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Carlos José García Jorge Enrique Restrepo

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PRICE INFLATION AND EXCHANGE RATE PASS-THROUGH IN CHILE

Carlos José García Economista Senior Gerencia de Análisis Macroeconómico Banco Central de Chile Jorge Enrique Restrepo Economista Senior Gerencia de Análisis Macroeconómico Banco Central de Chile

Resumen

En este trabajo se estimó una ecuación de precios, con datos de Chile entre 1986:1 y 2001:1, derivada de un modelo de competencia imperfecta. La estimación incluye la primera diferencia de la variable dependiente como lo hace la literatura acerca de la estimación de modelos de costos de ajuste lineales cuadráticos cuando la variable objetivo y algunas de las variables que mueven el proceso son procesos I(2). La ecuación se usa para generar proyecciones fuera de muestra de un índice de precios más restringido que el IPC. De los resultados podemos concluir: i) el traspaso de tipo de cambio a precios depende positivamente de la actividad económica (brecha del producto) lo que explica por qué el traspaso a precios ha sido tan bajo en los últimos años en Chile. En otras palabras una brecha del producto negativa ha compensado el impacto inflacionario de la depreciación del peso; ii) la productividad reduce los costos laborales unitarios y la inflación; iii) salarios y precios externos están relacionados positivamente con la inflación; iv) finalmente, la aceleración de la inflación esperada es una variable significativa en el modelo, lo que confirma que las expectativas importan en la determinación de la inflación.

Abstract

A price equation based on a model of imperfect competition was estimated using quarterly data for Chile from 1986:1 to 2001:1. 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. The equation is used to generate out-of-sample inflation forecast, of a narrower-than the-CPI price index. We can conclude from the estimation results: i) exchange-rate pass-through depends positively on economic activity (output gap) explaining why pass-through has been so low in recent years in Chile. In other words, a negative output gap has compensated the inflationary impact of exchange-rate depreciation; ii) productivity reduces unit labor costs and inflation; iii) wages and foreign prices are positively related to inflation; iv) Finally, expected inflation acceleration is significant, confirming that expectations matter determining inflation.

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I. Overview

This article estimates a price equation using quarterly Chilean data from 1986:1 to 2001:1. Several issues that are important for understanding and anticipating the behavior of inflation could motivate the estimation of such an equation. For instance: i) elasticity of inflation to the output gap ii) the permanent and cyclical movements of mark-ups, iii) effects of labor productivity growth on inflation, iv) credibility and v) the size of the exchange rate pass-through.

Even though the estimation is related to all these subjects, we take a closer look at the pass-through effect, defined as the effect of exchange-rate changes on domestic inflation, because apparently, this factor has substantially changed in recent years¹. The exchange rate pass-through has been low recently despite the fact that Chile is a small open economy. In fact, there has been significant peso depreciation since 1997 without having a strong impact on inflation. Why is this? Is a low pass-through a new permanent characteristic of the Chilean economy? Will depreciation's impact on inflation take place as soon as demand takes off again? The answer to these questions is crucial for defining monetary policy. The international evidence shows that a very low exchange-rate pass-through has also been observed in New Zealand, Brazil and Australia, where substantial depreciation has taken place after 1997 without having a proportional effect on inflation².

In general, the exchange rate affects the price of any tradable good³. However, the most important channel for passing depreciation to inflation is the direct short-term effect of the exchange rate on the imported part of the basket of goods that make up the CPI and the imported inputs. 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

¹ We compute it here as the ratio between accumulated inflation and accumulated depreciation after a shock has hit the last variable.

² There has been a great amount of articles written on pass-through over the years. For a survey see Golberg and Knetter (1997). Most of them try to estimate how much exchange rate fluctuations are responsible for the behavior of inflation. Some use CPI inflation others use producer price inflation. There is also a wide range of estimation techniques used to obtain a quantitative result. It goes from ordinary least squares (Woo 1984), to panel data (De Gregorio and Borensztein (1999), Goldfajn and Werlang 2000), vector auto regression (McCarthy 1999), cointegration analysis and error correction models (Beaumont et al 1994, Kim K. 1998, Kim Y. 1990), and state-space models (Kim Y. 1990).

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. It is important to note that we have considered in our estimation a narrower definition of prices than CPI, which we call core inflation throughout the paper⁴.

Monetary policy and agents' expectations also influence the effect on prices of exchange–rate depreciation. Although in the short-term, inflation may rise due to depreciation, in the medium– and long–term, inflation should fall back to the target or range level defined by the Central Bank. Of course, an active monetary policy implies affecting aggregate demand and the exchange rate itself⁵.

