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THE PASS-THROUGH FROM DEPRECIATION TO INFLATION: CHILE 1986-2001

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Abstract

A microeconomic model of imperfect Cournot competition is used to derive an explicit endogenous relationship between price level and the nominal exchange rate. We obtain a mark-up that varies endogenously with consumer real income. Using the model, the estimated pass-through –namely the impact of devaluation on inflation– ranges between 9-11% in the short run and between 21-32% in the long run for the period 1986-2001. However, the data supports a structural change in 1991, after which the pass-through coefficient declines significantly. Moreover, contrary to conventional wisdom, we find no evidence of procyclical pass-through.

Resumen

Utilizando un modelo microfundado de competencia oligopolística a la Cournot, se deriva una relación explícita entre el nivel de precios agregados y el tipo de cambio nominal. De esta forma se obtiene un precio cuyo margen sobre el costo marginal varía en forma endógena con el ingreso real de los consumidores, abandonando los modelos ad hoc usuales en la literatura de traspaso. Usando este marco teórico el coeficiente de traspaso estimado, esto es, el impacto de la devaluación cambiaria en la inflación doméstica, alcanza entre 9% y 11% en el corto plazo, y entre 21% y 32% en el largo plazo para Chile en el período 1986-2001. Contrario a la creencia generalizada no se encontró evidencia de un traspaso procíclico. Los datos apoyan la existencia de un cambio estructural en 1991, después del cual los coeficientes de traspaso se reducen significativamente desde valores cercanos al 20% hasta estimaciones que se ubican en el tramo entre 5% y 7%.

JEL Classification: F31, E31.

Keywords: *Exchange rate, Devaluation, Pass-through, Inflation, Endogenous Mark-up, Oligopolistic Cournot Competition.*

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I. Introduction

Is there a theory that supports a pass-through from devaluation to inflation? What is the magnitude of this supposed transfer? What determines the pass-through? Is this relationship constant all of the time? These are the questions that we will try to answer, using Chilean data from the period 1986-2001.

The importance of the relationship between the nominal exchange rate and domestic prices is crucial for all those countries that must decide its intervention when faced with movements in the nominal exchange rate (NER). The abandonment of a fixed exchange rate regime also brings the same concern about repercussions in national prices because of the free exchange rate movement. Therefore, the decision of some degree of exchange rate intervention or its absence will be conditioned by the prospective magnitudes of the mentioned pass-through. Likewise, this determination could consider the macroeconomic context in which the exchange movements are made, not allowing for a constant pass-through in all eventualities or a structural break.

There is a vast body of literature about the relationship between the nominal exchange rate and prices. In the theoretical field (Dornbusch 1987, Taylor 2000), there are recurrent contexts of oligopolistic competition or slow adjustment of prices to justify an incomplete pass-through or one conditioned by other factors.

There are two extreme theories about setting prices on tradable goods. First, *Producer-Currency pricing*: in this perspective the law of one price is assumed to hold across all individual goods, as in Obstfeld and Rogoff (1998). If it holds true, there is a full pass-through at least in all tradable goods.

Second, *Local-Currency pricing* supports completely the disconnection between NER and prices, so pass-through is equal to 0%. That is because export firms can set their prices in foreign currencies (home and foreign markets are segmented), so in the short run its decisions are not affected by NER changes. Devereux, Engel and Storgaard (2003) show firms that choose the currency in which to set their prices, so an endogenous pass-through arises.

Another vision centered the attention on distribution cost for a retail sale, which is to incorporate a non-tradable cost in a tradable sector, so domestic factors arise in costs and incorporate a wedge between retail prices in different countries and obviously the shift in tradable / non-tradable relative price. Burstein, Neves and Rebelo (2001) found that this cost is really important (40% in US tradable price) and studied this implication for exchange rate based stabilizations.

Those theories just consider tradable goods, but Kikuchi and Sumner (2002) emphasized that the NER effect on long run export price is only through raw material import prices. Given that in Chile imported inputs are very important, it justifies a pass-through analysis from NER to aggregate consumer domestic price.

In the empirical literature (Feenstra and Kendal (1994), Borensztein and De Gregorio (1999), Goldfajn and Werlang (2000), Campa and Goldberg (2002)), we find an incomplete pass-through whose magnitude is notably dissimilar among countries, spells of time and macroeconomic contexts.

For American countries Goldfajn and Werlang (2000) found a pass-through close to 20% in a 3-month horizon analysis. After, the pass-through coefficient increases the longer the time horizon analyzed. The NER pass-through coefficient has its maximum value in a 12-month horizon.

