Price and wage inflation in Chile

Carlos José García and Jorge Enrique Restrepo[1]

Abstract

Price and wage equations based on a model of imperfect competition were estimated using data from 1986:1 to 2000:4. From the estimations we can conclude: (i) as expected, productivity reduces unit labour costs and inflation and increases real wages; (ii) the findings of other studies are confirmed in the sense that the output gap and unemployment have a low impact on inflation due to widespread indexation; (iii) inflation imposes substantial costs on firms and workers; (iv) the exchange rate pass-through depends positively on economic activity and the inflation level, explaining why pass-through has been so low in recent years. Since inflation has been stabilised at around 3%, pass-through should be permanently lower than in the 1990s.

The estimation includes the first difference of the dependent variable following the literature on the estimation of linear quadratic adjustment cost (LQAC) models when the target and some of the driving variables follow I(2) processes. Given that it is a markup model, the price index fitted is narrower than the CPI to reflect the fact that these prices are formed where there is monopolistic competition. In order to model wages, we assume that a fraction of wages is negotiated, while the other fraction is adjusted according to past inflation. The nominal wages negotiated are determined following the theory of efficiency wage and bargaining model. The equations are used to generate out-of-sample inflation forecasts closer to actual inflation than before.

1. Overview

This article estimates equations for price and wage inflation using Chilean data from 1986:1 to 2000:4. Several issues crucial for understanding and anticipating the behaviour of inflation - which are at stake in the Phillips curve - motivate such estimation, for instance: (i) elasticity of inflation to the output gap, (ii) the permanent and cyclical movements of markups, (iii) effects of labour productivity growth on inflation, (iv) credibility, indexation and rationality, and (v) the size of the exchange rate pass-through.

Even though we touch on all these subjects in this paper, we take a closer look at the effect of exchange rate changes on domestic inflation because apparently this factor has substantially changed in recent years. Despite the fact that Chile is a small open economy, exchange rate pass-through has been low recently. In fact, there has been significant peso depreciation since 1997 without a strong impact on inflation. Why is this? Is a low pass-through a new permanent characteristic of the Chilean economy? Will the depreciation impact on inflation take place as soon as demand takes off again? The answer to these questions is crucial to defining monetary policy.

In order to tackle at least part of this research agenda, we present below a model of the Phillips curve based on some microfoundations and time series econometrics. Thus, we address these issues by estimating a structural equation for price inflation that considers explicitly a model of staggered nominal price setting by imperfectly competitive firms. In doing this, we use the quadratic price adjustment cost model of Rotemberg (1982), where the representative firm chooses a sequence of prices for solving its intertemporal problem. As a result, inflation can be represented as an error correction equation (Euler equation), relating this variable to expected inflation as well as to the gap between the "equilibrium" and actual price level.

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[1] Senior Economists, Central Bank of Chile.
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In addition, an I(2) analysis of inflation and the markup is undertaken. We find that the price level is best described as an I(2) process. To deal with I(2) processes, we incorporate inflation as an additional component of the "equilibrium" price in the Euler equation (Engsted and Haldrup (1999)). Having this variable in the cointegration equation reflects the existence of a long-run relationship between markups and inflation. In the estimations this relationship is negative, which may be interpreted as the cost to firms of overcoming missing information when adjusting prices in an inflationary environment (Banerjee et al (2001)). Different versions of the price equation are estimated (Gruen et al (1999)) by using a limited-information approach due to McCallum (1976).

Since there is a clear connection between prices and wages, we also estimated a model to explain wage dynamics. The model assumes that a fraction of wages is negotiated every period, while the other fraction is adjusted according to past inflation (Jadresic (1996)). The negotiated nominal wages are determined following the theory of efficiency wage and bargaining model. Thus, expected real wages depend on labour productivity, unemployment and past real wages (Blanchard and Katz (1997)). In order to incorporate the fact that nominal wages are also I(2), we included the inflation rate as a cost for workers when wages are negotiated. Since indexation is never perfect, the higher the inflation level, the lower real average wage each period.

The results show, as expected, that labour productivity reduces unit labour costs and inflation. In addition, a negative relationship between inflation and both markups and real wages indicates that inflation imposes substantial costs on firms and workers, fully justifying the stabilisation programme followed by the Central Bank since 1990. Moreover, the results confirm what was found in other studies in the sense that the output gap and unemployment have a low impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is perfectly adequate in this case.

Finally, since pass-through is related to economic activity and the level of inflation, it should be smaller than in the 1990s given that the level of inflation has been stabilised at around 3%. Taking the estimated price and wage equations simultaneously, the exchange rate pass-through is analysed by simulating an exchange rate shock, with and without output gap. Had not a negative output gap existed after 1997, exchange rate pass-through would have been higher.

This article is organised as follows. The second section shows several stylised facts and introduces some imperfect-competition theoretical frameworks for the Phillips curve and the exchange rate pass-through. The third presents the markup model for prices. The next section has a wage model based on indexation, efficiency wage and bargaining models. The fourth section presents the estimations for the price and wage equations. Finally, there are some conclusions and policy recommendations.

2. Inflation: stylised facts and theoretical considerations

Figure 1 shows that inflation has had a positive correlation with the output gap and foreign inflation (considering the depreciation rate as well). Meanwhile, inflation has a negative correlation with labour productivity growth. The strong relation between price and nominal wage inflation indicates the key role indexation plays in the Chilean economy. In addition, it is important to point out that there is a negative correlation between inflation and the markup.[2] This reveals that, contrary to what we initially expected, in periods of higher inflation it is much harder for firms to increase the markup.

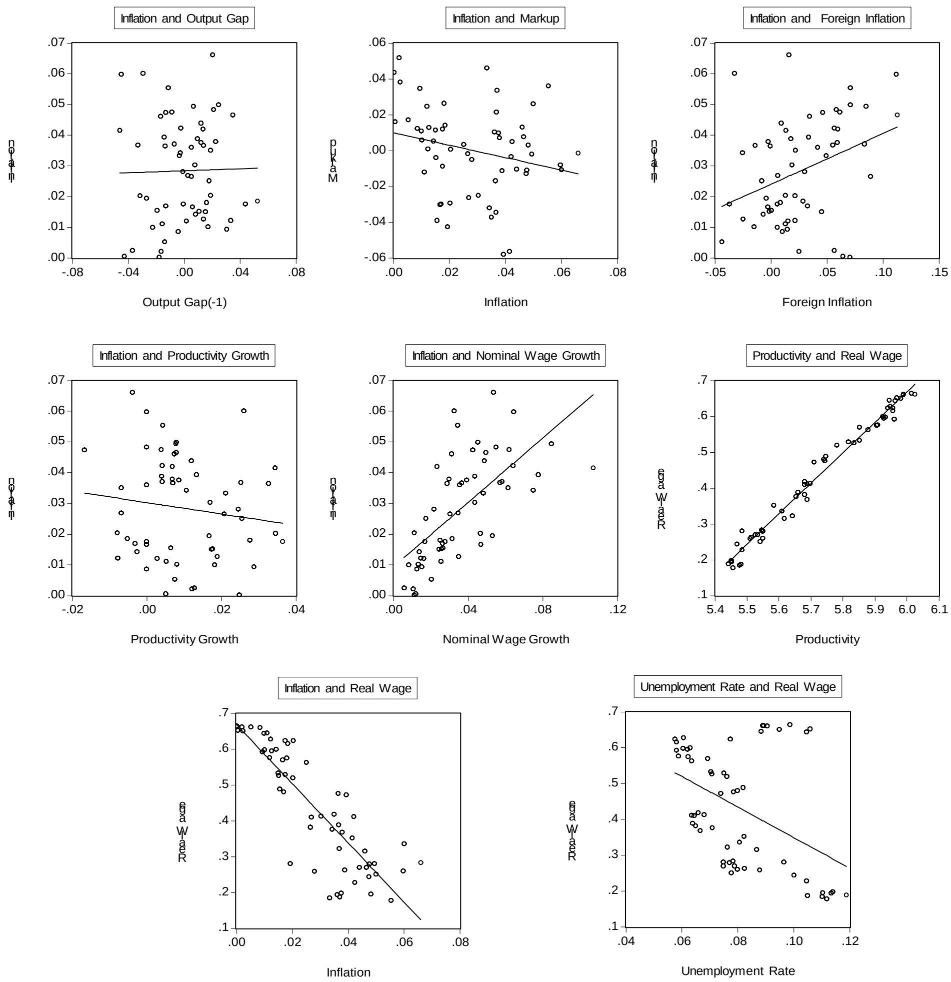
The negative correlation between real wages and inflation also indicates that workers suffer substantial costs from the latter, expressed in lower real wages. Furthermore, both labour productivity and unemployment are important in wage setting. As seen in Figure 1, both variables have a strong correlation with real wages but with different signs.