Phillips curves have been estimated for Chile before (García, Herrera, and Valdés 2000). Nonetheless, we will follow a different approach here. Instead of estimating a reduced form relation between the change in inflation and the output gap, we will estimate an equation for price inflation that considers explicitly a model of nominal price setting by imperfect competitive firms. In addition, we use the linear quadratic price adjustment cost model (LQAC) in 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. The error correction in the price equation ensures that in the steady state, the price level is a mark-up on unit labor costs. Different versions of the core–price equation are estimated by using a single–equation error correction procedure.

Moreover, an I(2) analysis of inflation and the mark-up is undertaken. We find that the price level is best described as an I(2) process. It is worth stressing that Chile is not an

³ The exchange rate effect on prices of exportables is empirically less important given that some of Chile's main exports are not included in the core price index, like: fruits, or even in the CPI like: copper, fishmeal, wood pulp, salmon, methanol, etc.

⁴ The price index is around 70% of CPI because we took out perishable goods and regulated services. Therefore, our estimation of the pass-through coefficient should be taken carefully, since some regulated services are very sensitive to changes in the exchange rate.

⁵ Another factor affecting the degree of pass-through is how permanent agents perceive the shock. We will not deal with exchange-rate volatility here, though.

exception in this regard. In fact, Roberts (2001) models inflation as a unit–root process for the USA. Johansen (1992) and Engstead and Haldrup (1999) do the same for UK. Barnerjee, Cockerell and Russell (2001) find that prices in Australia are better described as an I(2) process as well. In order 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; Barnerjee, et al. 2001). On the other hand, we deal with the inflation expectation term using the limited-information approach due to McCallum (1976).

Taking the estimated price equation, the exchange-rate pass-through is analyzed by simulating an exchange rate shock, with and without an output gap since pass-through is related to economic activity, but also with and without full wage indexation. Had a negative output gap not existed after 1997, the exchange–rate effect on inflation would have been significantly higher. In addition, as a consequence of prices being positively related to wages, the simulation shows that when wage indexation is not complete –and wages grow less than past inflation– pass-through is lower in the long run. The results also show, as expected, that labor productivity reduces unit labor costs and inflation.

This article is organized as follows. The second section introduces some preliminary evidence on the recent pass-through reduction and presents a price model. The third section presents the estimation results and the pass-through simulation. Finally there are some conclusions.

II. Pass-Through from Depreciation to Inflation

a. Stylized facts

The simplest exercise one can realize regarding the pass-through is to compute the correlation between inflation and exchange–rate depreciation. In this case, two rolling correlation statistics were computed (Figure 1). The first one (dark line) has its starting date fixed (1986:1) and the correlation coefficient is calculated adding a new observation at a time, starting in 1990. Therefore, each computation has a larger sample than the last one. Even though this coefficient is rather stable, it has some movement. It decreases at the beginning of the nineties, grows again from 1994 to 1996 and falls steadily after 1998.

Figure 1 Rolling Correlation Coefficient between Annual Inflation and Depreciation



The second statistic in Figure 1 (gray line) has a fully moving sample. Thus, each time the correlation coefficient is computed, both the starting and ending dates move. In this case the statistics fluctuates much more. The latter coefficient moves in a similar way to the former until to 1996. After that year it falls dramatically, to even become negative, showing an important change in the relationship between these two variables.



In addition, a rolling regression was estimated for annual inflation with exchange rate depreciation and a trend as right hand side variables using monthly data between 1986 and 2000 (Figure 2). Again the two types of rolling samples were used. The left side in Figure 2 shows the regression coefficient obtained when the initial date of the sample

does not change. The sample used to estimate the right side in the figure has both (initial and last) dates moving. The left panel of Figure 2 shows that the coefficient started falling in 1996, earlier than in the right panel and Figure 1. As one would expect, the coefficient is less stable with both dates moving⁶.

b. A Price Setting Model

1. Price Setting

In this section we derive a price model following Beaumont et al (1994) and Layard et al (1991). Given that prices adjust slowly, we also use the linear quadratic price adjustment model developed by Rotemberg (1982). Thus, firms should weigh the cost of changing prices against the cost of being away from the price that the firm would choose in case there were no adjustment cost (Roberts 1995). One could think of the latter price as being the "optimal price" or the long-run equilibrium price, given that prices are sticky in the short run.