For Chile in particular, García and Restrepo (2001), assumed sticky prices in the short run that makes price changing costly, so they derive an equation for prices and wages. Modeling wages and prices as I(2) series they find that a nominal devaluation has real effects that disappear in the long run.

Bravo and García (2002), using a VAR, estimate a NER pass-through of 10% in a year and 20% in two years. Choosing different periods of the sample they found a decreasing pass-through.

Morandé and Tapia (2002) showed a decreasing coefficient (using a recursive VAR), from close to 40% in the middle of the 90's, to between 10 and 15% at the end of the sample. Through OLS estimations, the authors find that the coefficient is explained by inflation volatility, output gap, real exchange rate misalignment and an exchange rate regime dummy. They also suggest other reasons for a decreasing pass-through: i) shifts in people's reaction to NER fluctuation, ii) development of financial instruments that allow hedging the exchange rate risk, iii) reduction of margins in retail activity.

The present paper seeks to contribute to the discussion of pass-through from devaluation to inflation at the theoretical level, developing a microeconomic model that shows an explicit relationship between the exchange rate and prices. At the empirical level, we estimate the magnitude and temporary characteristics of the pass-through in Chile between the years 1986-2001.

The paper is structured as follows: in section II the microeconomic model is developed, relating the nominal exchange rate to domestic prices; in section III the econometric estimations use data from Chile (1986-2001), and finally the conclusions are presented in section IV.

II. Theoretical Model

The main objective of this model is to develop, starting from microeconomic foundations, and using a context of oligopolistic Cournot competition, an explicit relationship between final prices and the NER, which could be conditioned by microeconomic theory variables and by other macroeconomic aspects.

II.1. Representative consumer

In this section, after the utility maximization of a representative agent who faces a budgetary restriction, the demand functions are obtained, whose arguments are income and prices. This demand is observable by the firms. They will later use this demand to determine the optimal price policy.

The representative consumer, who consumes two kinds of goods (tradable and non-tradable) faces an interest rate *r*. The representative consumer lives for infinite periods, maximizing his utility, subject to his budgetary restriction, which is expressed in nominal terms for every period.

$$(1) \qquad \underset{\{C_t^T, C_t^N\}}{Max} \; U = \int_0^\infty \left[\left(\frac{\left((C_t^T)^{\zeta} (C_t^N)^{1-\zeta} \right)^{1-\chi}}{(1-\chi)} \right) exp(-\rho t) \right] dt$$

$$s.t.:(2) \quad \dot{b}_t = rb_t + \frac{1}{e_t}(w_t L_t + F_t^N + F_t^T - P_t^T C_t^T - P_t^N C_t^N)$$

The agent's utility is determined by the consumption of the quantities C_N and C_T, to its respective nominal prices P_N and P_T, b is the stock of international assets, and e is the nominal exchange rate (pesos/dollar), ρ is the temporal discount rate and $(1/\chi)$ is the substitution intertemporal rate. The nominal incomes are represented by wage w (for each unit of work of L); the agent also receives a F_N and F_T (payment to a fixed factor of each representative production function (land, or any other specific factor).

To solve this problem, Ponzi games should not be allowed, that is:

$$\lim_{T \to \infty} \left[\left(\frac{1}{1+r} \right)^T b_T \right] = 0 \tag{3}$$

To find the demand functions for both goods, we assume $r = \rho$, and the usual assumption of NPG. To solve the demand in a simple form, the future nominal prices of each kind must be known, so we assumed that the consumer has static expectations:

$$P_t^T = P_{t+j}^T; \qquad P_t^N = P_{t+j}^N \quad \forall j \geq 1 \tag{4}$$

Solving the demand for each one of the goods:

$$C^T = \frac{Y\zeta}{P^T} = (Q^T)^d \tag{5}$$

$$C^N = \frac{Y(1-\zeta)}{P^N} = (Q^N)^d \tag{6}$$

Where Y represents the consumer's total wealth, in nominal terms:

$$Y = r\left[(1+r)e_0 b_0 + \int_0^\infty (w_t L_t + F_t^T + F_t^N) \exp(-rt) dt \right] \tag{7}$$

II.2. Representative Firms

In this section the optimal price policy will be derived. We assume a Cournot oligopolistic competition and a representative Cobb-Douglas production function firm, which, using consumer's known demands, finds a mark-up that depends on prices and consumer's income.

The price policy allows us to bind a steady state, where the firm's number would eliminate any revenues, reaching a zero-profit situation. The next step is to model the price transition after an exogenous change in consumer's income to achieve a new steady state.

Regarding the production function, it would be a technology with a constant marginal cost and a fixed cost; with two inputs:[1] work L and a productive factor M, that represents machinery or any other imported factor (including retail sales).

