close to zero which means there is a small group of firms that set new prices each period (a minor response of the domestic inflation to movements of the real marginal costs). Another tentative explanation is the degree of openness because substitutability between domestic and foreign goods dampens the adjustment in the marginal cost. Hence, with a small value of κ_α, the policy maker is confronted with a short-run trade-off between stimulating demand and creating low inflation.

But the most interesting issue is that this parameter is time-varying and this feature is crucial for policy design. This means that the output cost of disinflation and the speed of disinflation are dependent on the economic environment, i.e., it is subject to the existing regime.

The second finding is about the impact of monetary policy in the economic activity thorough the market equation (DIS). When the analysis of the interest rate is made as a deviation of its natural level, according to GMM estimation the interest rate has a low influence in the output gap. But when we allow the possibility of breaks this variable can alter the output gap in a considerable manner. There is a difference between the estimation of a single equation of the pseudo-structural model (Table 2) and the entire model (Table 6b) using the same estimated-break date. The information gain using the complete system contributes to have negative relationship in both regimes, even stronger in the latter.

The third finding is the better explanatory power of the forward-looking variables, thus the expectations channel matters in the end. In all cases, the variables with expectations guide the dynamics of each of the equations or the system as a whole. The pseudo-structural results in Table 2, Table 6a and Table 6c show that after the breaks in the NKPC (January-2008) and in the DIS (October-2008), these kind of variables drive the series. What is more, those breaks occurred in the same year and their interval of confidence are overlapped. More precisely, the break in the DIS coincided with the bankruptcy of Lehman Brothers in September-2008 which can be interpreted as a month in the delay of the contagion effect. Additionally, the value of the parameters could be understood as under uncertainty the agents prefer to grow instead of worrying about the inflation. These results are related to the context lived at that time: fall in international prices and their impact on the decline in domestic prices; Peru grew 0.9% in 2009 with two quarters of negative growth and the lack of confidence among the agents which diminished consumption and investment.

The fourth finding is related to the superiority of a simple reaction function of the Central Bank. In the previous subsection, we computed its preferences with a smoothing TR and we found that those values are uncorrelated with the Peruvian context due to the size of the adjustment of the policy instrument. Note that the policy makers react to inflation more than domestic inflation, however, we focus on the latter to keep coherence with the theoretical model.

Under the strong evidence that the monetary authority has different preferences over time, one of the main findings is related to $\alpha_{11} = \phi_x$. According to Organic Law of the Central Bank of Peru, *"the purpose of the Bank is to preserve monetary stability."* This result contradicts this law. Nonetheless, It could be seen that the output gap (x_t) is a function of expected domestic inflation ($E_t \{\pi_{H,t+1}\}$) and this issue can explain the statistically significance of this particular parameter. If it is the case, a policy maker who cares only about inflation would appear to be responding to the output gap in the model.

To understand better the break-dates it is valuable to mention that in January-2007 the Central Bank of Peru changed its inflation targeting to 2%. Since the adoption of explicit inflation targeting in 2003 (2.5%), the monetary authority had never changed its objective before.

Here some useful insights. During August-2003 and September-2004, the Central Bank maintained a position of monetary stimulus since a context of low inflation and lower international interest rates, as well as the conditioning of a slow economic growth. Then, from October-2004 until November-2005 it maintained an interest rate of 3% because Peru's GDP came into a boom driven by a favorable international environment, better private agents confidence and stable prices. For the following months, between December-2005 and May-2006, the monetary instrument rose 6 times ending in a value of 4.5%; in this period we identified the first break (January-2006).

In the second regime, the reaction to the domestic inflation is not in the magnitude required by Galí and Monacelli (2005) and this is due to the following reasons. Between May-2006 and May-2007 the inflation was 0.94% (lower than the target range of inflation - 1.0% to 3.0%) and there was an increase in the productivity, an appreciation of the national currency and a reduction of the inflation expectations. In 2008, it decided to increase the interest rate from 5.3% in January-2008 to 6.5% in September-2008 and after that, it kept this rate until January-2009. Finally, the interest rate fell to a level of 1.25% in August-2009.