Firms are identical and get an output (y) by using labor (l) and an imported input (z):

$$y_i = a_1 + a_2 l_i + (1 - a_2) z_i \tag{1}$$

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:

$$y_{di} = -\mathbf{h}(\tilde{p}_i - p) + y_d - f \tag{2}$$

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

$$\tilde{p}_{di} = -\log\left[\frac{n}{n-1}\right] + MC = m + MC = m + a_1 + a_2 w_t + (1 - a_2) p_t^*$$
(3)

Where the price (p_{di}) is fixed by charging a margin (m) over the marginal cost (MC). A pricing model based on a mark-up over costs would be inappropriate if it were applied to markets close to perfect competition like the ones for agricultural products (Woo 1984).

It is assumed that firms desire a constant mark-up, m in the long term. However, in the short run firms could postpone price adjustments and accept deviations of their mark-up

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

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). Demand fluctuations and anything affecting market power could have an impact on the mark-up (Barnerjee, Cockerell and Rusell 2001, Small 1997, Taylor 2000). If the economy is in the midst of a recession, companies will find it difficult to transfer to their prices higher costs due to depreciation.

In addition, margins and inflation may also be either positively or negatively related because there are two opposite effects. In Taylor's words "firms in low inflation economies will appear to have less pricing power than firms in high inflation economies." (Taylor (2000). Second, one would also expect that inflation imposes costs on firms and therefore the mark-up net of inflation is reduced with higher inflation rates (Benabou 1992, Banerjee, Cockerell, and Russell 2001).

Based on what was said in the last two paragraphs we assumed that the mark-up equation depends on average labor productivity, inflation and the output gap i.e. it has a cyclical component:

$$\boldsymbol{m} = \boldsymbol{c}_1 + \boldsymbol{c}_2 \boldsymbol{q}_t + \boldsymbol{c}_3 \left(\boldsymbol{y}_t - \boldsymbol{y}_t \right) + \boldsymbol{c}_4 \Delta \boldsymbol{p}_t \tag{4}$$

Following Beaumont et al (1994), and Banerjee et al (2001) one can approximate equation 4 by this expression⁷:

$$\tilde{p}_{di} = (a_1 + c_1) + a_2(w_t - q_t) + (1 - a_2)p_t^* + c_3(y_t - \overline{y}_t) + c_4\Delta p_t$$
(5)

Where p^* is equal to foreign input prices adjusted by nominal exchange rate and taxes and $w_t \cdot q_t$ is wages minus average labor productivity (unit labor 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 output gap from the long-run price equation (5) on the basis that it is equal to zero at the steady-state level although in the short run mark-up

⁷ Note also that w_t can be separated in private (*wpr*_t) and public wages (*wpu*_t).

(P – MC) depends on economic activity⁸. Following Layard et al. p_{di} and y_{di} are aggregated so $p_{di} = p$ and $y_{di} = y^9$.

2. Price Dynamics

The structural equation for inflation is in the spirit of the new Phillips curve literature. It evolves explicitly from a setting of imperfect competitive firms where nominal prices are rigid or adjust slowly. In doing this, we use the (Rotemberg 1982) LQAC model of the representative firm, which minimizes the loss of charging a different price for its product from the long-run level, weighed against the cost of changing its price. This intertemporal problem is solved by choosing a sequence of p_t , the decision variable, in order to:

$$\min_{\{p_{t+i}\}} E_{t} \sum_{i=0}^{\infty} \boldsymbol{b}^{i} \left[\boldsymbol{q} \left(p_{t+i} - \tilde{p}_{t+i} \right)^{2} + \left(p_{t+i} - p_{t+i-1} \right)^{2} \right]$$
(6)

where E_t is the expectations operator conditional on the full public information set, **b** is the subjective discount rate, **q** is the relative cost parameter, p_t denotes the optimal price and p_t the current or actual price. After rearrangement, the Euler equation from the minimization problem can be written as:

$$\Delta p_{t+i} = \boldsymbol{b} \Delta p_{t+i+1}^{e} - \boldsymbol{q} [p_{t+i} - \widetilde{p}_{t+i}]$$
(7)

Where Δp_{t+i+1}^{e} denotes expected inflation. One could think of it as being an errorcorrection 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 (5).