The tradable sector includes production and import firms.[2] The non-tradable sector corresponds to production firms of goods for domestic consumption only.

The minimization of costs, subject to technology is:

$$\underset{\{L,M\}}{Min} \quad C = wL + sM + F \tag{8}$$

s.t.: (9)
$$Q = A(M)^{\alpha}(L)^{1-\alpha}$$

where F is the nominal fixed cost, L represents the input work (nominal unitary cost of w) and M is the foreign input, where price s depends on international prices IP and the nominal exchange rate e $(s=IP*e)$. Notice that since both sectors have in their inputs labor and import factors then the nominal exchange rate affects both sectors' prices.

Total costs are:

$$C(Q,w,s) = \left[\frac{Q}{A}\right]\left(w^{1-\alpha}s^{\alpha}\right)\left[\left(\frac{\alpha}{1-\alpha}\right)^{-\alpha} + \left(\frac{\alpha}{1-\alpha}\right)^{1-\alpha}\right] + F \tag{10}$$

Therefore, marginal cost percentage variation is:

$$C\hat{M}g = (1-\alpha)\hat{w} + \alpha\hat{s} - \hat{A} \tag{11}$$

II.3. Steady State

Once costs structure is defined, we can analyze Nash's equilibrium in Cournot oligopolistic competition with symmetrical firms. Differences among sectors, are given only by parameters, therefore the reasoning shown can be generalized to both sectors.

Formally, each firm maximizes profits individually (Π_i), according to its own production consequences on price.

$$\underset{\{q_i\}}{Max} \quad \Pi_i = P(Q)q_i - C(q_i) \tag{12}$$

Therefore, the first order condition is:

[1] Similar to oligopolistic technology in Dixit and Stiglitz (1977).

[2] See Morandé (1986).

$$\frac{\partial P(Q)}{\partial q_i} q_i + P(Q) - \frac{\partial C(q_i)}{\partial q_i} = 0 \tag{13}$$

where Q represents total production (sum of the individual productions of each firm):

$$Q = \sum_{i=1}^{n} q_i = nq; \quad \frac{\partial Q}{\partial q_i} = \frac{\partial \sum_{j=1}^{n} q_j}{\partial q_i} = 1 \tag{14}$$

The demands (5) and (6), in (13) determine the quantity and equilibrium price (denoted *), defining the price policy, where n (number of firms), consumer preference parameters,[3] income and nominal marginal cost are constant.

$$q^* = \left(\frac{n-1}{n^2}\right)\left(\frac{\varepsilon Y}{CMg}\right) \tag{15}$$

$$Q^* = nq^* = \left(\frac{n-1}{n}\right)\left(\frac{\varepsilon Y}{CMg}\right) \tag{16}$$

$$P^* = \left(\frac{n}{n-1}\right)CMg = \left(1 + \frac{1}{n-1}\right)CMg \tag{17}$$

To find a steady state, the number of firms must be adjusted in such a way as to achieve zero-profits, as in Dixit and Stiglitz (1977). The number of firms, until now exogenous, determines quantities, prices and mark-up.

Each firm's nominal profits are:

$$\Pi(n) = \left(\frac{\varepsilon Y}{n^2}\right) - F \tag{18}$$

So that the number of firms allows for profits, however it is clear that revenues will attract or will take out firms from the market, thus in a long term perspective, the market will force the firm's number to this zero-profits condition:

$$\Pi(n^*) = 0 \Leftrightarrow n^* = \sqrt{\frac{\varepsilon Y}{F}} = \sqrt{\frac{\varepsilon Y_R}{F_R}} \tag{19}$$

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[3] ε could represent both sectors' parameter: tradable (ξ) or non-tradable ($1-\xi$).

In (19), we can transform the nominal relationship into a real one, using a common denominator. From the last equation an increase in consumer's real income implies that the firms' number will be greater, so we find an explicit relationship between the consumer's real income and the number of firms per sector.

II.4. Price Dynamics

Once price policy and long term conditions are characterized, we can introduce price dynamics. So that changes in demand, caused by income alterations, move prices and each producer's quantities.

The transition can be characterized by a partial adjustment in each sector's aggregate production. Thus, exogenous income movement does not imply an instantaneous adjustment in the firm numbers, nor in each individual production. This could be due to different technological, financial and legal obstacles, restrictions of capacity, etc. It is assumed that the firm's entrance or exit from the market is gradual, displacing the price-quantity relationship through the new demand.