These graphs seem to indicate that there is a Phillips curve with a small slope while other variables, such as labour productivity and foreign inflation, also play an important role in explaining inflation.

2 Markup is obtained as the error term of the equation $p_t = a_0 + a_1(w_t - q_t) + a_2 p^*{}_t + \varepsilon_t$. p_t is the price level, w_t is the nominal wage and p_t^* is the foreign price (adjusted for the exchange rate, tariffs and taxes).

Figure 1

Inflation in Chile: stylised facts



2.1 Phillips curve

A convenient and widely used setup to describe the behaviour of the short-run trade-off between the change in inflation and output is an expectations-augmented Phillips curve like the one shown in equation 1.

$$\pi_t = \beta_1 * \pi_{t-1} + \beta_2 * E\pi_{t+1} + \beta_3 * \Delta_4 ep^* + \beta_4 * gap + \beta_5 * \Delta mk_t + \beta_6 * R_t + \varepsilon_t \qquad (1)$$

where $E\pi_{t+1}$ = expected inflation, $\Delta_4 ep^*$ = annual imported price inflation, *gap* = output gap, Δmk = mark-up, *R*=raw materials, supply shocks or relative price changes (Romer (1996), Ball and Mankiw (1995)).

Equation 1 is also useful to summarise some of questions, already mentioned above, in which we are interested, since the coefficients are associated for instance with: (i) β_1: inertia and β_2: how forward-looking price formation is; (ii) β_3: the size of the exchange rate pass-through; (iii) β_4: elasticity of inflation to the output gap; (iv) β_5: the effect of markups on inflation; (v) β_6: effects of raw material shocks on inflation.[3]

[3] β_1 and β_2 coefficients are usually restricted to add up to 1.

Similar versions or variations of equation 1 have been estimated for Chile (García et al (2000)). Nonetheless, it is useful to pursue further research on Phillips curves since, first, there is uncertainty about the β parameters, second, they do not have a structural interpretation and, finally, some of those equations have consistently overpredicted Chilean inflation during the recent past.

We will follow a different approach: instead of estimating a reduced-form relation between the change in inflation and the unemployment rate, we will estimate separate price and wage equations based on a model of imperfectly competitive firms in error correction form. Thus, the error correction in the price equation ensures that in the steady state the price level is a markup on unit labour costs.

Besides the issues cited above, estimating price and wage equations will also allow us to say something about the relationship between labour productivity and inflation, and the effects inflation has on markups and wages. The non-competitive setting is also appropriate to analyse the low exchange rate passthrough experienced in recent years. Obtaining the right size of this coefficient is instrumental in implementing an appropriate monetary policy. In the next section, we introduce the non-competitive theoretical framework by relating the exchange rate pass-through to markups and imperfect competition.

2.2 Pass-through from depreciation to inflation

i. Theory

Although the exchange rate directly affects the peso price of imported goods, this movement is not necessarily transferred to the end consumer immediately. When this transfer occurs and to what degree depends on several factors, some of which are described below.

As said above, the impact of changes in the exchange rate on domestic inflation is known as the "pass-through coefficient". The direct short-term effect of the exchange rate on inflation is related to the imported part of the basket of goods that make up the CPI. The larger the share of imported goods within the CPI basket, the greater the exchange rate effect on prices. In Chile, about 48% of CPI goods are considered importable. The exchange rate also directly affects the cost structure of companies using imported inputs. Thus, the greater the proportion of imported inputs making up the costs, the more depreciation will affect these companies' prices. In a regime based on inflation targets, pass-through ultimately depends on monetary policy and agents' expectations. Although in the short-term inflation may rise due to depreciation, in the medium- and long-term inflation should fall back to the target level or range defined by the central bank.

The behaviour of demand determines whether or not companies can transfer to final prices any changes in their costs resulting from fluctuations in the exchange rate. For example, if the economy is in the midst of a recession, companies will find it difficult to pass on higher costs due to depreciation. Furthermore, movements in the exchange rate can influence both the level of aggregate demand and wages as well as the composition of demand. For instance, a depreciation in the exchange rate that tends to produce a contraction in aggregate demand could also end up reducing prices by an amount equivalent to the upward pressures generated by the same depreciation.

Currency devaluation brings with it a change in relative prices. Assuming that income is constant, when the prices of imported goods rise, consumers' real income falls. If demand for these imported goods is inelastic, the purchase of other goods and services will have to fall and, as a result, so will the prices of the latter, assuming that prices are perfectly flexible. However, prices are often rigid due to market imperfections. In this case, faced with currency depreciation, CPI inflation will rise. This is why many pass-through analyses are based on aspects related to industrial organisation (Dornbusch (1987)). This analysis emphasises, for example, the degree of import penetration, market structure in terms of greater or lesser concentration, and the differentiation and degree of substitution between domestic and imported products.

A greater concentration in a productive sector increases the producing company's control over price and therefore over profit margins (markups). The same occurs if there is a small degree of substitution between the domestic and imported products. This degree of control over the price could vary with the cycle (Small (1997)). In these situations, producers evaluate the costs of modifying their prices and when these are higher than the benefits, they accept transitory fluctuations in their profit margins, causing prices to react less to shifts in the exchange rate.

As a result, in the presence of imperfect competition, aggregate demand movements, combined with fluctuations in the exchange rate, affect importers' markups. More volatile aggregate demand would be associated with a reduced pass-through of exchange rate fluctuations to final prices. In this case, importers will be less willing to raise their prices for fear of losing market share.

The entry of new firms could have an impact similar to a demand reduction. For instance, during the 1990s the retailing sector in Chile went through a restructuring process. Huge superstores and supermarkets distributing a wide variety of products proliferated. These megastores are usually able to reduce costs because of their ability to negotiate with suppliers. At the same time they fight for their market share by holding sales and introducing different marketing strategies. Sometimes these sales imply markup reduction, particularly when demand is weak.

The volatility of the exchange rate is another factor influencing transfers affecting domestic inflation. The more volatile the exchange rate, the less its impact on domestic prices should be, because importers will be more cautious when it comes to changing prices, especially when the costs of an adjustment are high. As a result, expectations about the duration of a currency depreciation affect the speed and size of pass-through of a higher exchange rate to prices.

The level of inflation also affects the pass-through coefficient. In general, the magnitude of the transfer should decrease as the annual inflation rate declines. In a low-inflation economy, the price change of a good is more easily perceived as a modification of relative prices, which has more impact on demand for the good and its market share. Thus, the cost of increasing prices could be high for a company if its market share plays a decisive role in its margins and total profits (Taylor (2000)).

International evidence indicates that the pass-through from the exchange rate to prices is lower in developed countries than in Latin America and Asia.[4] In one panel estimate with 71 countries, Goldfajn and Werlang (2000) found a depreciation-to-inflation pass-through coefficient of 0.73 at the end of 12 months. When the sample was divided into OECD members and emerging economies, at the end of 12 months pass-through coefficients of 0.6 and 0.91 respectively were observed. When this sample was sorted by region, the 18-month coefficient for Europe was 0.46, while in America it was 1.24. Finally, as a result of an exercise based on their estimates, the authors found a bias towards predicting higher inflation than that actually observed in several well known cases of large depreciation.

ii. Rolling correlation

The simplest exercise one can perform is to compute the correlation between inflation and exchange rate depreciation. In this case, two rolling correlation statistics were computed (Figure 2). The first (black line) has its start date fixed (1986:1) and the correlation coefficient is calculated each time a new observation is added, starting in 1990. Therefore, each computation has a larger sample than the last. Even though this coefficient is rather stable, it has some movement. It decreases at the beginning of the 1990s, grows again from 1994 to 1996 and has steadily fallen since 1998.