Complementary to those changes in the interest rate, in 2008 the monetary authority used unconventional instruments as a reduction in the reserve rate, Repo operations up to 1-year, currency swaps and options to repurchase 1-year bonds of the Central Bank. From theory to practice, even if the unconventional monetary instruments are not in the theoretical framework they are important to understand how they can amplify the changes in interest rate. For instance, between January-2008 and April-2008, the Central Bank of Peru increased in 3% (from 6% to 9%) the minimum legal reserve rate which is equivalent to 0.75% in the interest rate[12].

Least but not last, in periods of contraction and economic uncertainty the dynamics of the economy can be extremely non-linear or parameters experiments a shift. For our purpose, $\pi_{H,t}$ and x_t are affected by their own expectations and this fact could be understood as what happens today is explained by what is expected to happen tomorrow. Consequently, there is a recognition that those variables respond endogenously to the state of the economy (state-contingent). Besides, the type of shifts in the jumping variables could be caused by an overreaction to ensure a new equilibrium, but there is not enough evidence to support this statement.

4 Conclusions

In this paper, we investigate possible structural changes in the New Keynesian model for an open economy and the evidence shows an answer to our initial question: there are structural breaks in the NKPC, DIS and TR in Peru. We think that the interest rate is driving the breaks in the other equations due to the changes in the parameters associated to the preferences of the Central Bank. The fact that those preferences are changing is in line with Rodríguez (2010a) and Llosa and Tuesta (2007) results, but we identify three monetary regimes.

The nature of the "ordered" breaks suggests that policy-reaction function induces a lagged break in the others equations of the system and it is linked with some nominal frictions and incomplete information in the Peruvian economy as Lucas (1976) statement. But the sudden change in the

[12] An increase in 1% of the minimum legal reserve rate is equivalent in impact to a change of 0.25% ; see Leon, D. and Z. Quispe (2010).

dynamic equilibrium system because of the reaction of the jumping variables is not conclusive and therefore, we cannot affirm that those breaks are necessary overreaction to ensure new equilibrium as Bardsen, Jansen and Nymoen (2004) view.

Second, the NKPC provide a good description of the dynamics of the domestic inflation in Peru. Its small slope means that the Central Bank can exploit the short-run trade-off between domestic inflation and unemployment. We estimated the NKPC with the output gap variable and in this regard, the output gap using GDP Index filtered by HP is a good proxy variable of the real marginal cost that drives the inflationary process.

Third, the statistical significance of ϕ_π and ϕ_x in the pseudo-structural model with breaks bring us closer understanding of the Central Bank's preferences. In fact, the inflation targeting is not its only concern since it reacts to output gap too (not allowed by law in Peru). As we present, the different values in each regime for both parameters suggest that the Central Bank finds optimal to accommodate its rule to inflationary pressure and negative real shocks. Indeed, if the Central Bank can reoptimize then it can choose an appropriate value of ϕ_π and ϕ_x to reduce simultaneously the volatility of both domestic inflation and the output gap.

The strengthening of the channel of expectations through the NKPC can make easier the control of the domestic inflation in order to stabilize it to the desired level. In this sense, the monetary authority does not need to increase too much the policy instrument in order to achieve its goals.

Finally, the technique we followed to process the data can be a subject of discussion. It is a research agenda to estimate the model with a different assumption of the expected variables, with another filtering method and with other monetary rule specifications.

References

[1] Alogoskoufis, G. S., and R. Smith, (1991), "The Phillips Curve, the Persistence of Inflation, and The Lucas Critique: Evidence from Exchange Rate Regimes", *American Economic Review* **81**, 1254-275.

[2] Bardsen, G., E. Jansen and R. Nymoen, (2004), "Econometric Evaluation of the New Keynesian Phillips Curve", *Oxford bulletin of Economics and Statistics* **66**, 671-686.

[3] Bai, J., and P. Perron, (1998), "Estimating and testing linear models with multiple structural changes", *Econometrica* **66**, 47-78.

[4] Bai, J., and P. Perron, (2003), "Computation and analysis of multiple structural change Models", *Journal of Applied Econometrics* **18**, 1-22.