The gradual adjustment of individual firm quantity (where *t* indicates a specific moment in time, and *F* means new steady production state) will be modeled as a simple partial adjustment process, being justified with models like Calvo (1983):

$$Q^t = (1-\lambda)Q^F + \lambda Q^{t-1} = Q^F + \lambda(Q^{t-1} - Q^F) \tag{20}$$

Neither an individual firm's quantity of goods, nor the number of firms can make an instantaneous adjustment in the short run. This could be justified because convex investment adjustment costs make a gradual investment of capacity optimal. Some congestion in the producer's requirements forces a non-instantaneous adjustment of the number of firms.

Although the transition will not distinguish the movement of each one of those variables, their new steady state values are known. We already know that after an increase in consumer's income, the number of firms of each sector and the long-term production of each firm will be greater; and following the model, the price will be smaller.

Replacing gradual adjustment (20) in goods demand (5) and (6), the equilibrium price is obtained for each instant. We noted *0* for initial state, *1* for the next one and so on. The final state (and new steady state) is noted by *F*:

$$P^0 = \left(\frac{\varepsilon Y^0}{Q^0}\right) = CMg\left(1 + \frac{1}{n^0 - 1}\right) \tag{21}$$

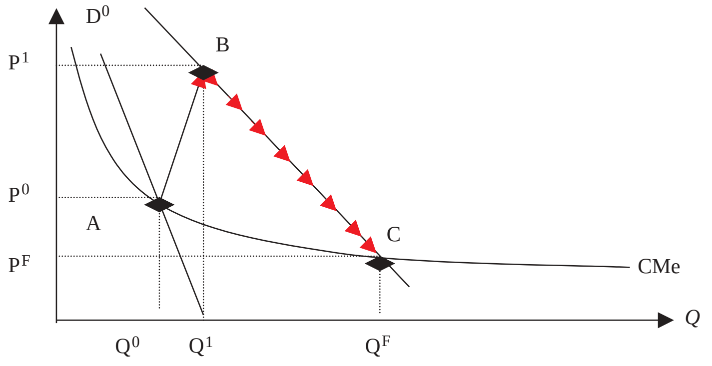
$$P^1 = \left(\frac{\varepsilon Y^F}{Q^1}\right) = \left(\frac{\varepsilon Y^F}{Q^F + \lambda(Q^0 - Q^F)}\right) \tag{22}$$

(23) $$P^{i+1} = \left(\frac{\varepsilon Y^F}{Q^{i+1}}\right) = \left(\frac{\varepsilon Y^F}{Q^F + \lambda(Q^i - Q^F)}\right); \forall i \in \mathrm{N}$$

(24) $$P^F = \left(\frac{\varepsilon Y^F}{Q^F}\right) = CMg\left(1 + \frac{1}{n^F - 1}\right)$$

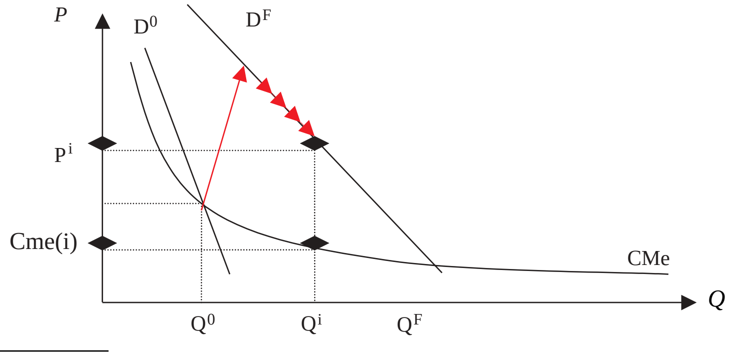
The new steady state is independent of adjustment speed. In the short run, if the adjustment is sufficiently gradual, a procyclical mark-up[4] can be observed (Graph 1).

GRAPH 1
PROCYCLICAL PRICE IN TRANSITION TO NEW EQUILIBRIUM



This gradual adjustment in aggregate production makes profits possible in the short term. The transitory benefits are shown in Graph 2.