The second statistic in Figure 2 (grey line) has a fully moving sample. Thus, both the start and end dates move each time the correlation coefficient is computed. In this case, the statistics fluctuate much more. This coefficient moves closely in line with the first coefficient up to 1996. Thereafter, it falls dramatically to even become negative, showing an important change in the relationship between these two variables.

It is worth pointing out that such a simple exercise shows that decision-making based exclusively on the pass-through coefficient used in the small structural model, or based on the first correlation statistics computed, could lead to policy mistakes. One could easily overestimate forecast inflation, missing the significant change that took place from 1997 to 1999 in the relationship between inflation and currency depreciation.

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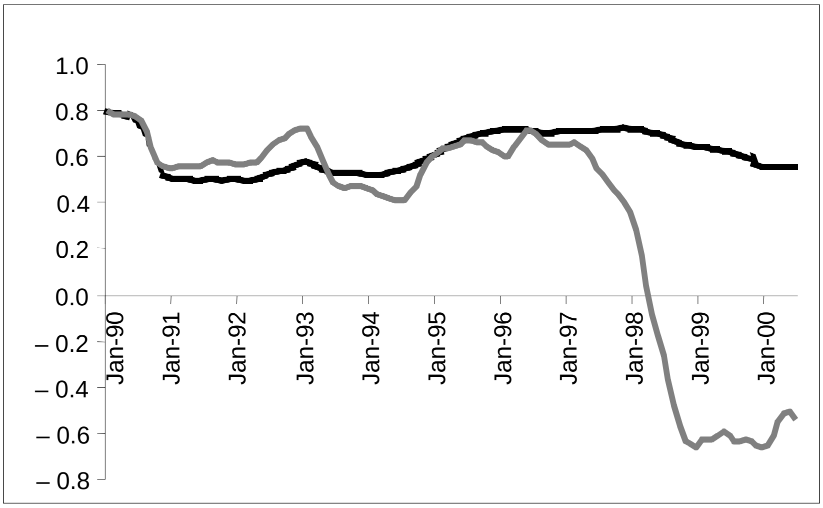
[4] A great many articles have been written on pass-through over the years. Most of them try to estimate the extent to which exchange rate fluctuations are responsible for the behaviour of inflation. Some use CPI inflation, others producer price inflation. There is also a wide range of estimation techniques used to obtain a quantitative result, ranging from ordinary least squares (Woo (1984)), to panel data (Goldfajn and Werlang (2000)), vector auto regression (McCarthy (1999)), cointegration analysis and error correction models (Beaumont et al (1994), Kim (1998), Kim (1990)), and state-space models (Kim (1990)).

Figure 2

Rolling correlation coefficient between annual inflation and depreciation

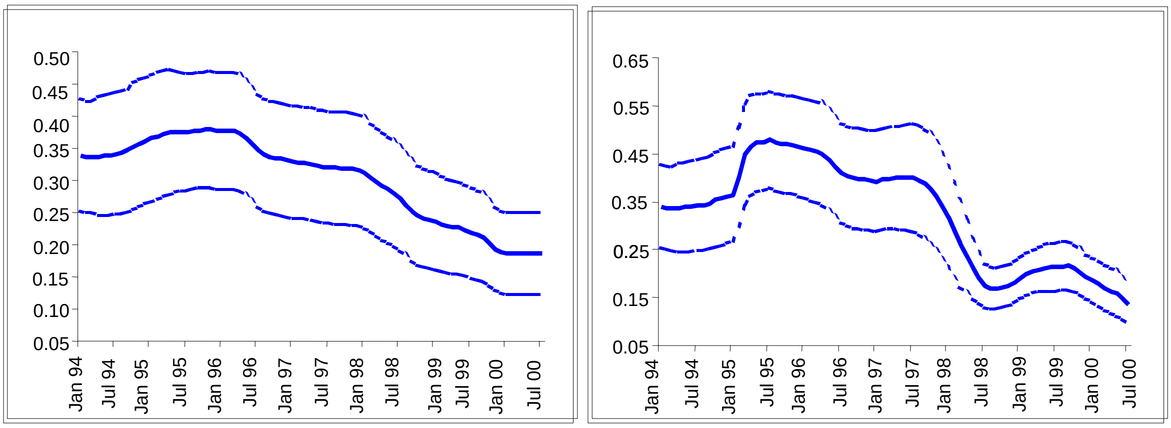


iii. Rolling regression and pass-through in a small model

A rolling regression was estimated for annual inflation with exchange rate depreciation and a trend as right-hand variables using monthly data between 1986 and 2000 (Figure 3).[5] Again, the two types of rolling samples were used. The left-hand panel in Figure 3 shows the regression coefficient obtained when the initial date of the sample does not change. Conversely, the sample used to estimate the right-hand panel in Figure 3 has both the initial and the last date moving. The left-hand panel of Figure 3 shows that the coefficient's fall started earlier in 1996. As one would expect, the coefficient is less stable with both dates moving.[6]

Figure 3

Rolling regression



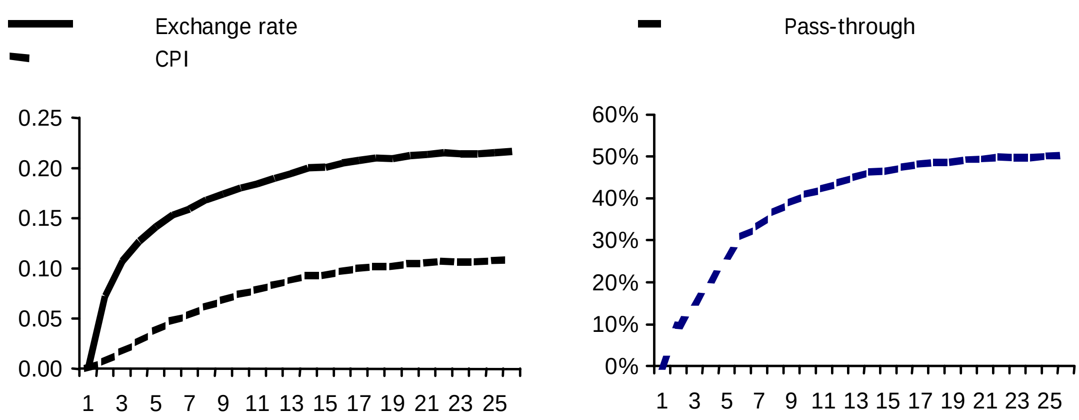
5 Annual CPI inflation was found to be trend-stationary using monthly data.

6 In fact, it matches some stylised facts of the economy during the last decade. It is well known that there was a consumption boom between 1995 and 1997, which coincides with a rebound of this coefficient.

