The Phillips Curve and the Role of Monetary Policy in Chile

Leonardo Salazar[*]

June 29, 2016

Abstract

In this article the empirical analysis finds that the dynamics of inflation and unemployment can be described by a Phillips curve when allowing for a positive co-movement between trend-adjusted productivity and unemployment. This suggests that improvements in productivity have been achieved by laying off the least productive part of the labor force. Furthermore, the natural rate of unemployment is a function of the long-term interest rate, suggesting that monetary policy might not be completely neutral over the business cycle. The results also show that there is a negative co-movement between trend-adjusted productivity and real exchange rate. This indicates that firms adjust profits through improvements in productivity in periods of real exchange rate appreciation.

Keywords Inflation; Unemployment; Phillips curve; Structural Slumps

JEL Classification C32; E31; E43

---

[*]leonardo.salazar@econ.ku.dk, Department of Economics, University of Copenhagen, Øster Farimagsgade 5, building 26, DK-1353, Copenhagen.

1 Introduction

Since Phillips (1958) observed a negative relationship between wage inflation and the unemployment rate, known as the Phillips curve, numerous studies have analyzed this relationship empirically and theoretically. Over time, the relationship between the inflation rate and some measure of the economic cycle has been analyzed, giving rise to different formulations of the Phillips curve that have been generally used for the design of economic policies and forecasting inflation.

Karanassou et al. (2010) present a thorough review of the historical development and formulations of the Phillips curve. They noted that models that analyze inflation dynamics are often classified either as standard Phillips curve models or New Keynesian Phillips curve models.

Standard Phillips curve models from the early 1960s find empirical support for a negative relationship between the inflation rate and unemployment as formulated by the traditional Phillips curve:

$$\triangle p_t = c - bu_t + \nu_{1t} \tag{1}$$

where $\triangle p_t$ is the inflation rate, u_t is the unemployment rate, $c > 0$ and $b > 0$ are constants, and ν_{1t} is a stationary error term. Phillips (1958) estimated equation (1) for the UK as did Samuelson and Solow (1960) for the United States with the expected coefficients signs. This relationship broke down in the 1970s when a positive relationship between inflation and unemployment was observed rather than a negative one; this was called stagflation. It caused Friedman (1968) and Phelps (1968) to develop a new form of the Phillips curve, the expectations-augmented Phillips curve. The idea was that the curve shifts over time as a function of changes in inflationary expectations. Thus, there is a natural rate of unemployment acting as a long-run attractor for the unemployment rate, and in the long run unemployment is independent of the rate of inflation. This formulation is given by:

$$\triangle p_t = \triangle p_t^e - b\left(u_t - u^*\right) + \nu_{2t} \tag{2}$$

where $\triangle p_t^e$ is the expected inflation rate, u^* is the natural rate of unemployment that is generally assumed to be constant, and ν_{2t} is a stationary error term. Thus, under the expectations-augmented Phillips curve, there is only a short-run trade-off between inflation and unemployment rate. The New Keynesian Phillips curve models relate actual and expected inflation to some measure of aggregate marginal cost instead of to unemployment.

Most of the the Phillips curve literature on Chile has dealt with the evaluation of the transmission mechanism of monetary policy (Cabrera and Lagos, 2000), the forecast of inflation (De Simone, 2001), and the estimation of NAIRU, or the non-accelerating inflation rate of unemployment (Restrepo, 2008). But some studies also analyze hysteresis as an explanation for the persistence of the unemployment rate (Solimano and Larraín, 2002; Gomes and da Silva, 2008).

These studies find that there is a significant and negative relationship between inflation and cyclical unemployment, as well as between cyclical unemployment and the inflation gap. This is interpreted as evidence for a short-run Phillips curve (Restrepo, 2008). The literature also finds that the Phillips curve seems to provide better forecasting of inflation when the explicit inflation target is used as an independent variable instead of the output gap (De Simone, 2001). Since the GDP gap as well as measures of the business cycle do not show a significant response to an increase in the monetary policy interest rate, Cabrera and Lagos (2000) argue that the Phillips curve is not a proper tool to analyze the transmission mechanism of a monetary policy.

The hysteresis hypothesis has been offered as a way to explain the persistence observed in the rate of unemployment in Chile. Solimano and Larraín (2002) show that this hypothesis cannot be rejected, and Gomes and da Silva (2008) argue that hysteresis is a better explanation of the actual unemployment than the NAIRU. Restrepo (2008) shows that the latter rate is time varying but does not offer an explanation for its cause.

Regardless of the specification of the Phillips curve, most of the available studies are based on a single-equation approach where the rate of inflation is explained by some indicator of the economic cycle (e.g., unemployment, production, marginal cost). Such an approach can be justified by the classical dichotomy that nominal variables do not affect real variables and that inflation and unemployment can be separately analyzed if there is no trade-off between them in the long run. However, the empirical evidence for this dichotomy is quite weak. For instance, Fisher and Seater (1993), King and Watson (1994), Fair (2000), and Karanassou et al. (2005) present evidence of a significant long-run trade-off between inflation and the unemployment rate. Even if the classical dichotomy holds, a single-equation approach is silent about any feedback mechanisms embedded in the data.

Furthermore, most empirical and theoretical studies assume the natural rate of unemployment to be an exogenous variable. This can also be justified by the classical dichotomy. Generally, in its first stage the Phillips curve is estimated under the assumption of a constant natural rate, and from the residuals of this equation, a time-varying natural rate of unemployment is then derived (Mankiw and Ball, 2002).

The results in this article show that the inflation-unemployment dynamic is described by a Phillips curve when allowing for a positive co-movement between trend-adjusted productivity and the unemployment rate. Furthermore, the natural rate of unemployment is a positive function of the long-term nominal interest rate, suggesting that monetary policy might not be completely neutral over the business cycle. This finding is in line with Blanchard (2003), which implicitly states that monetary policy may have real effects on the economy:

> ...if we accept the fact that monetary policy can affect the real interest rate for a decade and perhaps more, then, we must accept, as a matter of logic, that it can affect activity, be it output or unemployment, for a roughly equal time (Blanchard, 2003,

p.3)

Figure 1 shows the monetary policy interest rate, as determined by the Central Bank of Chile, together with the long- and short-term interest rates. The latter two are calculated as the average long (1 year) and short (3 months) deposit rates in the Chilean financial system. The three interest rates are co-moving over time, suggesting that market interest rates follow the policy rate.

Figure 1: Monetary policy interest rate (Central Bank), long-term interest rate (financial system), and short-term interest rate (financial system). Quarterly information 1990:4-2013:4
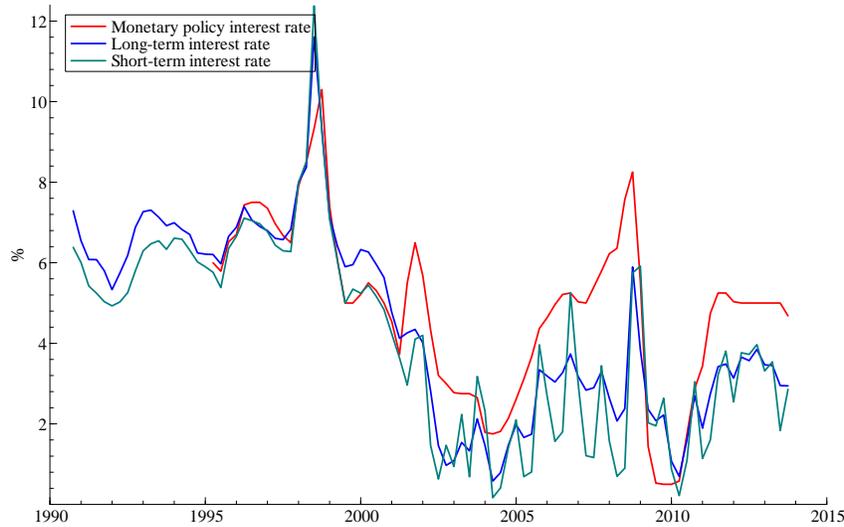
Note 1: Data on monetary policy rate is only available since 1995:2.