GRAPH 2
REVENUES BECAUSE OF GRADUAL ADJUSTMENT



4 See proof in appendix 10.

II.5. Effect on Wages

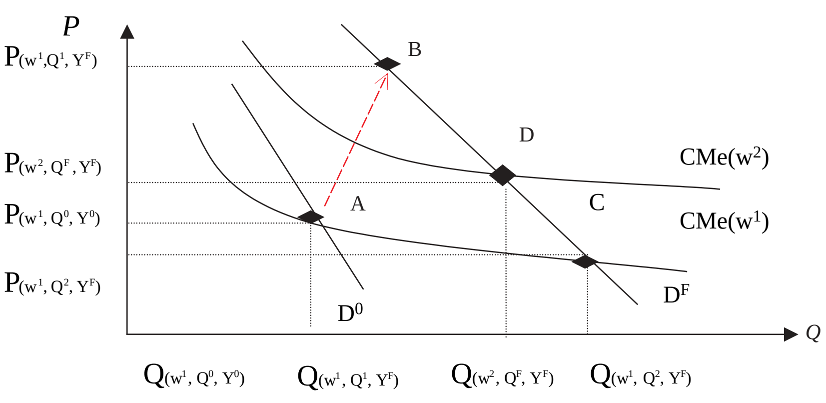
We also assume that the labor offer doesn't have an infinite elasticity, so an expansion in labor demand will necessarily bring an increase in real wages. Therefore, it has consequences in firm costs, changing the steady state.

II.6. Price Summary Dynamics

The price effects can be summarized in Graph 3. After a consumer income increase, the following must be expected:[5]

1. An increase in number of firms, in the long run.
2. An increase in each quantity of firm output.[6]
3. Given the assumed technology, this necessarily implies a drop in price.
4. A wage increase in the labor market implies an increase in the firm's costs.
5. A gradual adjustment of the output quantity generates a procyclical mark-up (if adjustment speed is not too fast).

GRAPH 3
SYNTHESIS OF THE TRANSITION MOVEMENTS OF PRICE



The effect of gradual adjustment is shown as the discreet displacement from the initial equilibrium A to B, over higher income demand. Since aggregate quantity is not enough for new demand, in the short run, a high price makes a firm's positive profits possible.

Therefore, a gradual output increase (graphically a gradual movement from B to C over the initial medium costs) decreases the price. In this context, a price lower than A is always implied.

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5 Without loss of generality one can obtain the inverse results for an income decrease.

6 See Proof in appendix 11.

Finally, a higher labor demand increases the real wages (from W_1 to W_2) and forces a higher marginal cost, reflected in the output price (from C to D).

In the short run, because of gradual adjustment, the prices are procyclical. In the long run, the final price is uncertain because of the unknown magnitude of opposing forces.

Thus, a change in price levels can be caused by exogenous increases of input price, or changes in consumer's income, so that the pass-through from costs to final price depends on the economic environment.

In this model, from equation 17, 19 and incorporating the effect on wages, we could say that prices are a non-linear function of consumer's income and marginal costs, so implicitly:

$$P = G(Y_R)CMg \tag{25}$$

Where *G(.)* is a non-linear function of real income. It can always be locally approximated by a linear function $G(Y_R) \approx \theta_0 Y_R$, so that price variation could be written as follows:

$$\hat{P} = \theta_0 \hat{Y}_R + C\hat{M}g + \theta_0 C\hat{M}g\hat{Y}_R \tag{26}$$

Finally, using equation 11:

$$\hat{P}^j = \theta^j \hat{Y}_R + (1-\alpha^j)\hat{w} + \alpha^j \hat{s} - \hat{A}_j + \theta^j(1-\alpha^j)\hat{Y}_R\hat{w} + \theta^j\alpha^j\hat{Y}_R\hat{s} - \theta^j\hat{Y}_R\hat{A}^j \tag{27}$$

Where j indicates each sector (tradable or non tradable), $j \in \{T, N\}$.

II.7. Aggregate Domestic Prices

Since domestic price level (PD) can be disassembled into tradable and non-tradable components, maintaining a homogeneous relationship of grade 1:

$$PD = (P^T)^{\phi}(P^N)^{(1-\phi)} \Rightarrow \Pi = \phi\hat{P}^T + (1-\phi)\hat{P}^N \tag{28}$$

Where ϕ represents the tradable goods share in total price level and inflation will be denoted Π.

For this paper, we attempt to determine the pass-through from the nominal exchange rate (NER) to inflation; therefore we do include money in the model.[7]

Replacing equation 27 in 28, we obtain the central equation:

$$\begin{aligned} \Pi_t = {} & \phi\left(\theta^T\hat{Y}_t + (1-\alpha^T)\hat{w}_t + \alpha^T\hat{s}_t - \hat{A}_t^T + \theta^T(1-\alpha^T)\hat{Y}_t\hat{w}_t + \theta^T\alpha^T\hat{Y}_t\hat{s}_t - \theta^T\hat{Y}_t\hat{A}_t^T\right) \\ & + (1-\phi)\left(\theta^N\hat{Y}_t + (1-\alpha^N)\hat{w}_t + \alpha^N\hat{s}_t - \hat{A}_t^N + \theta^N(1-\alpha^N)\hat{Y}_t\hat{w}_t + \theta^N\alpha^N\hat{Y}_t\hat{s}_t - \theta^N\hat{Y}_t\hat{A}_t^N\right) \end{aligned} \tag{29}$$