[5] Bazán, W. (2011), "No-Linealidades y Asimetrías en el Crédito Peruano", Central Bank of Peru, Working Paper **15**, 1-33.

[6] Clarida, R., J. Galí and M. Gertler, (1999), "The Science of Monetary Policy: A New Keynesian Perspective", *Journal of Economic Literature* **XXXVII**, 1661-1707.

[7] Clarida, R., J. Gali, and M. Gertler, (2001), "Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach", *American Economic Review* **91**, 248-252.

[8] Cogley, T., and A., Sbordone, (2008), "Trend Inflation, Indexation, and Inflation Persistence in the New Keynesian Phillips Curve", *American Economic Review* **98**, 2101-2126.

[9] Elliott, G., T. J. Rothenberg y J. H. Stock (1996), "Efficient Tests for an Autoregressive unit Root," *Econometrica* **64**, 813–836.

[10] Estrella, A., and J.C., Fuhrer, (2003), "Monetary Policy Shifts and the Stability of Monetary Policy Models", *Review of Economics and Statistics* **85**, 94-104.

[11] Fuhrer, J. C. (1997), "The (Un)Importance of Forward-Looking Behavior in Price Specifications", *Journal of Money, Credit and Banking* **29**, 338-350.

[12] Fuhrer, J. C. (2000), "Habit Formation in Consumption and Its Implications for Monetary-Policy Models", *The American Economic Review* **90**, 367-390.

[13] Fuhrer, J. C., and G.D. Rudebusch, (2004), "Estimating the Euler Equation for Output", *Journal of Monetary Economics* **51**, 1133-1153.

[14] Galí, J. and M. Gertler, (1999), "Inflation dynamics: A structural econometric analysis", *Journal of Monetary Economics*, **44**, 195-222.

[15] Galí, J., M. Gertler and D. J. Lopez-Salido, (2001), "European Inflation Dynamics", *European Economic Review* **45**, 1237-1270.

[16] Galí, J., M. Gertler and D. J. Lopez-Salido, (2005), "Robustness of the Estimates of the Hybrid New Keynesian Phillips Curve", *Journal of Monetary Economics* **52**, 1107-1118.

[17] Galí, J., and T. Monacelli, (2005), "Monetary Policy and Exchange Rate Volatility in a Small Open Economy", *Review of Economic Studies* **72**, 707-734.

[18] Garcia, R., and P. Perron, (1996), "An analysis of the real interest rate under regime shifts", *Review of Economics and Statistics* **78**, 111-125.

[19] Guillén, A. and G. Rodríguez (2014), "A Trend-Cycle Decomposition for Peruvian GDP: Application of an Alternative Method," *Latin American Economic Review* **23 (5)**, 1-44.

[20] Hasanov, M., A. Arac and F. Telatar, (2010), "Nonlinearity and structural stability in the Phillips curve: Evidence from Turkey", *Economic Modelling* **27**, 1103-1115.

[21] Hodrick, R. y E. Prescott (1997), "Postwar us Business Cycles: An Empirical Investigation," *Journal of Money, Credit and Banking* **29**, 1-16.

[22] Judd, J. P., and G. D. Rudebusch, (1998), "Taylor's Rule and the Fed: 1970-1997", Federal Reserve Bank of San Francisco, *Economic Review* **3**, 1-16.

[23] Juselius, M, (2008), "Testing the New Keynesian Model on U.S. and Euro Area Data", *Economics Journal*, **2**, 1-27.

[24] Kara, A., and E. Nelson, (2004), "International Evidence on the Stability of the Optimizing IS Equation", *Oxford Bulletin of Economics and Statistics* **66**, 687-712.

[25] Leith, C., and J. Malley, (2007), "Estimated Open Economy New Keynesian Phillips Curves for the G7", *Open Economy Review* **18**, 405-426.

[26] León, D. and Z. Quispe (2010), "El Encaje como Instrumento No Convecional de Política Monetaria," *Moneda* **143**, Central Bank of Peru.

[27] Llosa, G., and V. Tuesta, (2007), "Learning about Monetary Policy Rules when the Cost Channel Matters", Central Bank of Peru, Working Paper **17**, 1-41.