Most Phillips curve studies focused on industrialized economies, particularly in European countries, and only a small proportion on developing countries. The latter is probably due to the scarceness of homogeneous datasets that cover sufficiently long periods, which may be the result of economic and political instability in these economies. Whatever the reason, the lack of research on developing economies is likely to hinder a suitable design of economic policies.

2   Theoretical framework

This section discusses the expectations-augmented Phillips curve in a framework developed by Hoover (2011), assuming an economy with imperfect competition and imperfect information about the current price level. In this framework, supply shocks are also allowed to shift the relationship between the unemployment rate and inflation.[1]

---

[1]This section presents only the model's main results. For further details, see Chapter 15 in Hoover (2011).

2.1 Price setting

A firm sets its price based on its expectation of the price level prevailing during the current period, taking demand and supply conditions into account. The price setting is written as:

$$\triangle p_{j,t} = \triangle p_{j,t}^e + f \,(\text{demand factors}) + g \,(\text{supply factors}) \tag{3}$$

where $\triangle$ is the first difference operator, $p_{j,t} = \ln(P_{j,t})$ and $P_{j,t}$ is the price set by firm j, $p_{j,t}^e = \ln(P_{j,t}^e)$ and $P_{j,t}^e$ is the expected level of price prevailing during the current period. This price is set by firm j at the end of period $t-1$ based on an information set available at the end of the same period, $Z_{j,t-1}$. The expected price can be written as $P_{j,t}^e = E_{j,t-1}[P_t|Z_{j,t-1}]$ where $E[\cdot]$ is the expectation operator. Functions $f(\cdot)$ and $g(\cdot)$ determine how demand and supply factors affect the pricing decision of firm j.

Equation (3) represents a single firm's price behavior. Taking the average of all firms in the economy and assuming that firm-specific supply and demand factors average out, the economy's price behavior is written as:

$$\triangle p_t = \triangle p_t^e + f \left(\begin{array}{c} \text{aggregate demand} \\ \text{factors} \end{array} \right) + g \left(\begin{array}{c} \text{aggregate supply} \\ \text{factors} \end{array} \right) \tag{4}$$

where $\triangle p_t$ is the current inflation rate, $\triangle p_t^e$ is the average expectation of general price inflation for all firms, $f(\cdot)$ is reflecting demand-pull inflation, and $g(\cdot)$ captures cost-push inflation.

2.2 The Phillips curve and the natural rate of unemployment

Functions $f(\cdot)$ and $g(\cdot)$ must be explicitly defined to apply equation (4) to actual data. Since Phillips (1958), an accepted and usual measure of the aggregate demand, has been the unemployment rate:

$$f \,(\text{aggregate demand factors}) = a - bu_t \tag{5}$$

where u_t is the unemployment rate, b is assumed to be a positive constant given the countercyclical behavior of the unemployment rate, and $a > 0$.

Now, assuming for the moment that aggregate supply factors can be ignored, an unemployment rate that sets actual inflation equal to expected inflation is obtained by inserting equation (5) into equation (4):

$$u_t^* = \frac{a}{b} \tag{6}$$

where u_t^* is the natural rate of unemployment. If a and b are stable over time, the natural rate can be expressed without subscript t. Equation (4) can then be rewritten as:

$$\triangle p_t = \triangle p_t^e - \gamma \left(u_t - u^* \right) + g \left(\text{aggregate supply factors} \right) \tag{7}$$

where $\gamma = b$. Equation (7) is the extension of the Phillips curve that allows for supply shocks. When the unemployment rate is below (over) its natural rate, inflation tends to increase faster (slower) than expected.

Equations (6) and (7) show two classical results. First, the natural rate of unemployment is constant, and second, the Phillips curve is vertical at this level. That is, when expectations are fulfilled and the aggregate supply factors are set at their "natural" levels, there is no long-run trade-off between unemployment and inflation.

2.3 Discussion

According to the theoretical framework, the unemployment rate should converge to its natural rate after a supply shock. This assumption is known as the natural rate hypothesis (NRH) and posits that the Phillips curve is vertical in the long run. However, the NRH is not well supported empirically (see Gomes and da Silva, 2008, for Chilean data, and Farmer, 2013, for the US data).

Farmer (2013) proposes that the NRH can be tested in the following way. Under the assumption that expectations are rational, the number of periods (e.g., quarters) where actual inflation is above its expected value should be roughly equal to the number of periods in which the opposite situation is observed. Then, over a decade, the average inflation rate should be approximately equal to the average expected inflation. If the inflation rate over long periods is plotted together with the unemployment rate, a vertical line at the natural rate of unemployment should be visible, supporting the NRH and rational expectations.

Figure 2 shows Chile's average inflation and unemployment rates by decade.[2] The plotted points are not vertically aligned, and there is no tendency for them to lie around a vertical line. Farmer (2013) obtains a similar result for US data and categorically concludes that because expectations are unlikely to be systematically biased over decades, the NRH is false. However, such a strong conclusion should not rely on a simple graph, and further tests must be provided.

The result that unemployment does not converge to a unique constant value in the long run might potentially explain this variable's persistence. It also suggests that the natural rate of unemployment is time varying. Phelps (1994) argues, in his structural slumps theory, that the long swings observed in European unemployment rates can be explained by fluctuations in exchange rates and real interest rates. Specifically, domestic real interest rates likely influence the natural rate of unemployment. In this case, the natural rate of unemployment is time varying, and its fluctuations are associated with the movements observed in real interest rates.

---

[2]1980s includes the period 1986–1989 and 2010s includes the period 2010–2013.

Figure 2: Average inflation and unemployment by decade in Chile
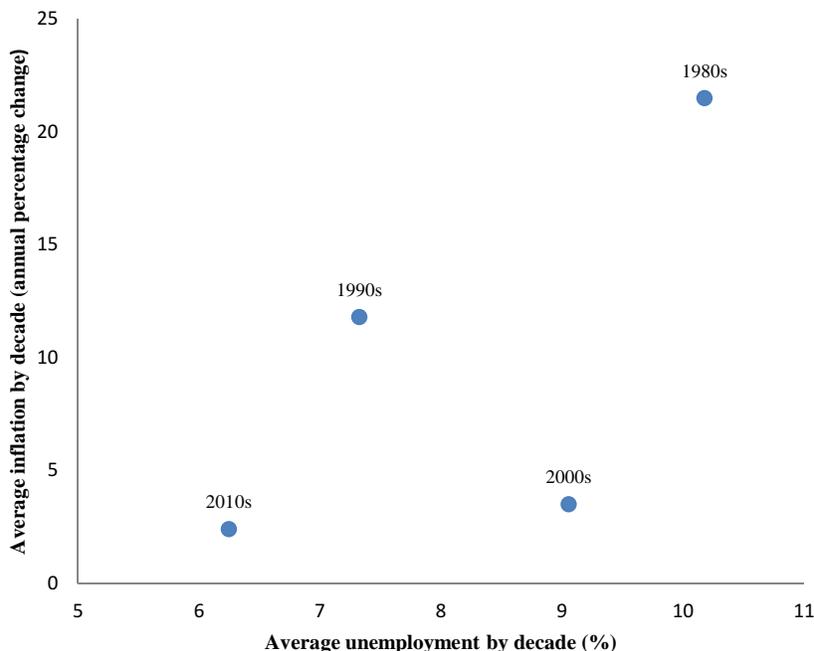
Note 1: 1980s includes 1986–1989, and 2010s includes 2010–2013.