The second step is to reparameterize equation (5) for carrying out the I(2) analysis. Following Haldrup (1995) the optimal price can be parameterized as:

$$\widetilde{p}_{t} = g_{1}x_{1,t-1} + g_{1}\Delta x_{1,t} + g_{2}x_{2,t-1} + g_{2}\Delta x_{t-1} + g_{2}\Delta x_{2,t-1} + g_{2}\Delta^{2}x_{2,t-1}$$

where x_i are the I(1) variables { q_t , Δp_t } while x_2 are the I(2) ones { w_t }. Therefore we transform the optimal price:

⁸ The theory about the relationship between margins and the cycle is ambiguous. Some models predict procyclical margins (Kreps and Scheinkman 1983, Haskel and Small 1995, Small 1997). Others, in contrast, predict that they are countercyclical (Rotemberg and Saloner 1986, Rotemberg and Woodford 1991).

⁹ The optimal price has been aggregated as in Layard et al. (1991) chapter 7, page 436.

$$\tilde{p}_{t} = (1 - a_{2})p_{t-1}^{*} + a_{2}(w_{t-1} - q_{t-1}) + c_{4}\Delta p_{t-1} + a_{2}\Delta w_{t-1} + (1 - a_{2})\Delta p_{t}^{*} + a_{2}(\Delta^{2}w_{t} - \Delta q_{t}) + c_{4}\Delta^{2}p_{t-1}$$

Now we transform $\boldsymbol{q}[p_t - \tilde{p}_t]$ to get the cointegration error correction term.

In order to do that we add and subtract Δp_{t-1} , and we also use two identities

$$p_t \equiv p_{t-1} + \Delta p_t$$
 and $\Delta p_{t-1} \equiv \mathbf{f} \Delta p_{t-1} + (1 - \mathbf{f}) \Delta p_{t-1}$ where $\mathbf{f} = \frac{\mathbf{b}}{1 + \mathbf{q}}$. Thus, equation (7) can

be written in acceleration form:

$$\Delta^{2} p_{t} = k_{1} (\Delta p^{e}_{t+1} - \Delta p_{t-1}) + k_{2} (1 - a_{2}) \Delta p_{t}^{*} + k_{2} a_{2} (\Delta^{2} w_{t} - \Delta q_{t}) + \mathbf{y} (y_{t-1} - \overline{y}_{t-1}) - k_{2} \left(p_{t-1} - \left[(1 - a_{2}) p_{t-1}^{*} + a_{2} (w_{t-1} - q_{t-1}) + a_{2} \Delta w_{t-1} + \left(c_{4} + \frac{(1 - \mathbf{f})(1 + \mathbf{q})}{\mathbf{q}} \right) \Delta p_{t-1} \right] \right) + \mathbf{e}_{t}^{(8)}$$

Where $k_{1} = \frac{\mathbf{b}}{1 + \mathbf{q}(1 - c_{4})}$ and $k_{2} = \frac{\mathbf{q}}{1 + \mathbf{q}(1 - c_{4})}$

Equation (8) is what we refer to as the Phillips curve. This equation relates inflation to expected inflation, wage growth, output gap, and average cost. In addition, there is an error correction term which ensures that in steady state the price level is set adding a mark-up on unit labor cost and imported-input prices (Layard et al. 1991).

Finally, it is important to notice 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) where the inflation rate can jump. However, it is usually found empirically that inflation shows a great amount of inertia¹⁰. A successful stabilization program should take this into account, in order to reduce the risk of causing a sharp fall in the rate of output growth.

III. 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

¹⁰ In Chile inflation is highly persistent to the extent that it is best described as being an I(1) process.

together with the dynamics, as in equation (8), following Harris (1995)¹¹. 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 concludes (citing Inder 1993) 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" (Harris op.cit., p.p. 60-61). At the same time it is also possible to test the null hypothesis of no cointegration by testing the significance of the error correction coefficient (Harris op cit., for an explanation and critical values see Banerjee, Dolado Galbraith, and Hendry, 1993 p. 223-233).

In addition, an I(2) analysis of inflation and the mark-up is done as in Haldrup (1995). We find that the levels of prices and unit labor costs are best described as I(2) processes, this result can probably be accounted for by the existence of an I(1) inflation target during the1990s. As said above, Chile is not unique in this regard. In fact, Roberts (2001) models inflation as a unit–root process for the USA. Johansen (1992) and Engstead and Haldrup (1999) also do the same for UK. Barnerjee, Cockerell and Russell (2001) who find that prices in Australia are also better described as an I(2) process as well. An I(1) inflation process is not necessarily inconsistent with inflation targeting, given that the target was not "stationary." Furthermore, an I(1) inflation could be allowed to wander inside a target range. Since in this case there would be an inaction zone, the monetary policy reaction function would be nonlinear and is called by Orphanides and Wieland (2000) "inflation zone targeting." Such a stochastic process is known in the (continuous time) literature as a Brownian motion with barriers. Although this kind of process is expected to settle down to a stationary one in the long run, it is not yet the case in the sample we are considering here¹².