[28] Llosa, G., and S. Miller, (2005), "Usando información adicional en la estimación de la brecha producto en el Perú: una aproximación mulivariada de componentes no observados", Central Bank of Peru, Working Paper **4**, 1-31.

[29] Lucas, R. (1976), "Econometric Policy Evaluation: A Critique", *Carnegie Rochester Conference Series on Public Policy* **1**, 19-46.

[30] Matheron, J., and T. P. Maury, (2004), "Supply-Side Refinements and the New Keynesian Phillips curve", *Economic Letters* **82**, 391-396.

[31] Matheson, T. (2008), "Phillips Curve Forecasting in a Small Open Economy", *Economics Letters* **98**, 161-166.

[32] McAdam, P., and A. Willman, (2004), "Supply, Factor Shares and Inflation Persistence: Reexamining Euro-area New-Keynesian Phillips Curves", *Oxford Bulletin of Economics and Statistics* **66**, 637-670, supplement.

[33] Mihailov, A., Rumler, F. and J. Scharler, (2008), "The Small Open-Economy New Keynesian Phillips Curve: A First Empirical Test and Implied Inflation Dynamics", Henley University, Working Paper **63**, 1-17.

[34] Monacelli, T. (2005), "Monetary Policy in a Low Pass-Through Environment", *Journal of Money, Credit and Banking* **37**, 1047-1066.

[35] Montoro, C. (2007), "Why Central Bank Smooth Interest Rate? A Political Economy Explanation", Central Bank of Peru, Working Paper **3**, 1-39.

[36] Nelson, C., and J. Lee. J, (2007), "Expectation Horizon and the Phillips Curve: the Solution to an Empirical Puzzle", *Journal of Applied Econometrics* **22**, 161-178.

[37] Perron, P., and Y. Yamamoto, (2009), "Estimating and Testing Multiple Structural Changes in Models with Endogenous Regressors", Boston University, Working Paper Series, 1-34.

[38] Qu, Z., and P. Perron, (2007), "Estimating and Testing for Structural Changes in Multivariate Regressions", *Econometrica* **75**, 459-502.

[39] Roberts, J. M. (2005), "How Well Does the New Keynesian Sticky-Price Model Fit the Data?", *Contributions to Macroeconomics,* **5**, 1-37.

[40] Rodríguez, G. (2010a), "Using A Forward-Looking Phillips Curve to Estimate the Output Gap in Peru", *Review of Applied Economics* **6**, 85-97.

[41] Rodríguez, G. (2010b), "Estimating Output Gap, Core Inflation and the NAIRU for Peru", *Applied Econometrics and International Development* **10**, 14-60.

[42] Rudebusch, G., and L. Svensson, (1999), "Policy Rules for Inflation Targeting", NBER, University of Chicago Press, Chicago, IL, 203-262.

[43] Rumler, F, (2007), "Estimates of the Open Economy New Keynesian Phillips Curve for Euro Area Countries", *Open Economy Review* **18**, 427-451.

[44] Sbordone, A. M, (2002), "Prices and Unit Labor Costs: a New Test of Price Stickiness". *Journal of Monetary Economics* **49**, 265-292.

[45] Taylor, J. (1999), "A Historical Analysis of Monetary Policy Rules", *Monetary Policy Rules*, University of Chicago Press, 319-41.

[46] Taylor, J. (2010), "Macroeconomic Lessons from the Great Deviation", *NBER Macroeconomics Annual* **25**, 387-95.

Table 1. GMM Estimation*

		Equations				
		NKPC		Dynamic IS		Taylor Rule
Parameters	α_1	0.002 (0.000)	α_4	-0.005 (0.000)	α_9	0.034 (0.000)
	α_2	0.275 (0.000)	α_5	0.570 (0.000)	α_{10}	1.654 (0.000)
	α_3	0.066 (0.000)	α_6	0.259 (0.000)	α_{11}	0.279 (0.000)
			α_7	1.057 (0.000)		
			α_8	-0.230 (0.000)		
$\overline{R}^2$		0.212		0.561		0.702
J-statistic				0.257		

*p-values are in parentheses.