Phelps (1994) provides two reasons for explaining the positive co-movement between the natural rate of unemployment and the interest rate. First, higher real interest rates increase the natural rate of unemployment by discouraging investment. Examples would be investment in the retention of workers (high interest rate reduces the probability of paying higher wages) or investment that could increase the productivity of the firm's workforce. Second, equilibrium employment will decrease with higher interest rates when government actions reduce firms' labor demand. For example, actions that affect the wealth of the working-age population will raise the real wage that workers demand (Aghion et al., 2003)

Phelps (1994) assumes a world where the unemployment rate and the real interest rate are stationary. However, empirical studies often find real interest rates to be indistinguishable from a unit root process. Such persistence in real interest rates is consistent with the theory of imperfect knowledge economics (IKE), developed by Frydman and Goldberg (2007, 2011), and Juselius and Juselius (2012) argue, based on Finish data, that the structural slumps theory based on IKE is better able to explain the persistent swings observed in the data.

Juselius and Juselius (2012) give the following rationale. Under IKE, nominal interest rates exhibit strong persistence due to a nonstationary uncertainty premium, whereas inflation rates are more stable over time due to international competitiveness. This implies that the Fisher effect does not hold as a stationary condition. The uncertainty premium is generally related to the concept of a "gap effect." In the foreign currency market the gap effect can be measured by the deviation of the real exchange rate from its long-run purchasing power parity value. In an IKE world, due

6

to speculative behavior in the currency market, nominal exchange rates tend to move away from relative prices for long periods of time, causing the real exchange rate to behave like a near $I(2)$ process. Persistent deviations of the real exchange rate from its long-run benchmark value will be reflected in the uncertainty premium and hence in domestic and foreign interest rates.

Then an increase (decrease) in nominal interest rates, in general, is not likely to be followed by an increase (decrease) in consumer price inflation, the real interest rate will tend to rise (drop). This is likely to result in inflows (outflows) of speculative capital, causing an appreciation (depreciation) of the real exchange rate and worsening (improving) domestic competitiveness. Under this situation, domestic firms in the tradable sector cannot count on exchange rates to restore competitiveness after a shock to relative costs (e.g., a large wage rise). In this case, domestic firms will be prone to adjust profits rather than prices. Profits can be adjusted through improvements in labor productivity by laying off the least productive workers. Thus, an increase in both labor productivity and unemployment might be expected in periods of real appreciation and rising real interest rates.

Then a more adequate and general representation of the Phillips curve is given by:

$$\triangle p_t = \triangle p_t^e - \gamma \left(u_t - u_t^* \right) + \nu_{3t} \tag{8}$$

where ν_{3t} is a stationary error term and the time-varying natural rate of unemployment, u_t^*, can be expressed as $u_t^* = z\left(i_t\right)$, where i_t is the real interest rate and $z' > 0$.

3   Stylized facts

Figure 3 Panel (a) shows the quarterly inflation rate, which exhibits a gradual decrease over the sample. This might be associated with the implementation of inflation targeting in 1990. By mandate, the Central Bank of Chile is compelled to keep the annual inflation rate centered on 3% with fluctuations in the range of 2%–4%. This has been more or less the case since 2000.

Figure 3 Panel (b) shows the evolution of the unemployment rate, which exhibits an important increase in 1998, possibly as a result of the Asian Crisis.[3] The unemployment rate exhibits a higher mean after that crisis, suggesting that the mean of the natural rate of unemployment might have increased as well. Indeed, the rate of unemployment rose from an average rate of 6.9% to 8.4% after the Asian crisis. The unemployment rate exhibits another significant increase in 2009 when the global financial crisis hit the Chilean economy. This increase, however, seems transitory.[4]

Unemployment rate is not the only variable seemingly affected by the Asian crisis. Figure 3

---

[3]The Asian crisis hit the Chilean economy in 1998. The tradable sector was the most affected because about 48% of the total exports were sent to Asia in 1998. The decrease in Asian demand triggered the bankruptcy of many companies, leading to a large increase in the unemployment rate.

[4]After the Asian crisis, structural reforms were introduced in the labor market to reduce the impact of domestic and international shocks.

Figure 3: Panel (a): Inflation rate. Panel (b): Unemployment rate. Panel (c): Real labor productivity. Panel (d): Real exchange rate. Panel (e): Long-term real interest rate. Panel (f): Interest rate spread (long and short-term interest rate). Quarterly information 1990:4–2013:04
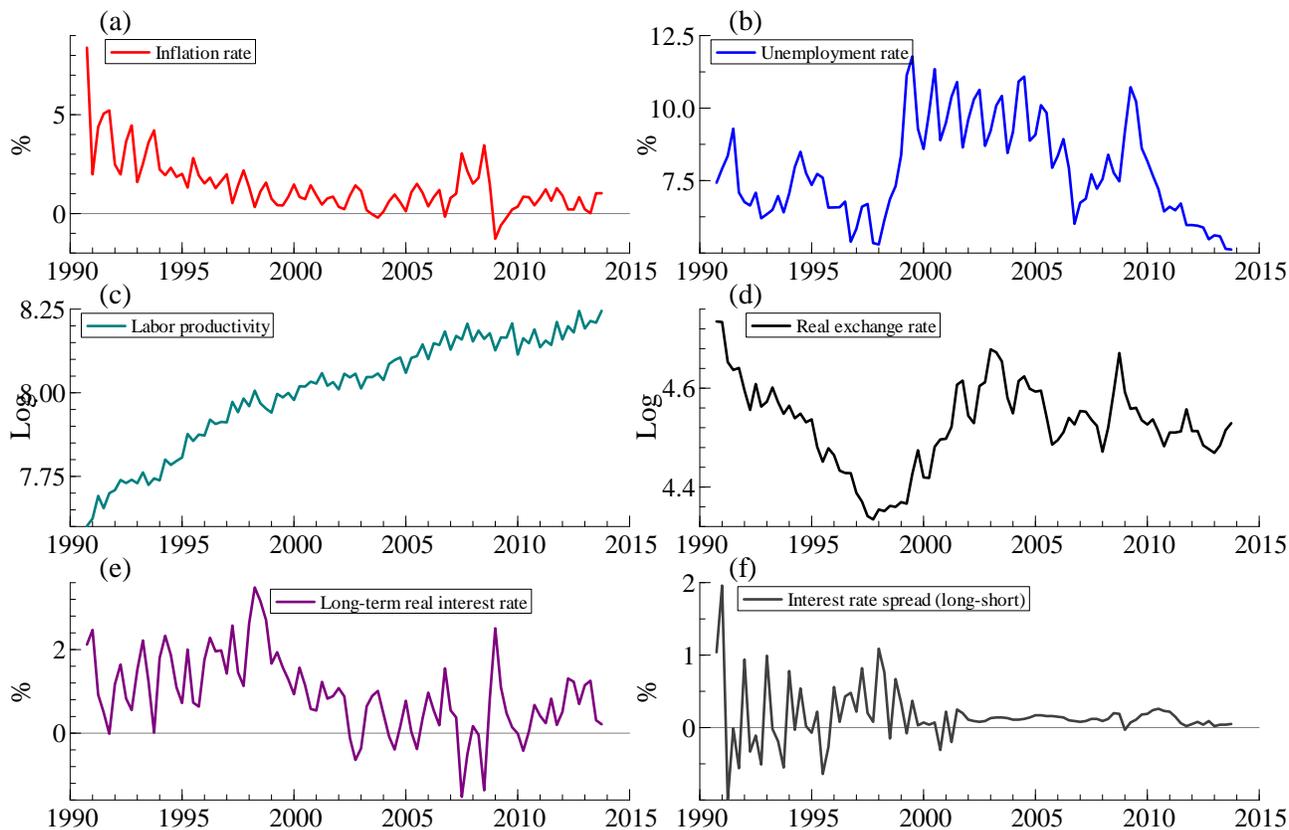
Panel (c) shows a deceleration in the growth of real productivity around 1998, which again might indicate a slowdown in economic activity as a result of the Asian crisis. The unemployment rate and productivity exhibit seasonality caused by the agricultural activity in Chile, which is higher during the last and first quarter of each year.