¹¹ Harris, R. *Cointegration Analysis in Econometric Modelling* pp 60-61. See also Phillips and Loretan (1991) for a comparison among several one-step (uniequational) cointegration methods used to estimate long-run economic equilibria.

 $^{^{12}}$ Another alternative would be treating inflation as a stationary process but using a calibrated autoregressive coefficient very close to 1. In this case, inflation would still be very persistent although being a stationary process. However, it would be a calibration experiment instead of being an econometric estimation.

a. Data, Unit Roots

The quarterly series (in logs) used in the model from 1986:1 to 2001:1 are the following:

p: price level, it excludes perishable food as well as gas, fuels and regulated services

q: average labor productivity

wpr: Nominal private wage

wpu: Nominal public wage

w : Nominal wage

e : Nominal exchange rate

*p**: Foreign prices

y- \overline{y} : The difference between actual output and its Hodrick-Prescott trend¹³

 $t : \ln(1 + VAT)$

 $ta:\ln(1+\text{Tariff})$

IT : Inflation target

D and D²: First and second difference, respectively.

We begin the empirical section testing the variables used in the estimations for the existence of unit roots. Table 1 indicates that price level is I(2). This confirms that the price equation can be estimated in acceleration form.

		-			
Unit Root Test					
Variables	Level	First Difference	Second Difference		
Price	—	-3.04 (-3.49) 5	-4.41 (-2.92) 6		
Private Wage	—	-3.07 (-3.49) 0	-4.47 (-2.92) 6		
Public Wage	—	-3.46 (-3.49) 5	-4.48 (-2.92) 6		
Foreign Price	-2.42 (-2.92) 6	-4.01 (-3.49) 5	—		
Average Labor Productivity	-2.36 (-3.49) 1	-5.20 (-3.49) 4	—		
Nominal Exch. Rate	-2.09 (-3.49) 1	-6.41 (-2.92) 0	-		
Private Unit Labor Cost	—	-5.01 (-3.49) 0	-4.5 (-2.92) 6		
Output Gap	-3.49 (-1.95) 3	-	—		
Critical value 5% no constant	-1.95				
Critical value 5% with const.	-2.92				
Critical value 5% const. & trend	-3.49				
* Critical values in parenthesis.					
**The number of lags used in the test is on the right side of every column.					

Table 1

¹³ Potential output was computed with a Hodrick-Prescott filter but, given the problems this filter has with final data points, it was adjusted by building an autorregresive forecast from 1998 to 2001:1.

In general one can say that Chilean inflation deviates from any given mean in the period here considered. Moreover, Chilean inflation has traditionally been very persistent due to generalized indexation. On the other hand, variables such as output gap and the nominal exchange rate are I(0) and I(1) respectively. Regarding cointegration we follow Banerjee, Dolado Galbraith, and Hendry's (1993) approach which states that a test of the null hypothesis Ho: $c_2 = 0$ (the error–correction coefficient in equation 8) based on the tstatistic $t_k = 0$ is a valid test for cointegration. If the variables are not cointegrated, this coefficient should be zero. They also include computed critical values for this test in Table 7.6 in their book. Both equations pass the test since the critical t value is 4.06 at 1% of significance (Table 2).

b. Price Equation

As stated in equation (8), price acceleration was run on wage, average labor productivity, output gap, lagged prices, foreign prices and several difference terms¹⁴. We have estimated two versions of equation 8.

• Model 1

In this estimation we imposed $\beta 6 = -\beta 7$, which implies that we can introduce unit labor costs instead of having private wages and labor productivity separated. Cost homogeneity (the various costs add up to prices) was also imposed: $-\beta 4 = \beta 5 + \beta 6 + \beta 7 + \beta 8 + \beta 9$. In consequence an increase in all nominal inputs generates a proportional increase in prices.