Table 2. Estimation using Bai and Perron (1998, 2003)*

		Equations				
		NKPC		Dynamic IS		Taylor Rule
Regime 1	α_1	0.002 (0.001)	α_4	-0.003 (0.652)	α_9	0.028 (0.000)
	α_2	0.079 (0.547)	α_5	0.094 (0.364)	α_{10}	-0.164 (0.703)
	α_3	-0.021 (0.561)	α_6	1.731 (0.000)	α_{11}	-0.026 (0.812)
			α_7	0.920 (0.030)		
			α_8	-1.669 (0.000)		
Regime 2	α_1	0.002 (0.001)	α_4	0.080 (0.004)	α_9	0.047 (0.000)
	α_2	0.285 (0.096)	α_5	0.179 (0.129)	α_{10}	0.666 (0.048)
	α_3	0.074 (0.013)	α_6	0.508 (0.009)	α_{11}	0.159 (0.014)
			α_7	0.545 (0.443)		
			α_8	-2.975 (0.001)		
Regime 3					α_9	0.027 (0.000)
					α_{10}	1.292 (0.013)
					α_{11}	0.295 (0.040)
Break 1		Jan08		Oct08		Jan06
C.I.	95%	Jul07- Mar09		Aug08–Jan09		Sep05-Mar06
	90%	Oct,07-Dic,08		Sep08-Dec08		Oct05-Mar06
Break 2						May09
C.I.	95%					Sep07-Oct09
	90%					Mar08-Sep09
$\overline{R}^2$		0.212		0.561		0.702

* p-values are in parentheses.

Table 3. Estimation using Bai and Perron (1998, 2003); Other Specifications*

		Equations				
		NKPC		Dynamic IS		Taylor Rule
Regime 1	α_1	0.002 (0.006)	α_4	0.005 (0.568)	α'_9	0.004 (0.035)
	α_2	0.153 (0.249)	α_5	-0.086 (0.548)	α'_{10}	0.017 (0.835)
	α_3	-0.040 (0.255)	α_6	-0.243 (0.284)	α'_{11}	0.007 (0.725)
			α_7	0.229 (0.666)	α_{12}	1.164 (0.000)
Regime 2	α_1	0.002 (0.000)	α_4	-0.014 (0.005)	α'_9	0.003 (0.161)
	α_2	0.250 (0.072)	α_5	0.576 (0.000)	α'_{10}	0.057 (0.462)
	α_3	0.086 (0.001)	α_6	0.248 (0.034)	α'_{11}	0.047 (0.001)
			α_7	1.497 (0.023)	α_{12}	0.945 (0.000)
Regime 3			α_4	0.023 (0.070)	α'_9	0.003 (0.000)
			α_5	-0.033 (0.819)	α'_{10}	0.308 (0.002)
			α_6	-0.622 (0.075)	α'_{11}	0.204 (0.000)
			α_7	-0.372 (0.700)	α_{12}	0.909 (0.000)
Break 1		Jan08		Jun07		May06
C.I.	95%	Jan07-Aug10		Mar07–Feb09		Mar06-Nov06
	90%	Apr07-Nov09		Apr07-Aug08		Mar06-Sep06
Break 2				May10		Nov09
C.I.	95%			Mar10-Jul10		Jul08–Mar09
	90%			Apr10-Jul10		Sep08-Mar09
$\overline{R}^2$		0.240		0.567		0.990

* p-values are in parentheses.

Table 4. Estimates of the Dynamic Equilibrium by Bai and Perron (1998, 2003)*

Equations				
		$\pi_{H,t}$		x_t
Regime 1	γ_1	0.001 (0.639)	γ_5	0.009 (0.276)
	γ_2	0.246 (0.017)	γ_6	0.281 (0.585)
	γ_3	0.020 (0.068)	γ_7	-0.107 (0.445)
	γ_4	0.029 (0.564)	γ_8	-0.367 (0.111)
Regime 2			γ_5	-0.054 (0.022)
			γ_6	1.766 (0.006)
			γ_7	0.468 (0.000)
			γ_8	1.173 (0.037)
Regime 3			γ_5	0.087 (0.046)
			γ_6	-0.475 (0.588)
			γ_7	0.010 (0.944)
			γ_8	-2.594 (0.048)
Break 1				Jun07
I.C.	95%			Mar07–Jan08
	90%			Apr07–Nov07
Break 2				Feb10
C.I.	95%			Jan10-Mar10
	90%			Jan10-Mar10
$\overline{R}^2$		0.102		0.586

* p-values are in parentheses.