Missing variables such as the output gap may cause the instability problem. We also simulated a (five-equation) small structural model, similar to the one in García et al (2000). The impact of the exchange rate on inflation is controlled by the output gap. The pass-through obtained with this simulation amounts to 50% over five to six years (Figure 4), meaning that the period over which the full impact of a depreciation is felt is rather long. However, Figure 4 shows that after the first three years most of the effect has already taken place. It is important to point out that this model includes a monetary rule consistent with the behaviour of a central bank in an inflation targeting regime. Therefore, it explains why pass-through is never complete in Figure 4.[7]

Figure 4

Pass-through in a small model



3. A price setting model

3.1 Optimal price in the long run

In this section, we derive a Phillips curve from the quadratic price adjustment cost model developed by Rotemberg (1982). Thus, firms weigh the cost of changing prices against the cost of being away from the price the firm would choose if there were no adjustment cost (Roberts (1995)). The latter price is called the "optimal price" and is determined following Beaumont et al (1994) and Layard et al (1991). The firms are identical and obtain an output *y* by using labour *l* and an imported input *z*:

$$y_i = a_1 + a_2\, l_i + (1 - a_2) z_i \qquad (2)$$

Each firm's demand is $y_d - f$, where f is the log of the number of identical firms. The demand curve faced by each firm would be:

$$y_{di} = -\eta\left(\tilde{p}_i - p\right) + y_d - f \qquad (3)$$

where p_i is the firm's price, *p* is the price level and η is the elasticity of demand. Therefore, the price that maximises benefits in the long run is given by:

$$\tilde{p}_{di} = -\log\left[\frac{n}{n-1}\right] + MC = m + MC = m + a_1 + a_2 w_t + (1 - a_2)\, p_t^{*} \qquad (4)$$

[7] Pass-through never reaches 100% because no traded good has a major share of all inputs and consumer goods.

where the price p_{di} is fixed by charging a margin m over the marginal cost MC.[8] A pricing model based on a markup over costs is inappropriate when applied to markets close to perfect competition like the ones for agricultural products (Woo (1984)). Since the price index to be explained should be the one reflecting monopolistic markets, core or underlying inflation, IPCX2, is used here.[9]

We now examine the margin. It is assumed that in the long term firms desire a constant markup, m. However, in the short run firms could postpone price adjustments and accept deviations of their markup from the desired level. In doing so, firms could be motivated by both market share and the actual cost of changing prices, or menu cost (Ghosh and Wolf (2001)). Therefore, demand fluctuations and anything affecting market power could have an impact on the markup (Barnerjee et al (2001)). On the other hand, margins and inflation may also be either positively or negatively related because there are two opposite effects. First, one would expect this coefficient to be positive since, as noted above, it is harder for employers to pass on cost increases to customers in a low-inflation environment (Taylor (2000)). In Taylor's words, "firms in low inflation economies will appear to have less pricing power than firms in high inflation economies". Second, one would also expect that inflation imposes costs on firms and therefore the markup net of inflation is reduced (Banerjee et al (2001)). We rely on the econometric estimation to determine its sign, ie which effect is greater.

We follow Banerjee et al (2001), Benabou (1992), Russell et al (1997) and others arguing that high inflation, which usually leads to higher volatility and uncertainty, is associated with lower markups. Therefore, we write the markup equation as a function of labour productivity, the output gap and inflation:

$$m = c_1 + c_2 q_t + c_3\left(y_t - \bar{y}_t\right) + c_4 \Delta p_t \quad (5)$$

Following Beaumont et al (1994) and Banerjee et al (2001), one can approximate equation 4 by this expression:

$$\tilde{p}_{di} = (a_1 + c_1) + a_2(w_t - q_t) + (1 - a_2)p_t^* + c_3\left(y_t - \bar{y}_t\right) + c_4 \Delta p_t \quad (6)$$

Where p* is equal to foreign input prices adjusted by the nominal exchange rate and taxes and w_t–q_t is wages minus labour productivity (unit labour cost). Here we are imposing $a_2 = -c_2$, which implies that income shares are independent of the level of productivity in the long run. We drop the output gap from the long-run price equation (6) on the basis that it is a stationary variable with a zero steady state level. In the short run (12), markup depends on economic activity. However, economic theory is not conclusive regarding this issue and it could be either pro- or countercyclical. Therefore, this question should be solved empirically.[10]

3.2 Optimal price in the short run

The structural equation for inflation is in the spirit of the new Phillips curve literature. It is derived explicitly from a setting of imperfectly competitive firms where nominal prices are rigid. In doing this, we propose a (Rotemberg (1982)) LQAC model of the representative firm, which minimises the loss of charging for its product a different price from the optimal one weighted against the cost of changing its price. This intertemporal problem is solved by choosing a sequence of *pt*, the decision variable, such that:

$$\min_{\{p_{t+i}\}} E_t \sum_{i=0}^{\infty} \beta^i \left[\theta\left(p_{t+i} - \tilde{p}_{t+i}\right)^2 + \left(p_{t+i} - p_{t+i-1}\right)^2\right] \quad (7)$$

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8 Note also that w_t can be separated into private (wpr_t) and public wages (wpu_t).

9 IPCX excludes perishable food as well as gas, fuels and regulated services. Throughout the article, we also call it core inflation.

10 The theory about the relationship between margins and the cycle is ambiguous. Some models predict procyclical margins (Kreps and Scheinkman (1983)). Others predict that they are countercyclical (Rotemberg and Saloner (1986), Rotemberg and Woodford (1991)).

where E_t is the expectations operator conditional on the full public information set, β is the subjective discount rate, θ is the relative cost parameter and $\tilde{p}_t$ denotes the optimal price of p_t. After rearrangement, the Euler equation from the minimisation problem can be written as:

$$\Delta p_{t+i} = \beta \Delta p^e_{t+i+1} - \theta\left[p_{t+i} - \tilde{p}_{t+i}\right] \tag{8}$$

Where Δp^e_{t+i+1} denotes expected inflation. One could think of it as an error correction equation relating the rate of inflation to the gap between the equilibrium and actual price levels. In order for this to be a useful theory of inflation, the optimal price level needs to be defined as in (6).

The second step is to reparameterise equation (8) to carry out the I(2) analysis. Following Haldrup (1995), the optimal price can be parameterised as:

$$\tilde{p}_t = \gamma_1 x_{1,t-1} + \gamma_1 \Delta x_{1,t} + \gamma_2 x_{2,t-1} + \gamma_2 \Delta x_{t-1} + \gamma_2 \Delta\, x_{2,t-1} + \gamma_2 \Delta^2 x_{2,t}$$

where x_1 denotes the I(1) variables $\{q_t, \Delta p_t\}$ while x_2 are the I(2) ones $\{w_t\}$.

Therefore we transform the optimal price:

$$\tilde{p}_t = (1-a_2)p^*_{t-1} + a_2(w_{t-1} - q_{t-1}) + c_4\Delta p_{t-1} + a_2\Delta\, w_{t-1} + (1-a_2)\Delta p^*_t + a_2(\Delta^2 w_t - \Delta q_t) + c_4\Delta^2 p_t$$

Now we transform $\theta\left[p_t - \tilde{p}_t\right]$ to obtain the cointegration error correction term.

In order to do this, we add and subtract Δp_{t-1}, and we also use two identities $p_t \equiv p_{t-1} + \Delta p_t$ and $\Delta p_{t-1} \equiv \phi\Delta p_{t-1} + (1-\phi)\Delta p_{t-1}$ where $\phi = \dfrac{\beta}{1+\theta}$. Thus, equation (8) can be written in acceleration form:

$$\begin{aligned}\Delta^2 p_t &= k_1(\Delta p_{t+1} - \Delta p_{t-1}) + k_2(1-a_2)\Delta p^*_t + k_2 a_2(\Delta^2 w_t - \Delta q_t) + \psi\left(y_{t-1} - \bar{y}_{t-1}\right) \\ &- k_2\left(p_{t-1} - \left[(1-a_2)p^*_{t-1} + a_2(w_{t-1} - q_{t-1}) + a_2\Delta w_{t-1} + \left(c_4 + \frac{(1-\phi)(1+\theta)}{\theta}\right)\Delta p_{t-1}\right]\right) + \varepsilon_t\end{aligned} \tag{12}$$

Where $k_1 = \dfrac{\beta}{1+\theta(1-c_4)}$ and $k_2 = \dfrac{\theta}{1+\theta(1-c_4)}$

Even though the model is overidentified and we need to impose some restrictions to identify all parameters, the parameters β, γ_{12} and θ can be obtained from the same number of equations:

$$\hat{k}_1 = \frac{\beta}{1+\theta(1-c_4)}, \quad \hat{k}_2 = \frac{\theta}{1+\theta(1-c_4)}, \quad \hat{k}_3 = \hat{k}_2 * \left(c_4 + \frac{(1-\phi)(1+\theta)}{\theta}\right) \tag{13}$$

Where k_1, k_2 and k_3 are parameters obtained from the unrestricted estimations.