7 In appendix 12, there is a possible way of including money and its effects on price level.

Remember, $\hat{s} = \hat{e} + \hat{P}i$, so we can write:

(30)
$$\Pi_t = \Phi_0(\hat{e}_t + \hat{P}i_t) + \Phi_1\hat{w}_t + \Phi_2\hat{Y}_t + \Phi_3\hat{A}_t^T + \Phi_4\hat{A}_t^N$$
$$+\Phi_5\hat{Y}_t(\hat{e}_t + \hat{P}i_t) + \Phi_6\hat{Y}_t\hat{w}_t + \Phi_7\hat{Y}_t\hat{A}_t^T + \Phi_8\hat{Y}_t\hat{A}_t^N$$

According to the theoretical framework, the coefficients should have the following restrictions:

Pass-through coefficient from NER to domestic prices.

$$\Phi_0 = \{\phi\alpha^T + (1-\phi)\alpha^N\} \in (0,1)$$

Pass-through coefficient from nominal wages to domestic prices.

$$\Phi_1 = \{\phi\left(1-\alpha^T\right) + \left(1-\phi\right)\left(1-\alpha^N\right)\} \in (0,1)$$

Effect of income on domestic prices.

$$\Phi_2 = \phi\theta^T + \left(1-\phi\right)\theta^N; \text{ (uncertain).}$$

Effect of tradable sector productivity.

$$\Phi_3 = \left(-\phi\right) \in (-1,0)$$

Effect of non-tradable sector productivity.

$$\Phi_4 = \left(\phi - 1\right) \in (-1,0)$$

Pass-through coefficient from NER to domestic prices, conditioned by income change.

$$\Phi_5 = \phi\alpha^T\theta^T + (1-\phi)\alpha^N\theta^N \text{ (uncertain).}$$

Pass-through coefficient from nominal wages, conditioned by income.

$$\Phi_6 = \phi(1-\alpha^T)\theta^T + \left(1-\phi\right)(1-\alpha^N)\theta^N \text{ (uncertain).}$$

Effect of tradable productivity, conditioned by income.

$$\Phi_7 = -\phi\theta^T \text{ (uncertain)}$$

Effect of non-tradable productivity, conditioned by income.

$$\Phi_8 = (\phi - 1)\theta^N \quad \text{(uncertain)}$$

Some of the most interesting implications of the model are:

- Pass-through from nominal exchange rate must be identical to international prices pass-through.
- The sum of the effects of the nominal exchange rate and nominal wages should be 1 to keep the homogeneity of grade one, between input prices and output prices.
- The sum of productivity coefficients should be -1, so that, an increase in productivity implies a decrease in prices.
- NER pass-through to inflation will never be 100%, because NER is just a share of the total costs of each sector.
- In contrast to a perfect market, this model price will never be equal to marginal costs due to fixed costs. The fixed cost determines the necessary mark-up (through the number of firms) to reach zero-profits in the long run.
- The main difference with a perfect market is a price associated to consumers' income. A way to validate the model would be to test if income coefficients are statistically significant.

III. Empirical Analysis

III.1. Data

This paper uses the quarterly data of Chile from 1986:1 to 2001:1 (domestic prices, product, nominal wages, observed nominal exchange rate, external prices), which are based on official information from the Central Bank of Chile (BCCh) and the National Institute of Statistics (INE). A detailed description of the sources, the methodologies and the descriptive statistic of the annual percentage of the variation of every series are in Noton (2002).

III.2. Econometric Estimations

The central equation to estimate is equation 30, which relates to inflation and NER movement. We have made all of the following possible specifications.

A) Liberation from theoretical restriction. So the NER pass-through coefficient is not obliged to be identical to international prices (abbreviated series CPI) pass-through coefficient.

B) We have considered a static version (only includes contemporary variables) and a dynamic version (includes lagged dependent variable).

C) To approximate income, we have used GDP growth (abbreviated series GDP) and also the gap between effective and potential outcome, the latter was obtained through an HP filter (abbreviated series GAP).

D) The External prices (abbreviated series IPE) built by the BCCh were used and USA inflation (abbreviated series CPI). The results obtained using the latter are supported by the theory. Therefore, IPE estimates (sensitive to the devaluations of trade partners) are only included in the appendix.

In all the following charts, the calculated t-test will be shown under each estimated coefficient. The variances and covariance's matrix used was Newey-West, which considers heteroskedasticity and autocorrelation (third order). The first two columns always include all variables.