Table 5. Estimation of the Dynamic Equilibrium by Qu and Perron (2007)*

Equations				
		$\pi_{H,t}$		x_t
Regime 1	γ_1	0.003 (0.200)	γ_5	-0.008 (0.314)
	γ_2	0.154 (0.219)	γ_6	0.973 (0.037)
	γ_3	0.068 (0.027)	γ_7	0.175 (0.126)
	γ_4	-0.019 (0.728)	γ_8	- 0.163 (0.426)
Regime 2	γ_1	-0.009 (0.066)	γ_5	-0.043 (0.151)
	γ_2	0.241 (0.799)	γ_6	0.808 (0.896)
	γ_3	0.031 (0.513)	γ_7	0.684 (0.017)
	γ_4	0.293 (0.068)	γ_8	0.999 (0.187)
Regime 3	γ_1	-0.017 (0.558)	γ_5	0.070 (0.025)
	γ_2	0.214 (0.929)	γ_6	-0.508 (0.236)
	γ_3	-0.107 (0.008)	γ_7	0.527 (0.415)
	γ_4	0.550 (0.523)	γ_8	-2.276 (0.029)
Break 1		May08		
C.I.	95%	Aug 07-Feb09		
	90%	Nov07-Nov08		
Break 2		May10		
C.I.	95%	Dec09-Aug10		
	90%	Jan09-Jul10		
$\overline{R}^2$		0.239		0.520

* p-values are in parentheses.

Table 6a. GMM Estimation using break date of TR
($\widehat{\tau}_1$ =Jan06, $\widehat{\tau}_2$ =May09)*

			Equations			
		NKPC		Dynamic IS		Taylor Rule
Regime 1	α_1	0.001 (0.000)	α_4	-0.031 (0.000)	α_9	0.031 (0.000)
	α_2	0.342 (0.000)	α_5	0.100 (0.065)	α_{10}	0.016 (0.814)
	α_3	-0.118 (0.000)	α_6	-0.083 (0.631)	α_{11}	-0.042 (0.084)
			α_7	-3.256 (0.000)		
			α_8	1.477 (0.000)		
Regime 2	α_1	0.002 (0.000)	α_4	-0.162 (0.000)	α_9	0.047 (0.000)
	α_2	0.178 (0.000)	α_5	0.318 (0.000)	α_{10}	1.225 (0.000)
	α_3	0.069 (0.000)	α_6	0.171 (0.142)	α_{11}	0.039 (0.001)
			α_7	0.747 (0.000)		
			α_8	3.443 (0.000)		
Regime 3	α_1	0.001 (0.825)	α_4	0.115 (0.000)	α_9	0.025 (0.000)
	α_2	0.402 (0.032)	α_5	-0.120 (0.000)	α_{10}	1.575 (0.000)
	α_3	0.069 (0.000)	α_6	0.431 (0.004)	α_{11}	0.250 (0.000)
			α_7	1.323 (0.000)		
			α_8	-4.286 (0.000)		
$\overline{R}^2$		0.163		0.241		0.660
J-statistic				0.322		

* p-values are in parentheses.

Table 6b. GMM Estimation using break date of DIS
($\widehat{\tau}_3$ =Oct08)*

Equations						
		NKPC		Dynamic IS		Taylor Rule
Regime 1	α_1	0.002 (0.000)	α_4	-0.002 (0.004)	α_9	0.040 (0.000)
	α_2	0.197 (0.000)	α_5	0.284 (0.000)	α_{10}	0.859 (0.000)
	α_3	0.056 (0.000)	α_6	1.695 (0.000)	α_{11}	0.342 (0.000)
			α_7	0.735 (0.000)		
			α_8	-1.691 (0.000)		
Regime 2	α_1	0.003 (0.000)	α_4	0.018 (0.000)	α_9	0.023 (0.000)
	α_2	0.386 (0.000)	α_5	0.429 (0.000)	α_{10}	3.722 (0.000)
	α_3	0.102 (0.000)	α_6	0.257 (0.000)	α_{11}	-0.107 (0.000)
			α_7	2.101 (0.000)		
			α_8	-0.986 (0.000)		
$\overline{R}^2$		0.182		0.497		0.246
J-statistic				0.254		

* p-values are in parentheses.