Equation (12) is what we refer to as the price equation. This equation relates inflation to expected inflation, wage growth, the output gap and average cost. In addition, there is an error correction term which ensures that in steady state the price level is set by adding a markup on the unit labour cost and imported-input prices. If one wants to obtain the expectations-augmented reduced-form Phillips curve, one should substitute $\Delta^2 w_t$ for a wage curve (Blanchard and Katz (1997) and Gruen et al (1999)).

Finally, it is important to note that expected inflation matters because prices are sticky. What happens with prices next period affects current prices. Note that expectations can be rational or adaptive. When expectations are rational, we will have a price curve similar to the New Phillips curve proposed by Galí (2000) and Roberts (1995). The inflation rate can jump. However, usually inflation shows a great amount of inertia.[11] This distinction is crucial when designing a successful stabilisation programme.

[11] In Chile, inflation is highly persistent to the extent that it is best described as being an I(1) process.

For example, in the case of sticky inflation a more gradual stabilisation programme is called for, in order to reduce the risk of causing a sharp fall in the rate of output growth.

3.3 Private wage equation

We have assumed that indexation is complete and there is uniform staggering in order to study wage behaviour. This implies that a proportion α of the wages is negotiated, while (1-α-δ) are adjusted according to past inflation (Jadresic (1996)). The remainders, δ, cannot adjust their wages with past inflation and suffer a loss with it.

$$\Delta wpr_t = (1-\alpha-\delta)\Delta p_{t-1} + \alpha\Delta x_t \tag{14}$$

The negotiated wages are set as in Blanchard and Katz (2001):

$$x_t - p^e_{t+1} = \mu b_t + (1-\mu)q_t - \beta u_t + \varepsilon_t \tag{15}$$

The expected real wage depends on the reservation wage b_t, labour productivity q_t and the unemployment rate u_t, where $0 \leq \mu \leq 1$. The reservation wage is related to non-labour income. However, Blanchard and Katz (2001) argue that labour productivity increases "in the informal and home production sectors are closely related to those in the formal market economy". Therefore, the reservation wage depends on past real wage and labour productivity.

$$b_t = a + \sigma(wpr_{t-1} - p_{t-1}) + (1-\sigma)q_t \tag{16}$$

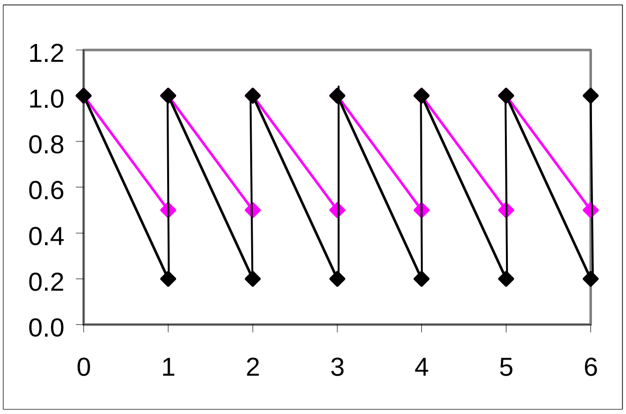
Substituting equation (16) into (15) and performing some algebra, we obtain equation (17):

$$\Delta x_t = \left[p^e_{t+1} - p_{t-1} \right] + \mu a - (1-\sigma\mu)(wpr_{t-1} - p_{t-1} - q_{t-1}) + (1-\sigma\mu)\Delta q_t - \beta u_t \tag{17}$$

where p_t is the consumer price level, which includes all goods,[12] and q_t is labour productivity.

Figure 5

Average real wage and inflation



By substituting equation (17) into equation (14) and performing a reparameterisation yields the aggregate wage acceleration:

$$\Delta^2 wpr_t = \alpha \left[\Delta p^e_{t+1} - \Delta p_{t-1}\right] + (\Delta p_{t-1} - \Delta wpr_{t-1}) + \alpha\mu a - \alpha(1-\sigma\mu)(wpr_{t-1} - p_{t-1} - q_{t-1}) + \alpha(1-\sigma\mu)\Delta q_t - \alpha\beta u_t - \delta\Delta p_{t-1} + D_t + Z_t + \varepsilon_t \tag{18}$$

[12] Indexation is based on CPI.

where α, μ, λ and δ are all greater than zero. D_t represents variables such as seasonal dummies. Variables such as minimum wages and public wages are included in Z_t. Thus, in the absence of an adjustment cost, an increase in either the price level or labour productivity will cause an increase in the desired nominal wage. We have also incorporated the rate of inflation to consider the negative effect this variable has on real wages. Since indexation is never perfect, the higher the inflation level, the lower average real wage each period. This loss is equal to $\delta\Delta p$ (Figure 6).

Some parameters of interest can be obtained from this specification. For instance, the impact of unemployment on wage acceleration for workers who are changing their wage contracts can be calculated as $\alpha\beta$.

4. Results

We present here the estimation results. Instead of applying the two-step method proposed by Engle and Granger (1987) and Haldrup (1995), we estimated the long-run relationship together with the dynamics, as in equation 12, following Harris (1995).[13] As this author puts it, when estimating a long-run equation, superconsistency ensures that it is asymptotically valid to omit the stationary I(0) terms, however the long-run relationship estimates will be biased in finite samples (see also Phillips (1986)). Therefore, Harris cites Inder (1993) to conclude that in the case of finite samples, "the unrestricted dynamic model gives ... precise estimates (of long-run parameters) and valid t-statistics, even in the presence of endogenous explanatory variables". At the same time, it is also possible to test the null hypothesis of no cointegration.

In addition, an I(2) analysis of inflation and the markup is performed as in Haldrup (1995). We find that the levels of prices and unit labour costs are best described as I(2) processes.

4.1 Unit roots and cointegration

We begin the empirical section by testing the estimation variables for unit roots. Table 1 indicates that price level and wage are I(2). This confirms that the price equation can be estimated in acceleration form. In general, one can say that Chilean inflation deviates from any given mean in the period considered here. Moreover, Chilean inflation has traditionally been very persistent due to generalised indexation. In addition, variables such as the output gap and the nominal exchange rate are I(0) and I(1) respectively.

In order to test for cointegration, Phillips-Perron and Dickey-Fuller tests were applied to the residuals obtained in the regression: $p_t = c + \beta_1 w_t + \beta_2 q_t + \beta_3 p^*_t + \beta_4 \Delta p_t + \varepsilon_t$. The unit root is rejected at standard critical values.

However, when using I(2) variables the appropriate critical values are tabulated in Haldrup (1994). In this case, the Phillips-Perron statistic is high enough to reject the null hypothesis. On the other hand, the Dickey-Fuller statistic roughly matches the 10% Haldrup critical value (Table 2). We consider that with these results it is possible to reject the null of no cointegration, especially when the Z test is considered.

[13] Cf pp 60-61. See also Phillips and Loretan (1991) for a comparison of several one-step (uniequational) cointegration methods used to estimate long-run economic equilibria.

Table 1
Unit root test

Variables	Level	First differences[1]	Second differences[2]
Price	– 0.02	– 0.68[3]	– 2.92
Wage	1.13	– 2.68	– 8.56
Labour productivity	– 2.38	– 7.80	– 12.72
Nominal exchange rate	– 2.16	– 6.13	– 10.18
Foreign price	– 1.59	– 4.07	– 9.02
Output gap	– 4.26	– 5.40	– 9.87
Private unit labour cost	– 0.22	– 2.40	– 4.60
Public wage	0.72	– 1.00	– 7.00
Unemployment rate	– 2.41	– 2.22	– 3.55
1% Critical value[4]	– 3.56	– 3.56	– 2.61
5% Critical value	– 2.92	– 2.92	– 1.95
10% Critical value	– 2.60	– 2.60	– 1.65

[1] Test includes a constant. [2] Neither a constant nor a trend is included. [3] We also tested inflation including a constant and a trend. In this case, the statistic (– 2.7) does not allow us to reject the unit root hypothesis either. [4] MacKinnon critical value for rejection of a unit root hypothesis.