Figure 3 Panel (d) shows the real exchange rate, and since 2000, it exhibits a higher mean. This may be related to the the free floating exchange rate regime implemented by the Central Bank of Chile in September 1999. The graph suggests that the real exchange rate may be fluctuating around a constant level, though with persistent deviations.

Two major reforms were introduced in the Chilean financial market between 2000 and 2001. While the first reform, promulgated in 2000, gave greater protection to both domestic and foreign investors, the second reform, enacted in 2001, liberalized the financial system, implying, among other things, capital account deregulation. These reforms seemed to affect the real interest rate which had exhibited a lower mean since 2001 (Figure 3 Panel (e)). At the same time, Figure 3 Panel (f), shows a large volatility reduction in the the interest rate spread between the long- and short-term rates.

8

4 The empirical model analysis

4.1 Baseline model

The quarterly data cover the period 1990:4–2013:4, and the information set[5] is given by $\boldsymbol{x}_t' = [\triangle p_t, u_t, ri_t, sp_t, c_t, q_t]$ where

- $\triangle p_t$ is the inflation rate.

- u_t is the unemployment rate.

- $ri_t = i_t^L - \triangle p_t$ is the long-term real interest rate, and i_t^L is the long-term nominal interest rate.

- $sp_t = i_t^L - i_t^S$ is the interest rate spread, and i_t^S is the short-term nominal interest rate. Following Juselius and Juselius (2012), this spread is used as a proxy for expected inflation.

- c_t is the real labor productivity.

- q_t is the real exchange rate.

All variables are in logs, except unemployment rate, real interest rate, and spread.

The baseline cointegrated VAR (CVAR) model for vector $\boldsymbol{x}_t$ is:

$$\triangle \boldsymbol{x}_t = \boldsymbol{\alpha}\tilde{\boldsymbol{\beta}}'\tilde{\boldsymbol{x}}_{t-1} + \boldsymbol{\Gamma}_1\triangle\boldsymbol{x}_{t-1} + \sum_{i=0}^{1}\boldsymbol{\delta}_i d_{s98:3,t-i} + \boldsymbol{\mu}_0 + \boldsymbol{\delta}_2\boldsymbol{D}_{p,t} + \boldsymbol{\delta}_3\boldsymbol{S}_t + \boldsymbol{\varepsilon}_t \qquad (9)$$

where $\tilde{\boldsymbol{x}}_t = [\boldsymbol{x}_t, d_{s00:4,t}, t_{98:3,t}, t]'$, $d_{s00:4,t}$ is a step dummy that takes the value of 1 since 2000:4, 0 otherwise; $t_{98:3,t}$ is a broken linear trend taking values of $1, 2, \ldots, 62$ since 1998:3, 0 otherwise; and t is a linear trend. $d_{s98:03,t}$ is a shift dummy that takes the value of 1 since 1998:3, 0 otherwise, corresponding to the first difference of the broken linear trend. $\boldsymbol{\mu}_0$ is a vector of constant terms, $\boldsymbol{D}_{p,t}$ contains 14 permanent dummies $(0, \ldots, 0, 1, 0, \ldots, 0)$,[6] and $\boldsymbol{S}_t$ is a vector of centered seasonal dummies. Finally, $\boldsymbol{\varepsilon}_t$ is an i.i.d. vector of normally distributed stochastic errors.

The step dummy $d_{s00:4,t}$ accounts for deregulation in the Chilean financial markets, and the broken linear trend accounts for the productivity slowdown in 1998. Both deterministic variables, together with the linear trend, are restricted to lie in the cointegration space.

4.2 Misspecification tests and determining the cointegration rank

Table 1 reports the residual misspecification tests of model (9).[7] The upper part shows that the model is, in general, well behaved. The hypotheses of non-autocorrelation and non-ARCH cannot

---

[5]Appendix A presents the source and transformation of the data.

[6]Each permanent dummy takes the value of 1 in 1992:1, 1993:1, 1993:4, 1994:1, 1995:3, 1995:4, 1997:4, 2000:4, 2003:1, 2006:4, 2007:3, 2008:3, 2009:1, and 2010:1; 0 otherwise.

[7]Dennis (2006) provides a thorough description of the misspecification tests.

be rejected, and there are only weak signs of non-normality. The univariate tests in the lower part of Table 1 show that only residual ARCH and signs of non-normality are present in the interest rate spread. The ARCH problem is evident from Figure 3 Panel (f) and the normality problem is associated with excess of kurtosis rather than skewness. Except for these minor misspecification signs, the model seems reasonably well specified.

Table 1: Misspecification tests CVAR model

Multivariate tests				
Autocorrelation		Normality	ARCH	
Order 1 : $\chi^2(36)$	Order 2 : $\chi^2(36)$	$\chi^2(12)$	Order 1 : $\chi^2(441)$	Order 2 : $\chi^2(882)$
34.78 [0.53]	45.44 [0.14]	21.39 [0.05]	382.66 [0.98]	925.35 [0.15]

Univariate tests						
	$\triangle^2 p_t$	$\triangle u_t$	$\triangle ri_t$	$\triangle sp_t$	$\triangle c_t$	$\triangle q_t$
ARCH Order 2:$\chi^2(2)$	0.29 [0.86]	3.20 [0.20]	0.85 [0.65]	13.83 [0.00]	3.27 [0.19]	4.77 [0.10]
Normality $\chi^2(2)$	1.66 [0.44]	1.99 [0.37]	0.61 [0.74]	11.01 [0.00]	0.81 [0.67]	0.17 [0.92]
Skewness	0.05	0.24	-0.16	0.02	0.16	0.10
Kurtosis	3.33	3.34	2.99	4.47	3.06	2.77

Note 1: [·] is the p-value of the test.