We call the equations that just include contemporaneous variables "static" representations, because the estimates will be the long run coefficients. We call the equation that includes a dependent variable lagged "dynamic" representation, because the specification allows finding a short and a long run coefficient.

The 3rd and 4th columns are the best static representations. The last two columns (5th and 6th) are the best dynamic representations. The odd columns use growth of GDP and the even columns use the gap between outcome and potential outcome (GAP). A constant and a deterministic trend have been included in order to model the successful reduction targeting inflation policy. That implies a stationary inflation trend in the period analyzed, where shocks are transitory around the decreasing trend in the 90's.

The estimates in Chart 1 do not impose restrictions on NER pass-through and international prices pass-through (point A).

As a result of this first approach by OLS we can say:

- NER pass-through, in static specifications, is between 12% and 15%.
- NER pass-through, in dynamic specifications, is between 9% and 11% in the short run, while in the long run it is between 12% and 14%.
- GDP growth or gap does not explain much of the inflation.
- Change in wage transfers to prices between 39% and 47% in the long term, and between 28% and 44% in the short run.
- Increase in non-tradable productivity implies a decrease in domestic prices; but tradable productivity is not transferred to domestic prices.
- A deterministic trend is always negative and significant, showing the inflation targeting policy.
- Dynamic versions indicate that lagged inflation explains 24% or 25% of inflation forecast.
- The null hypothesis that all coefficients related to income are simultaneously not significant is rejected.

A possible critique to recent estimations is that inflation determines NER in the contemporary relationship. Moreover, in this period a system of exchange rate bands was established by the monetary authority, which determined the feasible range for NER.

CHART 1
OLS ESTIMATIONS

	1	2	3	4	5	6
Constant	0.03 *1.17*	0.02 *1.00*				
Trend	–0.0010 *–3.00*	–0.0009 *–3.40*	–0.0007 *–5.06*	–0.0007 *–5.48*	–0.0005 *–4.10*	–0.0005 *–4.07*
NER	0.11 *2.19*	0.16 *5.45*	0.12 *3.51*	0.15 *5.20*	0.09 *2.89*	0.11 *3.07*
NER*GDP	0.09 *0.10*					
NER*GAP		–0.97 *–0.95*				
CPI	1.28 *2.55*	1.31 *5.99*	1.77 *9.16*	1.49 *7.83*	0.90 *6.79*	1.21 *7.94*
CPI* GDP	–4.58 *–0.63*		–8.80 *–7.57*			
CPI*GAP		–12.77 *–2.60*		–8.90 *–8.28*		–7.15 *–5.32*
GDP	–0.12 *–0.61*					
GAP		0.003 *0.018*				
Wages	0.47 *3.54*	0.35 *5.71*	0.47 *12.15*	0.39 *9.13*	0.44 *4.72*	0.28 *4.03*
Wages*GDP	–0.66 *–0.38*				–1.57 *–5.13*	
Wages*GAP		1.14 *0.90*				
Tradable Prod.	0.44 *2.78*	0.65 *3.93*	0.40 *2.83*	0.69 *6.01*	0.38 *2.91*	0.59 *4.23*
Tradable Prod.*GDP	4.87 *2.92*		5.18 *3.88*		4.83 *3.69*	
Tradable Prod.*GAP		4.97 *2.95*		6.41 *4.67*		5.81 *4.03*
Non-Tradable Prod.	–0.18 *–2.92*	–0.35 *–3.95*	–0.17 *–3.58*	–0.39 *–5.83*	–0.14 *–4.65*	–0.37 *–5.44*
Non-Tradable Prod.*GDP	–3.47 *–2.08*		–4.11 *–4.33*		–4.54 *–4.02*	
Non-Tradable Prod.*GAP		–3.97 *–2.70*		–5.22 *–5.13*		–4.93 *–4.05*
Lagged Inflation					0.25 *1.94*	0.24 *1.84*
Adjusted R-squared	0.96	0.96	0.97	0.96	0.97	0.97

The t-test is under each coefficient (Newey-West HAC matrix). Not reported coefficients are statistically not significant.

We did tests trying to determine weak exogeneity for the parameter in question. The evidence shows that a contemporary relationship exists, and that the series do not have a weak exogeneity. Due to this, we have carried out the same estimates using instrumental variables. The variables used as instruments were lagged NER, lagged GDP (or GAP), lagged nominal wages, and lagged inflation. Quantity of money (M1A) was also used as an instrument that is related to possible endogenous variables. Residues of each column of Chart 2 are not correlated with their corresponding instruments so they are really exogenous.

Chart 2 shows two stages least square estimates (TSLS), where international inflation and productivity are considered exogenous. The differences among columns are the same as in Chart 1.