Table 2
Cointegration test for prices[1,2]

Test	Value	Critical value	5%	10%
Phillips-Perron	– 5.90	PP	– 2.60	– 1.95
		Haldrup	– 4.30	– 3.90
ADF	– 4.20	ADF	– 2.60	– 1.95
		Haldrup	– 4.30	– 3.90

[1] The equation for obtaining the error term was the following: $p_t = c + \beta_1 w_t + \beta_2 q_t + \beta_3 p*_t + \beta_4 \Delta p_t + \varepsilon_t$. [2] Each test was estimated with four lags. Serial correlation LM and ARCH tests do not indicate autocorrelation or heteroskedasticity.

4.2 Price equation

As stated in equation (12), price acceleration was run on wages, productivity, the output gap, lagged prices, foreign prices and several difference terms.[14] We have estimated two versions of equation (12).

- Model 1

  In this estimation, we imposed $\beta_6 = -\beta_7$, which implies that we can introduce unit labour costs instead of private wages and labour productivity. Cost homogeneity (the various costs add up to prices) was also imposed: $-\beta_4 = \beta_5 + \beta_6 + \beta_7 + \beta_8 + \beta_9$.

  $$\Delta^2 p_t = \beta_1 + \beta_2 (\Delta p^e_{t+1} - \Delta p_{t-1}) + \beta_3 (y_{t-1} - \bar{y}_{t-1}) + \beta_4 p_{t-1} + \beta_5 (wpr_{t-1} - q_{t-1}) + \beta_6 (wpu_{t-1} + taxes) + (-\beta_4 - \beta_5 - \beta_6) p^*_{t-1} + \beta_7 \Delta p_{t-1} + \beta_8 \Delta^2 w_{t-1} + \beta_9 \Delta q_t + \beta_{12} \Delta e_{t-1} + \beta_{10} \Delta e_{t-3}$$

  where *wpr* denotes private wages and *wpu* corresponds to public wages.

[14] Even though the oil price was included in these regressions to take into account short-run shocks to the system, it was not significant. Therefore we dropped it.

- Model 2

  Model 2 includes exchange rate terms multiplied by inflation, besides also having the unit labour cost restriction.

$$\Delta^2 p_t=\beta_1 + \beta_2 (\Delta p^e_{t+1}-\Delta p_{t-1})+\beta_3 \frac{1}{2}\left[(y_{t-1}-\bar{y}_{t-1})+(y_{t-2}-\bar{y}_{t-2})\right]+\beta_4 p_{t-1}+\beta_5 (wpr_{t-1}-q_{t-1})+\beta_6 wpu_{t-1}+ [\beta_7+\beta_8 (p_{t-1}- p_{t-4})/4)]\, p^*_{t-1}+ \beta_9\Delta p_{t-1}+\beta_{10} \Delta^2 wpr_{t-1}+\beta_{11} \Delta^2 wpu_{t-1}+\beta_{12}\Delta q_t +\beta_{13}\Delta e_t + \beta_{14}\Delta p_t\Delta e_t + \beta_{15}D883 + \beta_{16}D911$$

where $p^* = e + pext + taxes$

The results are presented in Table 3.

Table 3

Price equation (dependent variable: $\Delta^2 p_t$)

Sample 1987.4 2000.4

Variables[1]	**Model 1**	**Variables**	**Model 2**
Const	0.57 (2.80)	*Const*	0.58 (3.30)
$\Delta pe_{t+1}-\Delta p_{t-1}$[2]	0.34 (2.30)	$\Delta p^e_{t+1}-\Delta pt-1$[2]	0.19 (2.00)
$(y_{t-1}-\bar{y}_{t-1})$	0.08 (3.40)	$(y_{t-1}-\bar{y}_{t-1})$	0.08 (2.60)
p_{t-1}	– 0.23 (– 5.20)	p_{t-1}	– 0.25 (– 10.00)
$wpr_{t-1}-q_{t-1}$	0.15 (4.70)	$wpr_{t-1}-q_{t-1}$	0.13 (6.20)
wpu_{t-1}	0.05 (3.40)	wpu_{t-1}	0.08 (8.30)
p^*_{t-1}	0.23 – 0.15 – 0.05 = 0.03	p^*_{t-1}	0.02 (1.70)
Δp_{t-1}	– 0.30 (– 1.80)	$p^*_{t-1}*(p_t-p_{t-4})/4$	0.05 (3.60)
$\Delta^2 w_{t-1}$	0.17 (3.90)	Δp_{t-1}	– 0.61 (– 4.70)
Δq_t	– 0.23 (– 3.20)	$\Delta^2 wpr_{t-1}$	0.15 (4.30)
Δe_t	0.04 (1.70)	$\Delta^2 wpu_{t-1}$	0.02 (1.80)
Δe_{t-3}	0.04 (2.30)	Δq_t	– 0.11 (– 2.10)
		Δe_t	– 0.05 (– 3.10)
		$\Delta e_t \bullet \Delta p_t$	3.10 (3.50)
		D883	– 0.012 (– 8.70)
		D911	– 0.009 (– 4.70)

Table 3 (cont)			
Variables[1]	**Model 1**	**Variables**	**Model 2**
R^2	0.70		0.87
DW	2.06		2.34
ARCH(4)[3]	0.60 (66%)		1.20 (32%)
LM(4)[3]	0.80 (52%)		4.90 (0%)
Jarque Bera[3]	5.40 (6%)		0.40 (82%)
β	1.20		
θ	0.80		
c_4	– 2.04		
assuming $\beta = 1$			
c_4	[– 2.40, – 1.80]		
θ	[0.7,1]		

[1] *pt* is core inflation and each variable is in logs. [2] Δpe_{t+1} is estimated by instrumental variables. We use contemporaneous values and three lags of domestic inflation, external inflation, rate of depreciation, wage growth, labour productivity growth, output gap, and the rate of growth of oil price. We also include seasonal dummies. [3] Probabilities are reported in brackets.

Table 3 shows the estimation of equation (12).[15] The various diagnostic residual tests indicate that the models have the desired properties for OLS estimation.[16] Multivariate tests are satisfactory, as can be seen from the lower part of the table. In general, the econometric fit is satisfactory with high R-squareds and highly significant variables. Moreover, the results presented in Table 3 provide evidence of the existence of I(2) data trends and cointegration because Δp_{t-1}1 is significant and the error terms are stationary.

We tested the two restrictions of Model 1 using an unrestricted version of it. First, we tested the hypothesis of the coefficient for private wages being equal to that for labour productivity, though of opposite sign. If this is the case, we can include unit labour cost (*w*-*q*) as a variable in the model. As shown in Table 4, the Wald test indicates that we fail to reject the null hypothesis at a 89% of significance. Second, we tested in Model 1 the hypothesis of cost homogeneity, or that the various costs add up to prices. We also fail to reject this null hypothesis at a 35% level of significance (Table 4). As a result, we imposed both restrictions in Model 1. The third estimated model, which generates the best out-of-sample inflation forecast, includes only the unit labour cost restriction. This model is also different in the sense that it has two dummy variables and the exchange rate terms are multiplied by the rate of inflation: $\beta_8 \bullet \Delta p_t \bullet p^*_{t-1}$ $\beta_{14} \bullet \Delta e_t \bullet \Delta p_t$. The out-of-sample forecast of this model is better as can be seen in the second row of Figure 6.

A major outcome of these econometric estimations is that the parameters have the expected signs and the restrictions of the model hold. The coefficient for the output gap (y_{t-1}-$\bar{y}_{t-1}$) is positive but small, indicating that a 10% output gap will accelerate the inflation rate by 0.8%. Thus, these results confirm what was found in other studies in the sense that the output gap and unemployment have a small impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is perfectly appropriate in this case.