The upper part of Table 2 reports the eigenvalues, λ_i, for the null hypothesis of $r = 0, 1, 2, 3, 4, 5$ and the corresponding Bartlett-corrected $I(1)$ trace test with the p-value in brackets. The hypothesis $r = 5$ cannot be rejected based on a p-value of 0.34. To check the adequacy of this choice, the lower part of Table 2 reports the four largest characteristics roots for $r = 6, 5, 4, 3$. The unrestricted model, $r = 6$, has only one reasonably large root, 0.75, suggesting that the model contains one unit root at most. $r = 5$ leaves a complex pair of roots with a modulus of 0.65 as the largest root in the system. Thus, the following analysis is based on $r = 5$ cointegrating vectors.

4.3 Identification of the long-run structure

To identify plausible economic relationships among the variables, a set of restrictions, $\mathscr{H}_{\tilde{\beta}} : \tilde{\beta} = (\boldsymbol{H}_1 \boldsymbol{\varphi}_1, \boldsymbol{H}_2 \boldsymbol{\varphi}_2, \ldots, \boldsymbol{H}_r \boldsymbol{\varphi}_r)$, must be imposed on $\tilde{\beta}$, where $\boldsymbol{H}_i$ is a restriction matrix of dimension $p_1 \times (p_1 - m_i)$, p_1 is the dimension of $\tilde{\boldsymbol{x}}$, m_i is the number of restrictions imposed on $\tilde{\beta}_i$, $p_1 - m_i$ is the number of freely varying parameters, and $\boldsymbol{\varphi}_i$ is a $(p_1 - m_i) \times 1$ vector of unknown parameters. This test is asymptotically χ^2 distributed with degrees of freedom equal to $\sum_{i=1}^{r} (m_i - (r - 1))$ (Johansen, 1996). When $\alpha_{ij} \beta_{ij} < 0 \ (> 0)$, the cointegrating relation is equilibrium correcting (increasing) in the equation $\triangle \boldsymbol{x}_{j,t}$ (Juselius, 2006).

Table 3 reports an identified structure on $\tilde{\beta}$ with nine overidentified restrictions that could not be rejected based on $\chi^2(9) = 7.60$ with a p-value of 0.58.[8] To facilitate interpretation, an α_{ij}

---

[8]Appendix B indicates that the eigenvalue fluctuation test does not show signs of parameter-no constancy.

Table 2: Cointegrating rank and model adequacy

		$I(1)$ *trace test*			
$p-r$	$H_0 : r =$	Eigenvalues (λ_i)	Trace test	p-value	$Q_{.95}$
6	0	0.76	333.74	[0.00]	137.90
5	1	0.57	215.05	[0.00]	107.06
4	2	0.48	142.22	[0.00]	79.91
3	3	0.43	88.14	[0.00]	54.99
2	4	0.26	38.47	[0.02]	34.88
1	5	0.11	11.12	[0.34]	17.64

Modulus of the five largest characteristic roots

$r = 6$	0.75	0.65	0.65	0.63
$r = 5$	1.00	0.65	0.65	0.63
$r = 4$	1.00	1.00	0.65	0.65
$r = 3$	1.00	1.00	1.00	0.60

Note 1: p is the number of variables in vector $\boldsymbol{x}_t$

Note 2: [·] is the p-value of the trace test simulated according to model (9)

Note 3: $Q_{.95}$ is the 5% critical value of the trace test

coefficient in boldface means that the cointegrating relation i is equilibrium correcting, whereas an error increasing coefficient is in italics. The results in Table 2 showed that all eigenvalues are inside of the unit circle. Thus, the system is stable, and any error-increasing behavior is compensated by error-correcting behavior.

Table 3: The estimated long-run $\tilde{\boldsymbol{\beta}}$ structure ($\chi^2(9) = 7.60\ [0.58]$)

	$\triangle p_t$	u_t	ri_t	sp_t	c_t	q_t	$d_{s00:4,t}$	$t_{98:3,t}$	t
$\tilde{\boldsymbol{\beta}}'_1$	1.00	0.48 (8.54)	-	-	−0.22 (−8.09)	-	-	−0.003 (−11.83)	0.004 (12.20)
$\boldsymbol{\alpha}'_1$	**−0.51** (−6.76)	*0.22* (2.47)	0.25 (3.62)	*	**1.07** (3.85)	−2.11 (−4.79)			
$\tilde{\boldsymbol{\beta}}'_2$	-	1.00	−1.00	-	-	-	−0.01 (−2.97)	-	0.001 (12.35)
$\boldsymbol{\alpha}'_2$	0.30 (4.95)	**−0.44** (−6.08)	*−0.25* (−4.55)	*	*	1.05 (2.96)			
$\tilde{\boldsymbol{\beta}}'_3$	-	-	1.00	−1.00	-	-	0.01 (4.08)	-	-
$\boldsymbol{\alpha}'_3$	0.39 (3.36)	−0.29 (−2.13)	**−0.80** (−7.55)	*−0.11* (−2.55)	*	*			
$\tilde{\boldsymbol{\beta}}'_4$	0.07 (3.10)	-	-	1.00	-	-	-	0.0003 (8.34)	−0.0003 (−8.34)
$\boldsymbol{\alpha}'_4$	*1.00* (4.31)	*	−1.44 (−6.72)	**−1.18** (−13.39)	*	*			
$\tilde{\boldsymbol{\beta}}'_5$	-	-	-	-	1.00	1.00	−0.16 (−7.64)	-	−0.002 (−5.11)
$\boldsymbol{\alpha}'_5$	*	*	*	*	*	**−0.58** (−7.60)			

Note 1: ($\cdot$) is the t-value. $*$ stands for an alpha coefficient with |t-value| ≤ 2.0.

Note 2: "-" is a zero restriction.

Note 3: a coefficient in boldface stands for an equilibrium error correcting behavior.

Note 4: a coefficient in italics stands for an equilibrium error increasing behavior.

The first cointegrating vector, $\tilde{\boldsymbol{\beta}}'_1\tilde{\boldsymbol{x}}_t$, is interpreted as a Phillips curve over the business cycle and is expressed as:

$$\triangle p_t = -0.48\left(u_t - 0.45\tilde{c}_t\right) + \hat{v}_{1,t} \tag{10}$$

where $\tilde{c}_t = c_t + 0.013t_{98:3,t} - 0.018t$ stands for trend-adjusted productivity and $\hat{v}_{1,t} \sim I(0)$ measures the equilibrium error. Equation (10) shows that unemployment in excess of trend-adjusted productivity would lead to downward pressure on the inflation rate. This finding is consistent with the reasoning above that in a world of imperfect knowledge, firms exposed to international competition facing a positive shock to relative costs cannot, in general, count on exchange rates to restore competitiveness. Accordingly, firms will be prone to adjust profits rather than prices (Juselius and Juselius, 2012). Profits can be adjusted through improvements in productivity by laying off the least productive workers. Evidence of a positive co-movement between unemployment and productivity has also been found in Juselius (2006) for Danish data.

The adjustment coefficients show that, while the inflation rate and productivity are equilibrium

error correcting to the Phillips curve, the unemployment rate is equilibrium error increasing. Thus if unemployment is above its long-run equilibrium value, the trend-adjusted productivity will tend to increase and, at the same time, the unemployment rate will tend to increase as long as enterprises improve labor productivity over its long-run trend. This introduces further increases in the equilibrium error. The inflation rate will start decreasing, which tends to restore equilibrium. Moreover, the adjustment coefficients show that long-term interest rate has been positively affected by the equilibrium error in the Phillips curve and that the real exchange rate has appreciated when the unemployment rate has been above its long-run equilibrium value.