 $D^{2}p_{t}=b_{1}+b_{2}(Dp^{e}_{t+1}-Dp_{t-1})+b_{3}([(y_{t-1}-\bar{y}_{t-1})+(y_{t-4}-\bar{y}_{t-4})]/2)+b_{4}p_{t-1}+b_{5}(wpr_{t-1}-q_{t-1})+b_{6}(wpu_{t-1}+taxes)+(-b_{4}-b_{5}-b_{6})(e_{t-1}+p^{*}_{t-1}+ta_{t-1}+t_{t-1})b_{7}Dp_{t-1}+b_{8}(D^{2}wpr_{t}-Dq_{t})+b_{9}(De_{t+}Dp^{*}_{t}+Dq_{t}+Dq_{t})+b_{9}(De_{t+}Dp^{*}_{t}+Dq_{t})+b_{9}(De_{t+}Dq^{*}_{t}+Dq^{*}_{t}+Dq_{t})+b_{9}(De_{t+}Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+Dq^{*}_{t}+$

• Model 2

¹⁴ Based on De Gregorio and Borensztein (1999), Goldfajn and Werlang (2000), we also tried including the real exchange rate misalignment multiplied by the depreciation rate, but the coefficient associated with this variable was not statistically significant. We also tried including the oil price in these regressions, to take into account short-run shocks to the system, but it was not significant.

In this model we used the inflation target as a proxy for expected inflation

 $D^{2}p_{t} = b_{1} + b_{2} (IT_{t+1} - Dp_{t-1}) + b_{3} ([(y_{t-1} - \overline{y}_{t-1}) + (y_{t-4} - \overline{y}_{t-4})]/2) + b_{1} + b_{4} p_{t-1} + b_{5} (wpr_{t-1} - q_{t-1}) + b_{6} (wpu_{t-1} + taxes) + (-b_{4} - b_{5} - b_{6}) (e_{t-1} + p^{*}_{t-1} + ta_{t-1} + t_{t-1}) b_{7} Dp_{t-1} + b_{8} (D^{2}wpr_{t} - Dq_{t}) + b_{9} (De_{t+} Dp^{*}_{t} + Dq_{t}) + b_{9} (De_{t+} Dp^{*}_{t} + Dq_{t}) + b_{9} (De_{t+} Dp^{*}_{t}) + b_{1} + Dq_{1} + b_{2} (De_{t+} Dp^{*}_{t-1} + dq_{t-1}) + b_{1} + Dq_{1} + b_{2} (De_{t+} Dp^{*}_{t-1} + dq_{t-1}) + b_{2} (De_{t+} Dp^{*}_{t-1} + dq_{t-1$

Regarding the possible endogeneity of the exchange rate in these single equation models, we can argue that it does not affect the long-run coefficient of the exchange rate in the cointegrating vector. This kind of bias could only affect the coefficient of the contemporaneous exchange rate dynamics.

The results of the estimation of equation (8) are presented in Table 2. The parameters of these econometric estimations have the expected signs and the restrictions of the model hold. The coefficient on output gap $[(y_{t-1}-\overline{y}_{t-1})+(y_{t-4}-\overline{y}_{t-4})]/2$ is positive, indicating that the direct impact of a 10% output gap will be a 1.35% acceleration of the inflation rate.

The results also show, as expected, that labor productivity reduces unit labor costs and inflation. On the other hand, expected inflation acceleration Δp^{e}_{t+1} - Δp_{t-1} is significant, confirming that expectation matters in determining inflation. Wages and foreign prices also accelerate inflation. Finally, lagged inflation (Δp_{t-1}) is also significant¹⁵.

Table 2 also shows the various diagnostic residual tests indicating that the models have the desired properties for OLS estimation¹⁶. Multivariate tests are satisfactory as seen in the lower part of the table. In general, the econometric fit is satisfactory with high Rsquares and highly significant variables. Also, the results presented in Table 2 provide evidence of the existence of I(2) data trends and cointegration because the parameter of $D_{p_{t-1}}$ is significant (according con Banerjee et al (1993) critical values) and the error terms are stationary.

¹⁵ We are not able to distinguish its long-run effect on mark-ups from its contribution to the short-run dynamics.

¹⁶ Standard errors were obtained with the Newey-West heteroscedasticity and autocorrelation consistent procedure.