[15] Instead of using the contemporaneous acceleration of nominal wages, we included its first lag because the former was not significant and had the wrong sign.

[16] However, the second model may have some autocorrelation. Standard errors were obtained with the Newey-West heteroskedasticity and autocorrelation consistent procedure.

Table 4

Restriction tests

Wald test hypothesis	Model 1
Unit labour cost	89%
Linear homogeneity	35%

The results also show, as expected, that labour productivity reduces unit labour costs and inflation. In addition, a negative relationship between inflation and both markups and real wages indicates that inflation imposes substantial costs on firms and workers, fully justifying the stabilisation programme put in place by the central bank since 1990.[17] On the other hand, expected inflation acceleration Δpe_{t+1}-Δp_{t-1} is significant, confirming that expectations matter in determining inflation.

The parameters β, c12 and θ can be obtained from equation (13). This implies that the long-run relationship between markup and inflation is negative, ie, c12 is around (– 2). On the other hand, θ is 0.8. This parameter is the weight firms place on costs associated with deviations from the optimal price. Notice that inflation imposes a high cost on firms: a 1 percentage point increase in annual steady state inflation (0.25) reduces markups on average by 0.5% (0.25*2).[18]

In order to compare the models, we estimated them up to 1997:4 and generated out-of-sample inflation forecasts (Figure 6). We find that the restrictions imposed on Model 2 reduce the error when compared to a fully unrestricted estimation (first row in Figure 6). On the other hand, the second model is better at forecasting inflation. This confirms that pass-through is positively related to inflation and, at the same time, that inflation overprediction in the recent past is linked to mis-measurement of the pass-through coefficient.

4.3 Wage equation

Regarding wages, Table 5 indicates that, using the error term from the regression $w_t = c + \beta_1 p_t + \beta_2 q_t + \beta_3 \Delta p_t + \varepsilon_t$, the Phillips-Perron statistic does reject the null of no cointegration at a 10% Haldrup critical value. On the other hand, Table 6 shows that the wage model replicates the dynamics of wage inflation remarkably well (the out-of-sample forecast confirms this as well, see Figure 7). The regressors explain most of the movements of the dependent variable since the adjusted R-squared is around 80%. In addition, the ARCH test and LM test on the residuals allow us to reject the presence of significant heteroskedasticity and autocorrelation respectively.

[17] Banerjee et al (2001) obtained a similar result for Australia.

[18] One problem with estimation is that β is far above what is theoretically reasonable. In empirical studies, it is common to obtain imprecise estimates of the discount factor, hence it may be preferable to fix it. Nevertheless, the model is overidentified when β is fixed and it is only possible to obtain a range of values for c_{12} and θ. Fixing $\beta = 1$, we obtain a range between 0.7 and 1.0 for θ. In the case of c_{12}, in equation (12), it is negative and similar to the value obtained without fixing $\beta = 1$ (see Table 3).

Figure 6

Out-of-sample inflation forecast

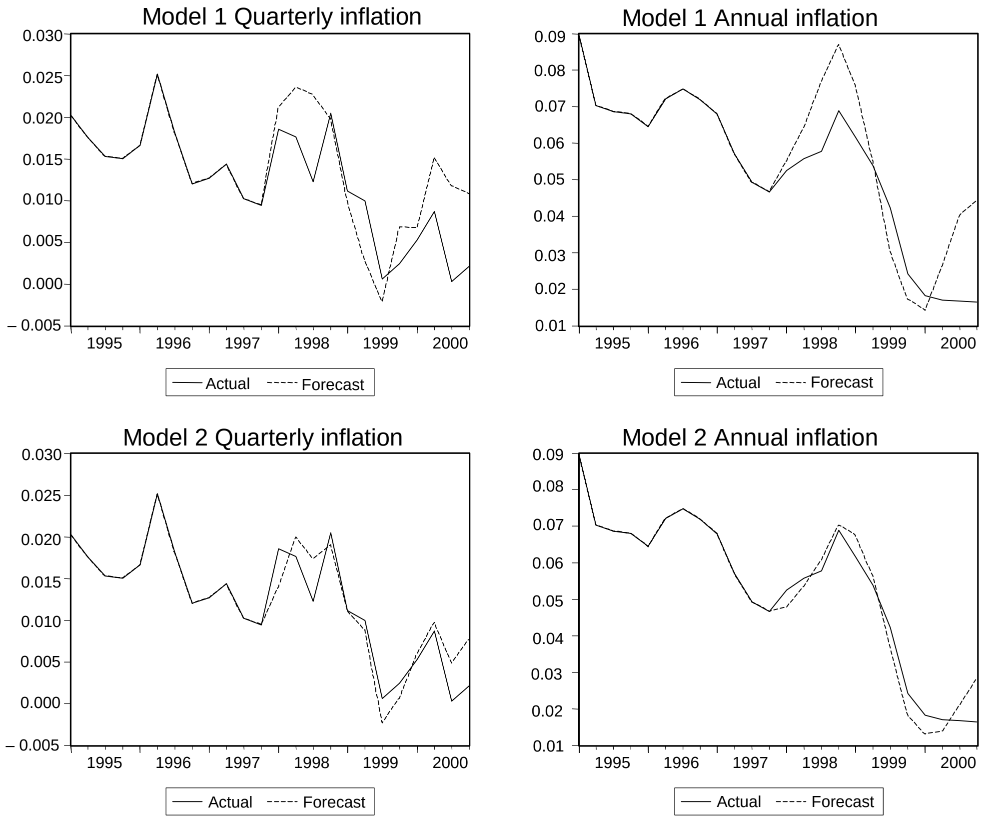


Table 5

Cointegration test for private wages[1,2,3]

Test	Value	Critical value	5%	10%
Phillips-Perron	– 4.15	PP	– 2.6	– 1.95
		Haldrup	– 4.3	– 3.9
ADF	– 2.7	ADF	– 2.6	– 1.95
		Haldrup	– 4.3	– 3.9

[1] The equation to obtain the error term was $wpr_t = c + \beta_1 p_t + \beta_2 q_t + \beta_3 \Delta p_t + \varepsilon_t$. [2] Each test was estimated with four lags. Serial correlation LM and Arch tests do not indicate autocorrelation and heteroskedasticity. [3] A Hodrick-Prescott filter is used to calculate productivity.

As shown in Table 6, the data confirms a negative relationship between the acceleration of wage inflation $\Delta^2 w_t$ and unemployment U_t, with a – 0.15 parameter. This is a Phillips curve itself. It is worth pointing out that there is a close relation between wage and CPI inflation due to widespread indexation (the term $\Delta p_{t\text{-}1}$–$\Delta w_{t\text{-}1}$). Our estimation indicates that a 10% increase in inflation above wages will lead to a 7% acceleration of wage inflation next period.[19]

[19] It is worth noting that expected inflation was not significant and was thus dropped.