The second vector, $\tilde{\boldsymbol{\beta}}_2' \tilde{\boldsymbol{x}}_t$, is interpreted as an unemployment relationship and is expressed as:

$$u_t = ri_t + 0.01 d_{s00:4,t} - 0.001t + \hat{v}_{2,t} \tag{11}$$

where $\hat{v}_{2,t} \sim I(0)$ is the equilibrium error. The linear trend in (11) can be understood from Figure 3 Panel (e). The graph shows that the real interest rate has shown a tendency to decrease over time,[9] which is approximated by the deterministic trend in equation (11).

The adjustment coefficients show that, while the unemployment rate is equilibrium error correcting to equation (11), the real interest rate is equilibrium error increasing. Then, even though the interest rate is above its long-run equilibrium value, it will continue to rise. At the same time, the unemployment rate will also increase, restoring equilibrium. This seems to be greatly aggravated by the fact that the inflation rate has been positively affected by the equilibrium error $\hat{v}_{2,t}$. That is, the inflation rate shows a tendency to decrease when the real interest rate is increasing, generating further increases in the unemployment rate. In addition, the adjustment coefficients show that the real exchange rate has appreciated when the real interest rate has been above its long-run trend.

The natural rate of unemployment can be derived from equation (11),[10] and is expressed as:

$$u_t^* = i_t^L \tag{12}$$

where the natural rate of unemployment, u_t^*, is time varying and positively associated with the long-term nominal interest rate. This result indicates that monetary policy in Chile may not be completely neutral over the business cycle. That is, the Central Bank of Chile conducts its monetary policy using the interest rate as the main tool to keep the inflation rate close to its target, and equation (12) suggests that fluctuations in the nominal interest rate are positively associated with the natural rate of unemployment. Equation (12) shows that the natural rate is a function of the nominal rather than the real interest rate, which can be explained by the fact that the rate of inflation has been fairly stable over time, as shown in Figure 3 Panel (a).

---

[9] Appendix C shows that this tendency is more evident in the nominal long-term interest rate.

[10] Equation (11) can be equivalently rewritten as $u_t = \left(i_t^L - \triangle p_t \right) + 0.01 d_{s00:4,t} - 0.001t + \hat{v}_{2,t}$, implying that $\triangle p_t = -u_t + i_t^L + 0.01 d_{s00:4,t} - 0.001t + \hat{v}_{2,t} = -\left(u_t - u_t^* \right) + 0.01 d_{s00:4,t} - 0.001t + \hat{v}_{2,t}$, where $u_t^* = i_t^L$.

In an IKE world, this finding provides empirical support for Phelps's hypothesis of a Phillips curve where the natural rate of unemployment is positively co-moving with the interest rate. A time-varying natural rate of unemployment is consistent with the non-vertical scatter of the inflation and unemployment rates shown in Figure 2. Evidence of a natural rate of unemployment as function of the interest rate has also be found in Juselius and Ordóñez (2009) for Spanish data and in Juselius (2006) for Danish data.

Equation (11) also shows that unemployment is nonstationary per se and needs to be combined with another variable to obtain stationarity. This result provides another explanation of the persistence of the unemployment rate than the hysteresis hypothesis of previous studies in Chile.

The third vector, $\tilde{\boldsymbol{\beta}}_3'\tilde{\boldsymbol{x}}_t$, is interpreted as a short-term real interest rate relationship and is expressed as:

$$ri_t = sp_t - 0.01 d_{s00:4,t} + \hat{v}_{3,t}$$

or, equivalently:

$$\left(i^S - \triangle p\right)_t = -0.01 d_{s00:4,t} + \hat{v}_{3,t} \tag{13}$$

where $\hat{v}_{3,t} \sim I(0)$ measures the equilibrium error. It describes a stationary short-term real interest rate after controlling for an equilibrium mean shift in 2000:4. The latter is likely to reflect the effect of reforms introduced in the Chilean financial system. The adjustment coefficients show that, while the long-term real interest rate is equilibrium error correcting to equation (13), the spread is equilibrium error increasing. When the real interest rate is above its long-run equilibrium value, the spread will tend to decrease which increases the equilibrium error. At the same time, the real interest rate will tend to decrease, restoring the equilibrium. The inflation rate has been positively affected by the equilibrium error, which also helps to reduce the real interest rate.

The fourth relation, $\tilde{\boldsymbol{\beta}}_4'\tilde{\boldsymbol{x}}_t$, is interpreted as a central bank's reaction rule and is expressed as:

$$sp_t = -0.07\triangle p_t + 0.0003 t_{(90:4-98:3),t} + \hat{v}_{4,t} \tag{14}$$

where $\hat{v}_{4,t} \sim I(0)$ measures the equilibrium error. It indicates that the central bank tends to increase the short-term interest rate to counteract inflationary pressures, thereby reducing the spread. This is consistent with the countercyclical policy of the Central Bank of Chile. The latter tends to increase its interest rate when there are signs of inflationary pressure. The term $t_{(90:4-98:3),t}$,[11] that stands for a trend between 1990:4 and 1998:3, is needed because before 1998:3 the inflation rate behaved as a trending variable, which is shown in Figure 3 Panel (a), but since 1998:3 the inflation rate is fluctuating around a roughly constant average, which is consistent with the full implementation of inflation targeting in 1999.

---

[11]The term $t_{(90:4-98:3),t}$ is equivalent to $t - t_{98:3,t}$.

The adjustment coefficients show that while the the spread is equilibrium error correcting to the central bank's reaction rule, the inflation rate is equilibrium error increasing. When the spread is above its long-run equilibrium value, the inflation rate will tend to increase, generating further increases in the equilibrium error. At the same time, the spread will tend to narrow, restoring the equilibrium. The long-term interest rate has been negatively affected by the equilibrium error, which helps to narrow the interest rate spread.

Finally, the fifth relation, $\tilde{\boldsymbol{\beta}}_5' \tilde{\boldsymbol{x}}_t$, is interpreted as a productivity relationship and is expressed as:

$$\breve{c}_t = -\breve{q}_t + \hat{v}_{5,t} \tag{15}$$

where $\breve{c}_t = c_t - 0.002t$ stands for trend-adjusted productivity, $\breve{q}_t = q_t - 0.16d_{s00:4,t}$ stands for the real exchange rate after controlling for an equilibrium mean shift, and $\hat{v}_{5,t} \sim I(0)$ measures the equilibrium error. It shows that the trend adjusted productivity has been negatively co-moving with the real exchange rate. This finding provides empirical support for the predictions of Phelps's structural slumps theory in an IKE world. That is, firms exposed to international competition that face a positive shock to relative costs will improve productivity rather than increase prices to adjust profits in periods of real appreciation.

Figure 4 shows the cointegrating relationships and despite some signs of persistent deviations, they seem mean-reverting.