Table 6c. GMM Estimation using break date of DIS and TR
($\widehat{\tau}_1$ =Jan06, $\widehat{\tau}_2$ =May09, $\widehat{\tau}_3$ =Oct08)*

		Equations				
		NKPC		Dynamic IS		Taylor Rule
	α_1	0.002 (0.000)	α_4	-0.002 (0.005)	α_9	0.031 (0.000)
	α_2	0.275 (0.000)	α_5	0.284 (0.000)	α_{10}	0.017 (0.745)
	α_3	0.066 (0.000)	α_6	1.696 (0.000)	α_{11}	-0.044 (0.009)
			α_7	0.735 (0.000)		
			α_8	-1.691 (0.000)		
Break Date				Oct-2008		Jan-2006
			α_4	0.018 (0.000)	α_9	0.047 (0.000)
			α_5	0.429 (0.000)	α_{10}	1.220 (0.000)
			α_6	0.257 (0.000)	α_{11}	0.040 (0.000)
			α_7	2.101 (0.000)		
			α_8	-0.988 (0.000)		
Break Date						May-2009
					α_9	0.025 (0.000)
					α_{10}	1.583 (0.000)
					α_{11}	0.249 (0.000)
$\overline{R}^2$		0.168		0.497		0.659
J-statistic				0.253		

* p-values are in parentheses.