Variables ¹	Model 1	Variables	Model 2
Const	0.59	Const.	0.59
	(2.75)		(3.19)
$\Delta p_{t+1}^{e} \Delta p_{t+1}^{2}$	0.45	$IT_{t+1} \Delta p_{t+1}$	0.25
	(2.83)	t+1Pt-1	(1.62)
$[(v_{t,1}-v_{t,1})+(v_{t,1}-v_{t,1})]/2$	0.16	$[(v_{t,1}-v_{t,1})+(v_{t,1}-v_{t,1})]/2$	0.20
$[(j_{t-1}, j_{t-1}), (j_{t-4}, j_{t-4})] =$	(3.0)	$[(j_{t-1}) j_{t-1}) (j_{t-4}) j_{t-4} (j_{t-4})]$	(4.0)
D t-1	-0.23	D t-1	-0.23
1 * 1	(-4.8)	1	(-4.6)
$Wpr_{t-1} - q_{t-1}$	0.16	$Wpr_{t-1} - q_{t-1}$	0.16
I CI KI	(4.0)	I the fit	(4.21)
$wpu_{t-1} + t_{t-1}$	0.044	$Wpu_{t-1}+t_{t-1}$	0.04
<u>r</u> tr tr	(3.5)	I de l'action de la companya de la c	(3.5)
$p_{t-1}^{*} + e_{t-1}$	0.24-0.16-	$p_{t-1}^{*} + e_{t-1}$	0.22-0.16
$+ta_{t-1}+t_{t-1}$	0.044=0.03	$+ta_{t-1}+t_{t-1}$	-0.05=0.03
An ₁	-0.44	An 1	-0.54
Δpt-1	(-2.4)	⊐pt-1	(-2.6)
Λ^2 wpr $\Lambda \alpha$	0.13	Λ^2 wpr $\Lambda \alpha$	0.15
	(2.6)		(2.7)
$\Delta e_t + \Delta p_t^*$	0.06	$\Delta e_t + \Delta p_t^*$	0.05
$\Delta t_t + \Delta ta_t$	(2.9)	$\Delta t_t + \Delta ta_t$	(2.3)
Seas(2)	0.01	Seas(2)	0.006
Seas(2)	(3.8)	Seas(2)	(3.15)
Seas(3)	-0.003	Seas(3)	-0.006
Seas(3)	(-1.1)	Seas(3)	(-2.46)
Adjusted R^2	0.77		0.76
DW	2.1		2.2
$ARCH(4)^3$	1.1 (37%)		0.48 (75%)
$LM(4)^{3}$	0.72 (58%)		0.50 (73%)
Jaque Bera ³	0.65 (72%)		0.40 (82%)
Mean Absolute Error ⁴	0.05 & 0.0015		0.05 & 0.008
Errors Unit Root test (1% critical	-6.29 (-2.6)		-6.06 (-2.6)
value in brakets)			

Table 2Price Equation (Dependent Variable: $\mathbf{D}^2 p_t$)Sample1986.3-2001.3

(1) p_t is core inflation and each variable is in logs.

(2) \mathbf{D}_{t+1}^{e} is estimated by instrumental variables. We use as IV contemporaneous values \mathbf{D}_{t}^{*} , \mathbf{D}_{t-1} , $\mathbf{D}_{l_{t}}$, $\mathbf{D}_{vpu_{t}}$, $\mathbf{D}_{vpr_{t}}$, $\mathbf{D}_{e_{t}}$, $(y_{t}, \overline{y}_{t})$, IT_{t} , $\mathbf{D}_{(oil price)_{t}}$, contemporaneous unemployment rate, and Seasonal

variables.

(3) Probabilities are reported in brackets.

(4) Out-of- Sample Forecast for 1998.1-2001 and also for 1999.1-2001.

(5) In both equations variables $\mathbf{D}vpu_{t-1}$ and $\mathbf{D}vpr_{t-1}$ were not statistically significant.

We tested the two restrictions of model 1 using an unrestricted version of it. First, we tested the hypothesis of the coefficient on private wages being equal to the one on labor productivity, though with opposite signs. If this is the case we can include unit labor cost (w-q) as a variable in the model.

Restrictions Tests on Model 1		
Wald Test Hypothesis	Model 1	
Unit Labor Cost	90%	
Linear Homogeneity and	61%	
Unit Labor Cost		

Table 3				
Restrictions Tests on Model 1				
1 To at House the atte	Madal 1			

As shown in Table 3, the Wald test indicates that we fail to reject the null hypothesis of different coefficients at 90% of significance. Second, we tested in Model 1 the hypothesis that the various costs add up to prices (cost homogeneity). We also fail to reject this null hypothesis at a 61% of significance (Table 3). As a result we imposed both restrictions in Model 1.

In order to evaluate the models' forecasting ability, we estimated them until 1997:4 and generated out-of-sample inflation forecast from 1998:1 up to 2001:1 (Figure 3). Then, we estimated them again until 1998:4 and generated out-of-sample inflation forecast from 1999:1 up to 2001:1 (Figure 3). We find that both models follow actual inflation rather well. However, both overestimate inflation at the end of 2000. The mean absolute error of both forecasts is found in Table 2 and Figure 3.