Figure 4: Cointegrating relations $\tilde{\boldsymbol{\beta}}' \tilde{\boldsymbol{x}}_t$
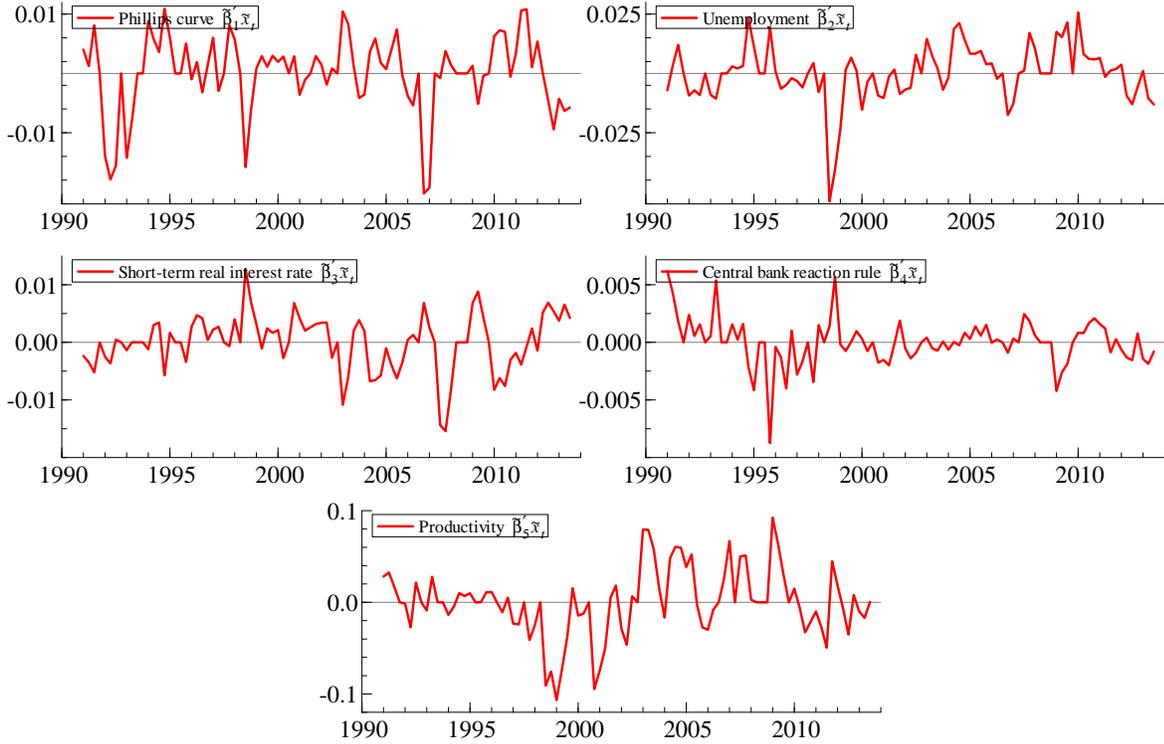
Note 1: The graphs correspond to the cointegrating relationships in model (9) where the effects of the short-run dynamics, $\boldsymbol{\Gamma}_1 \triangle \boldsymbol{x}_t$, have been concentrated out. For further details, see Chapter 7 in Juselius (2006).

5   Policy implications

According to the IKE theory, the long swings observed in the nominal exchange rate around relative prices will be associated with similar swings in the interest rate spread between the domestic and foreign interest rates. Furthermore, the structural slumps theory predicts that the domestic real interest rate may influence the unemployment rate. Then, the latter is likely to be affected by persistent swings in the real exchange rate and by the monetary policy of central banks that impact interest rates.

The main objective of the Central Bank of Chile is "safeguarding the stability of the currency and the normal functioning of the internal and external payment systems" (BCCh 1989, Section III). To achieve its objective, the Central Bank conducts its monetary policy based on inflation targeting in a free-floating exchange rate regime. The main instrument to keep inflation close to its target is the monetary policy interest rate. Changes in the latter are passed to the interbank interest rate through open-market operations, interest-bearing reserves, and discount-window policy. Commercial banks, in turn, pass these fluctuations to lending and/or deposit rates,[12] which

---

[12]Figure 1 shows the co-movement between the monetary policy interest rate and the deposit rates.

changes consumption, savings, and investments, affecting the aggregate demand and, hence, the price level in the economy.

The results in this article indicate that the Central Bank, in pursuing its mandate, may affect not only the unemployment rate but also the natural rate of unemployment. Moreover, the adjustment coefficients show that when the real interest rate is above its long-run equilibrium, it will tend to rise as real interest exhibits an equilibrium error-increasing behavior. Whatever the case, it seems that high and persistent unemployment might be caused by fighting inflation. Thus, Chilean monetary policy must be efficiently combined with other economic policies (e.g., fiscal policy) that stimulate employment in periods in which contractionary monetary policy is at work.

The results also suggest that firms exposed to international competition in a world of imperfect knowledge adjust profits through productivity improvements by laying off the least productive workers. Because Chile has a small and open economy that is fairly and increasingly exposed to international competition, then in periods of real exchange appreciation, policies aimed to reduce unemployment should focus on the tradable sector.

6   Conclusion

In this article, the author has empirically analyzed the dynamic of inflation and unemployment in Chile using a CVAR model. The results indicate that these dynamics may be described by a Phillips curve when allowing for a positive co-movement between trend-adjusted productivity and unemployment rate. That is, unemployment in excess of trend-adjusted productivity would lead to downward pressure on inflation. Moreover, the natural rate of unemployment is time varying and positively associated with the long-term interest rate, suggesting that monetary policy might not be completely neutral over the business cycle.

The results also show that the trend-adjusted productivity is negatively co-moving with the real exchange rate, implying that during periods of real exchange rate appreciation competitiveness is negatively affected. Consequently, firms adjust profits by increasing productivity rather than prices.

Altogether, the empirical analysis provides support for the Phelps's (1994) structural slumps theory in a world of imperfect knowledge. Phelps states that fluctuations in exchange rates and the real interest rate may explain the fluctuations in unemployment rate and that the natural rate of unemployment is a function of the domestic real interest rate in the economy. The imperfect knowledge theory states that pronounce persistence in real exchange rates are associated with a similar persistence in the real interest rate. Therefore, these theories predict that unemployment and labor productivity increase in periods of rising real interest rates and real exchange appreciation.

References

Aghion, P., R. Frydman, J. Stiglitz, and M. Woodford (2003). Edmund S. Phelps and modern macroeconomics. *Knowledge, Information, and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, 3–22.

BCCh (1989). *Ley Orgánica Constitucional del Banco Central de Chile. Ley No. 18.840*. Banco Central de Chile.

Blanchard, O. (2003). Monetary policy and unemployment. In *Remarks at the Conference" Monetary Policy and the Labour Market: A Conference in Honor of James Tobin", New School University*.

Cabrera, A. and L. F. Lagos (2000). *Monetary policy in Chile: A black box?*, Volume 88. Banco Central de Chile.

De Simone, F. N. (2001). Proyección de la inflación en Chile. *Economía Chilena 4*(3), 59–85.

Dennis, J. G. (2006). *CATS in RATS Cointegration Analysis of Times Series. Version 2*. Estima.

Fair, R. C. (2000). Testing the NAIRU model for the United States. *Review of Economics and Statistics 82*(1), 64–71.

Farmer, R. E. (2013). The natural rate hypothesis: An idea past its sell-by date. Technical report, National Bureau of Economic Research.

Fisher, M. E. and J. J. Seater (1993). Long-run neutrality and superneutrality in an ARIMA framework. *The American Economic Review*, 402–415.

Friedman, M. (1968, March). The role of monetary policy. *American Economic Review 58*.

Frydman, R. and M. D. Goldberg (2007). *Imperfect knowledge economics: Exchange rates and risk*. Princeton University Press.

Frydman, R. and M. D. Goldberg (2011). *Beyond mechanical markets: Asset price swings, risk, and the role of the state*. Princeton University Press.

Gomes, F. and C. G. da Silva (2008). Hysteresis vs. natural rate of unemployment in Brazil and Chile. *Applied Economics Letters 15*(1), 53–56.