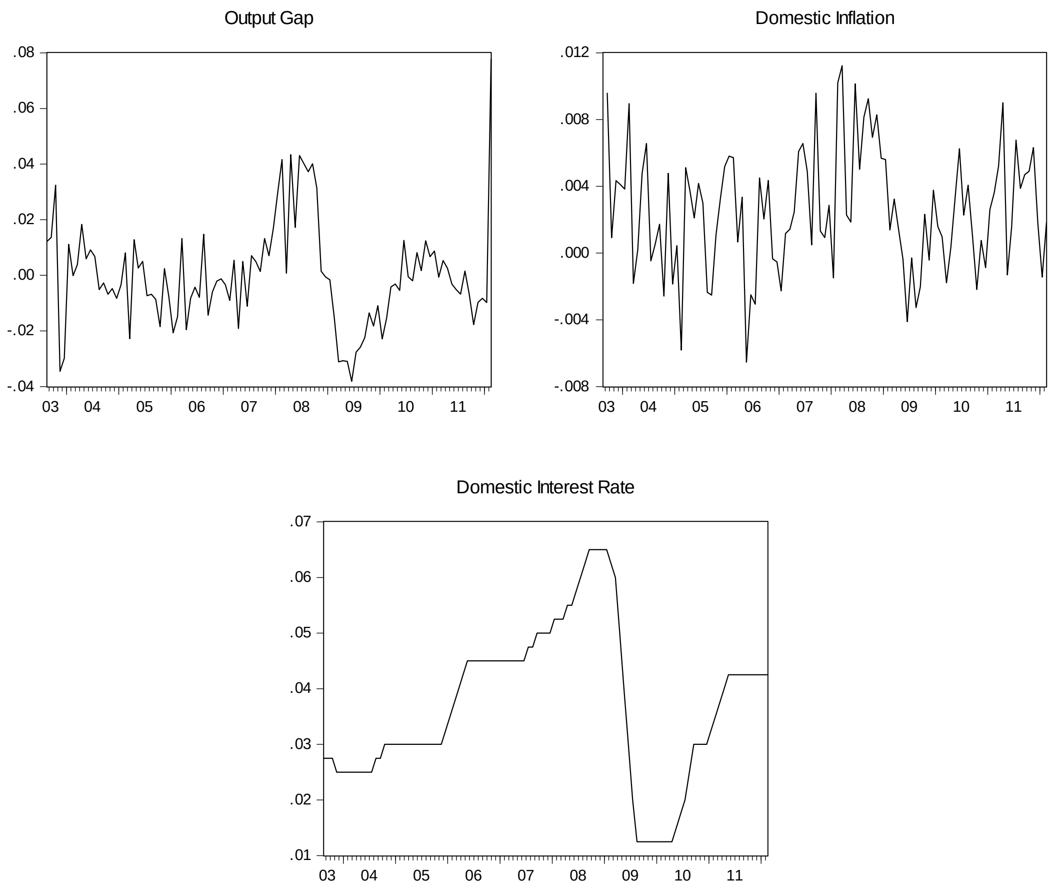

Figure 1. Output Gap, Domestic Inflation and Interest Rate in Peru

ÚLTIMAS PUBLICACIONES DE LOS PROFESORES
DEL DEPARTAMENTO DE ECONOMÍA

Libros

Carlos Conteras (Edt.)
2014 *El Perú desde las aulas de Ciencias Sociales de la PUCP.* Lima, Facultad de Ciencias Sociales, Pontificia Universidad Católica del Perú.

Waldo Mendoza
2014 *Macroeconomía intermedia para América Latina.* Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Carlos Conteras (Edt.)
2014 *Historia Mínima del Perú.* México, El Colegio de México.

Ismael Muñoz
2014 *Inclusión social: Enfoques, políticas y gestión pública en el Perú*. Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Cecilia Garavito
2014 *Microeconomía: Consumidores, productores y estructuras de mercado*. Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Alfredo Dammert Lira y Raúl García Carpio
2013 *La Economía Mundial ¿Hacia dónde vamos?* Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Piero Ghezzi y José Gallardo
2013 *Qué se puede hacer con el Perú. Ideas para sostener el crecimiento económico en el largo plazo*. Lima, Fondo Editorial de la Pontificia Universidad Católica del Perú y Fondo Editorial de la Universidad del Pacífico.

Cecilia Garavito e Ismael Muñoz (Eds.)
2012 *Empleo y protección social.* Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Félix Jiménez
2012 *Elementos de teoría y política macroeconómica para una economía abierta* (Tomos I y II). Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Félix Jiménez
2012 *Crecimiento económico: enfoques y modelos.* Lima, Fondo Editorial, Pontificia Universidad Católica del Perú.

Serie: Documentos de Trabajo

No. 383 “An Application of a Random Level Shifts Model to the Volatility of Peruvian Stock and Exchange Rates Returns”. Junior Ojeda y Gabriel Rodríguez. Noviembre, 2014.

No. 382 “Firms’ Innovation, Constrains and Productivity: the Case of Peru”. Mario Tello. Octubre, 2014.

No. 381 “The Great Recession: on the Ineffectiveness of Domestic Adjustment Policies and the Need of Multilateral Arrangements”. Jorge Rojas. Octubre, 2014.

No. 380 “The Political Economy of Growth, Inequality, the Size and Composition of Government Spending”. Klaus Schimdt-Hebbel y Jose Carlos Tello. Setiembre, 2014.

No. 379 “Sistema educativo peruano: balance y agenda pendiente”. Guillermo Jopen, Walter Gómez y Herbert Olivera. Setiembre, 2014.

No. 378 “International Competition and Inequality: A Generalized Ricardian Model”. Adolfo Figueroa. Setiembre, 2014.

No. 377 “Total Factor Productivity Estimation in Peru: Primal and Dual Approaches”. Nikita Céspedes y Nelson Ramírez-Rondán. Mayo, 2014.

No. 376 “Crecimiento económico en el Perú bajo los Borbones, 1700-1820”. Carlos Contreras. Mayo, 2014.

No. 375 “Assesing the Impact of a Student Loan Program on Time-to-Degree: The Case of a Program in Peru”. Luis García. Abril, 2014.

No. 374 “Incluir socialmente a los adultos mayores: ¿Es suficiente pensión 65?”. Luis García. Marzo, 2014.

Departamento de Economía - Pontificia Universidad Católica del Perú
Av. Universitaria 1801, Lima 32 – Perú.
Telf. 626-2000 anexos 4950 - 4951
http://www.pucp.edu.pe/economia