Figure 3 Out-of-sample Forecast of Annual Inflation (1999.1-2001.1)

c. Pass-Through¹⁷

Finally, we analyze the implications of our estimations on exchange rate pass-through by simulating an unexpected permanent 10% shock to the nominal exchange rate¹⁸. In order to do so, besides using the estimated equation (first column in Table 2), we assume fully indexed wages. Thus, we solve the model (not estimate it) simultaneously, by also including the following equation: $w_t = w_{t-1} + \Delta p_{t-1}$, for both private and public sectors, respectively. After we introduce a shock to the nominal exchange rate, we compute the pass-through effect using the simulated paths followed by both the nominal exchange rate and domestic prices. It is worth noting that the exercise does not consider any monetary policy action.

Figure 4 shows the exchange–rate pass-through effect when the nominal exchange rate unexpectedly increases. It indicates that a 100% rise in the exchange rate produces an accumulated impact on prices of around 33% in the first two years (8 quarters) which is considered the relevant policy horizon¹⁹. This means that a nominal devaluation will not be proportionally translated into prices in the short run, affecting the real exchange rate. After that, pass-through increases approximating to 100% in the very long run.

¹⁷ Again, the reader should take into account that these results do not consider the exchange rate effect on regulated services and gas. Therefore exchange-rate pass-through is actually somewhat higher.

¹⁸ Pass-through will be smaller if the exchange rate shock is not a permanent one. It could also be smaller, at least in the short run, if agents believe the shock is only temporary.

¹⁹ International evidence indicates that the pass-through of the exchange rate to prices is lower in developed countries than in Latin America and Asia. In one panel estimate with 71 countries, Goldfjan and Werlang (2000) found a depreciation-to-inflation pass-through coefficient of 0.73 at the end of 12 months. When the sample was sorted between OECD members (Organization for Economic Cooperation and Development) and emerging economies, at the end of 12 months, pass-through coefficients of 0.6 and 0.91 respectively appeared. When this sample was sorted by regions, 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 toward predicting higher inflation than actually observed in several well-known cases of large depreciation.



We also realized an exercise imposing the limitation that private wages do not have full indexation: $w_t = w_{t-1} + 0.9^* \Delta p_{t-1}$. Figure 4 shows that in this case, pass-through is much smaller in the long run. Nonetheless, this effect is not large in the first two years. Of course, this scenario assumes that private wages will permanently bear the cost of a higher nominal exchange rate, which is not realistic.

Evidence suggests that there is a pass-through decrease when the output is below potential (recession) because a negative output gap tends to compensate the inflationary effect of depreciation by reducing margins. This is what usually happens when a currency depreciation is the result of a negative terms of trade shock with negative effects on output (Mishkin, 2001). Figure 4 shows that the exchange-rate effect is much smaller when there is an exogenous 2% negative output gap, which fades linearly in 3 years. In this case, a 100% increase in the exchange rate will translate into a 13,5% price increase i.e. less than half of what it was before. Hence, a fraction of the depreciation is not passed on to consumers. In the long run, as output gap disappears, pass-through approaches $100\%^{20}$.

IV. Conclusions

A price equation based on a model of imperfect competition was estimated and used to generate out-of-sample forecasts for core inflation. The parameters of these econometric estimations have the expected signs and the restrictions of the model hold. It was

²⁰ Since 1998 the output gap in Chile has probably been higher than what we assumed for this simulation.

empirically found, as expected, that labor productivity reduces unit labor costs and inflation. On the other hand, expected inflation acceleration $\Delta p^{e}_{t+1}-\Delta p_{t-1}$ is significant, confirming that expectation matters for determining inflation. Wages and foreign prices are also positively related to inflation. The coefficient on output gap $(y_{t-1}-\overline{y}_{t-1})$ is positive, indicating that the direct impact of a 10% output gap will be a 1.6% acceleration of the inflation rate.

We analyze the implications of our estimations on exchange rate pass-through by simulating an unexpected permanent 10% shock to the nominal exchange rate. A nominal devaluation has real effects that disappear in the long run. In the case of incomplete wage indexation, pass-through is much smaller in the long run. Nonetheless, this effect is not large in the first two years.

The simulation also shows that a negative output gap tends to compensate the inflationary effect of depreciation since exchange–rate pass-through depends positively on economic activity. In this case, a fraction of the depreciation is not passed on to prices in the short run, explaining why pass-through has been so low in recent years. However, as time goes on and the output gap disappears, pass-through approaches 100%.

If the recent peso depreciation in Chile is permanent, one can conclude from the results, that pass-through will increase as soon as aggregate demand starts recuperating. Nevertheless, this will only be the case if monetary authorities take no action.

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