Table 6

Private wage equation (dependent variable: $\Delta^2 w_t$)
Sample 1987.4–2000.4

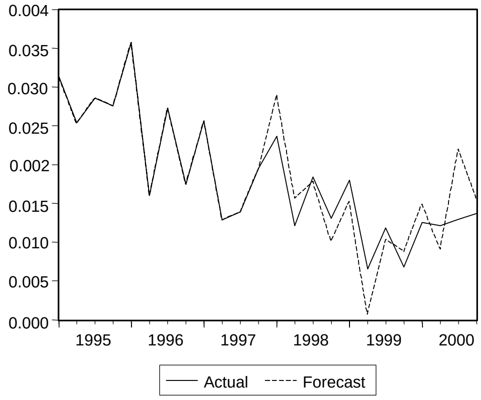
$\Delta^2 wpr_t = \beta_1 + \beta_2 \Delta q_t + \beta_3(\Delta p_{t-1} - \Delta wpr_{t-1})\ \beta_4\ w_{t-1} + \beta_5\ p_{t-1} + \beta_6\ q_{t-1} + \beta_7 \Delta p_{t-1} + \beta_8 u_t + \quad \beta_9 d2 + \beta_{10} d3 + \beta_{11} d4$

	Variables[1]	**Coefficient**[2] (*t*-statistic)
β_1	c	– 0.8 (– 2.8)
β_2	Δq_t	0.1 (1.3)
β_3	Δp_{t-1} - Δwpr_{t-1}	0.68 (7.6)
β_4	wpr_{t-1}	– 0.35 (– 3.4)
β_5	p_{t-1}	0.37 (3.4)
β_6	Q_HP_{t-1}	0.15 (2.7)
β_7	Δp_{t-1}	– 0.33 (– 2.7)
β_8	u_t	– 0.15 (– 1.84)
β_9	*Seas_d*2	– 0.006 (– 2.2)
β_{10}		0.001 (0.5)
β_{11}	*Seas_d*4	– 0.003 (– 1.3)
R^2		0.79
DW		2.17
ARCH (4)[3]		0.67 (61%)
LM(4)[3]		0.43 (78%)
Jarque-Bera[3]		1.3 (51%)

[1] Log values, except for the unemployment rate. [2] A Hodrick-Prescott filter is used to calculate the level of productivity. However, the first difference is calculated without using this filter. [3] Probabilities are reported in brackets.

On the other hand, the parameters of productivity confirm that it has a positive effect on wages. In addition, the negative parameter of lagged inflation indicates that this variable imposes a cost for workers. Even though the sign of this variable can be derived from the model (inflation is multiplied only for positive parameters), the overidentification does not allow us to determine its exact magnitude.

Figure 7
Out-of-sample forecast for private wage growth



4.4 Pass-through

Finally, we analyse in detail the implications of our estimations on exchange rate pass-through. We have incorporated second-round effects of wages on prices. Thus, we have a simultaneous system for prices (Model 2) and wages, which depends on productivity, the exchange rate, foreign prices and lagged variables. In the first round, the nominal exchange rate directly affects prices. Subsequently, wages, through indexation, impact prices again. We generated out-of-sample inflation forecasts with both equations simultaneously.[20] The results are shown in Figure 8.

Figure 8
Simultaneous equation inflation forecast

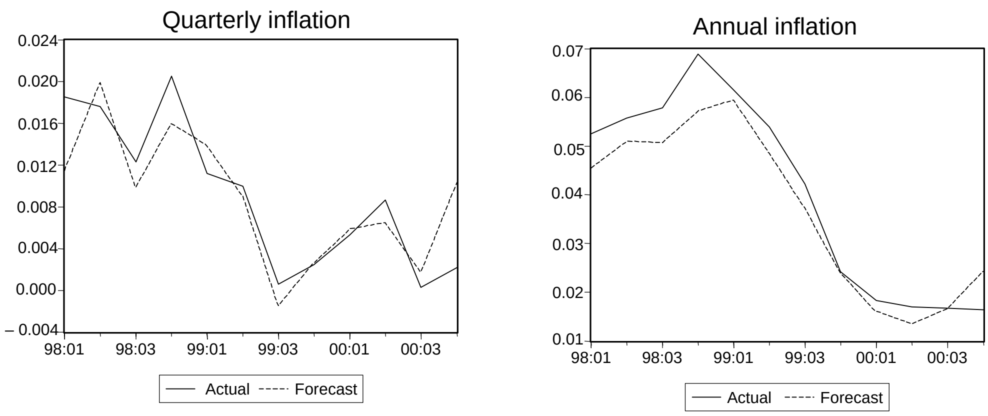
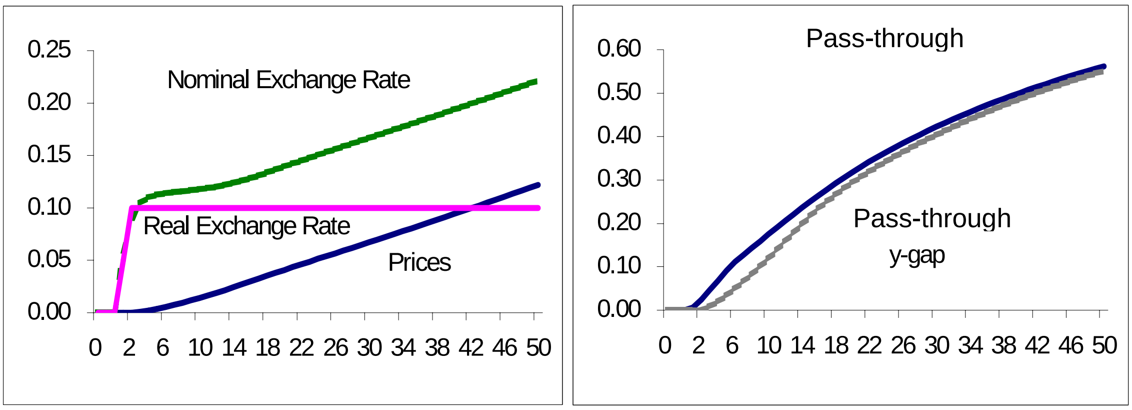


Figure 9 shows pass-through when the nominal exchange rate increases. First, we incorporated both equations in the García et al (2000) five-equation model - instead of their Phillips curve. Next, we hit both real and equilibrium real exchange rates with a 10% shock. We then followed the nominal exchange rate and price paths.

[20] This exercise was performed with our restricted price index IPCX2, instead of CPI, affecting wages. We consider that it is the origin of the underestimation of the inflation forecast shown in Figure 8.

Figure 9 indicates that after a 1% rise in the real exchange rate, the nominal exchange rate also increases, producing an accumulated impact on prices of around 0.16% after three years.

Figure 9



Next, we explore how the effect of an exchange rate shock depends on economic activity. Evidence suggests that there is a pass-through decrease when the economy is in a "recession". Figure 9 shows what happens in our artificial environment with prices, and the pass-through effect, if we have a temporary increase of 10% in the exchange rate in two alternative scenarios. The first scenario has an endogenous output gap. The second has an exogenous 2% negative output gap which fades linearly in three years. The accumulated inflation effect of depreciation is higher when the economy is at potential (zero output gap). A negative output gap tends to offset the inflationary effect of a nominal depreciation. The negative output gap reduces margins and hence a fraction of the depreciation is not passed on to consumers.[21]

Finally, Model 2 in Table 3 suggests that the size of exchange rate pass-through is positively related to the inflation level. This effect is captured in the variables where the nominal exchange rate is multiplied by inflation. In both cases, the coefficients are positive and strongly significant. Therefore, one could conclude that the low pass-through from the exchange rate to inflation observed in recent years is permanent since inflation has been stabilised at around 3%. It also suggests, as stated above, that inflation overprediction in the recent past is probably related to mis-measurement of the pass-through coefficient.

5. Conclusions

Price and wage equations based on a model of imperfect competition were estimated and used to generate out-of-sample inflation forecasts. From the estimations we can conclude:

The findings of previous studies are confirmed in the sense that the output gap and unemployment have a small impact on inflation due to widespread indexation. Therefore, a gradual monetary policy is called for.

Despite the fact that generalised wage indexation is one of the major elements explaining price and wage behaviour, expectations of future inflation matter. This is a very important variable to consider in an inflation targeting regime, since credibility could substantially reduce the sacrifice ratio.

We empirically found that productivity reduces unit labour costs and inflation, affecting real wages positively. In addition, a negative relationship between inflation and both mark ups and real wages

[21] In this exercise, output calculation was performed assuming a zero unemployment rate because unemployment was not linked to the output gap. Considering this second-round effect in this particular exercise would probably generate a lower pass-through.

indicates that inflation imposes substantial costs on firms and workers. This result emphasises the benefits of stabilising the inflation rate. This cost rises even more when the impact of inflation on real wages is considered.

Finally, the exchange rate pass-through depends positively on economic activity and the inflation level, explaining why pass-through has been so low in recent years. Therefore, one could conclude that pass-through would be permanently lower than in the 1990s, given that inflation has been stabilised at around 3%.

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