Hoover, K. D. (2011). *Applied Intermediate Macroeconomics*. Cambridge University Press.

Johansen, S. (1996). *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford University Press.

Juselius, K. (2006). *The cointegrated VAR model: methodology and applications.* Oxford University Press.

Juselius, K. and M. Juselius (2012). Balance sheet recessions and time varying coefficients in a Phillips curve relationship: An application to Finnish data. *Essays in Nonlinear Time series Econometrics.*

Juselius, K. and J. Ordóñez (2009). Balassa-Samuelson and wage, price and unemployment dynamics in the Spanish transition to EMU membership. *Economics: The Open-Access, Open-Assessment E-Journal 3* (2009-4).

Karanassou, M., H. Sala, and D. J. Snower (2005). A reappraisal of the inflation–unemployment tradeoff. *European Journal of Political Economy 21* (1), 1–32.

Karanassou, M., H. Sala, and D. J. Snower (2010). Phillips curves and unemployment dynamics: a critique and a holistic perspective. *Journal of Economic Surveys 24* (1), 1–51.

King, R. G. and M. W. Watson (1994). The post-war US Phillips curve: a revisionist econometric history. In *Carnegie-Rochester Conference Series on Public Policy*, Volume 41, pp. 157–219. Elsevier.

Mankiw, N. G. and L. Ball (2002). The NAIRU in theory and practice. *Journal of Economic Perspectives 16* (Fall).

Phelps, E. S. (1968). Money-wage dynamics and labor-market equilibrium. *The Journal of Political Economy*, 678–711.

Phelps, E. S. (1994). *Structural slumps: The modern equilibrium theory of unemployment, interest, and assets.* Harvard University Press.

Phillips, A. W. (1958). The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861–19571. *Economica 25* (100), 283–299.

Restrepo, J. (2008). Estimaciones de la NAIRU para Chile. *Economía Chilena 11* (2), 31–46.

Samuelson, P. A. and R. M. Solow (1960). Analytical aspects of anti-inflation policy. *The American Economic Review*, 177–194.

Solimano, A. and G. Larraín (2002). From economic miracle to sluggish performance: Employment, unemployment and growth in the Chilean economy. *ILO multidisciplinary Team Santiago de Chile. Santiago de Chile, International Labour Office, mimeo.*

A Data

Table A.1: Data source, description and transformation

Variable	Description	Source	Transformation
$\triangle p_t$	Inflation rate	Own elaboration based on data from Central Bank of Chile	Log difference of the CPI
u_t	Unemployment rate	Own elaboration based on data from Central Bank of Chile and National Statistics Institute of Chile	Ratio of unemployed people to labor force
i_t^L	1-year nominal interest rate for deposits	Own elaboration based on data from Central Bank of Chile	Original series is divided by 400
i_t^S	3-months nominal interest rate for deposits	Own elaboration based on data from Central Bank of Chile	Original series is divided by 400
c_t	Real labor productivity	Own elaboration based on data from Central Bank of Chile and National Statistics Institute of Chile	Log of the ratio between real GDP and employed people
q_t	Real exchange rate	Central Bank of Chile	Log of the real exchange index

Note 1: Labor series are spliced because the Statistics Institute of Chile changed the employment survey in 2010 from Encuesta Nacional de Empleo (ENE) to Nueva Encuesta Nacional de Empleo (NENE).
Note 2: The data set and the CATS file to replicate the results are available upon request.

B Fluctuation test

Figure A.1 shows the eigenvalue fluctuation test for each individual eigenvalue λ_i, $i = 1, 2, 3, 4, 5$ and for the weighted average. The individual fluctuation tests correspond to Tau (Ksi (i)) and the weighted average of them to Tau(Ksi(1)+$\cdots$+Ksi(5)).[13] When the graph is above the unit line, the parameter constancy can be rejected at the 5% level. Based on this critical value, Figure A.1 suggests that there are no signs of parameter-non constancy in the model. This is valid for the full model (9), corresponding to the $X(t)$ graph, and for the concentrated model, represented by $R1(t)$ graph where the short-run effects, $\boldsymbol{\Gamma}_1 \triangle \boldsymbol{x}_t$, have been concentrated out of the full model.

---

[13]For further details, see Chapter 9 in Juselius (2006).

Figure A.1: Eigenvalue fluctuation test
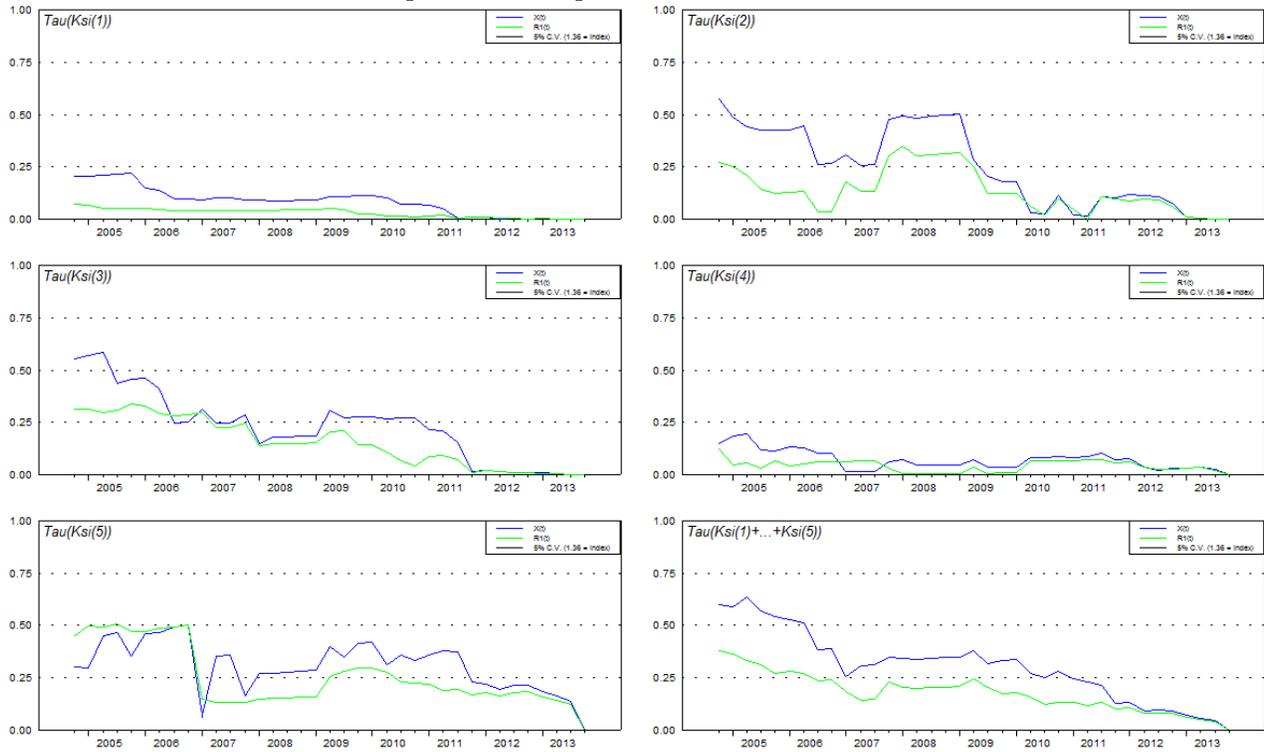
C   Nominal interest rate

Figure A.2: Nominal long-term interest rate