As a result of this second approach by TSLS we can say:

- The estimation of the NER pass-through is higher than the international prices pass-through.
- NER pass-through, in static specifications, was around 18%. Slightly higher than those presented in Chart 1 (OLS).
- NER pass-through, in dynamic specifications, was estimated at 12% in the short run, and close to 20% in the long run.[8]
- NER pass-through, where the interaction with income was statistically significant, the coefficient observed is contracyclical.
- Income does not explain much of the inflation.
- Nominal wages explain between 43% and 48% in the long run, while in the short term the figure lies between 18% and 20%.
- Again, the evidence shows that an increase in non-tradable productivity is transferred into a decrease in domestic prices. Tradable results are the opposite, that is to say, the sign found in the coefficient is positive and is robust for any specification. This could be because of a measurement error in calculating the productivity. Another null hypothesis could be that a productivity increase (or technological advance) is related to a quality improvement and not to a price reduction. Unfortunately this kind of analysis cannot be tested in this homogeneous quality benchmark.
- As in chart 1, the deterministic trend is always negative and significant, showing the inflation targeting policy, and the null hypothesis that all coefficients related to income are simultaneously not significant is rejected.
- Dynamic versions indicate that the inflationary inertia increases significantly, in relation to chart 1, explaining between 40% and 68% of the inflation forecast.

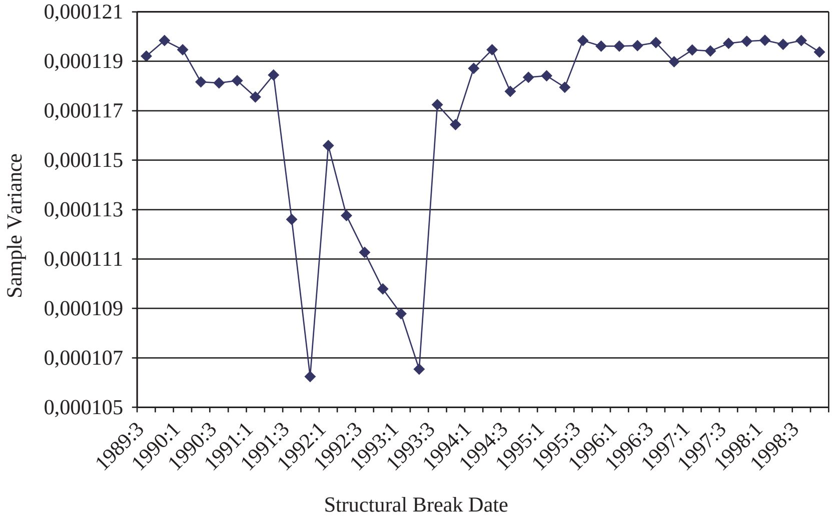
8 5th column was not considered, since it was extremely unstable and sensitive to the specification.

CHART 2
TSLS ESTIMATIONS

	1	2	3	4	5	6
Trend	–0.0008 *–2.95*	–0.0006 *–3.47*	–0.0007 *–5.34*	–0.0006 *–3.90*		–0.0004 *–3.01*
NER	0.22 *2.01*	0.14 *1.30*	0.18 *3.24*	0.18 *4.66*	0.18 *4.93*	0.12 *2.13*
NER * GDP	–0.10 *–0.07*				–2.14 *–4.40*	
NER * GAP		–2.54 *–0.48*				–2.39 *–2.04*
CPI	1.30 *1.85*	1.52 *4.09*	1.54 *9.94*	1.41 *6.72*		0.97 *6.20*
CPI * GDP	–6.52 *–0.59*		–9.04 *–7.56*			
CPI * GAP		–23.65 *–1.92*		–28.79 *–3.84*		
GDP	0.11 *0.36*					
GAP		–0.25 *–0.38*				
Wages	0.52 *3.59*	0.42 *11.30*	0.48 *11.35*	0.43 *11.84*	0.18 *2.61*	0.20 *2.63*
Wages * GDP	–0.99 *–0.45*					
Wages * GAP		3.33 *1.14*		4.75 *2.87*		
Tradable Prod.	0.36 *1.65*	0.53 *2.75*	0.40 *2.69*	0.47 *3.44*	0.33 *3.63*	0.48 *2.60*
Tradable Prod.* GDP	5.41 *2.57*		4.93 *3.51*			
Tradable Prod.* GAP		4.41 *1.60*				3.49 *3.10*
Non-Tradable Prod.	–0.11 *–1.03*	–0.33 *–4.17*	–0.16 *–3.45*	–0.27 *–4.04*	–0.28 *–4.49*	–0.32 *–3.99*
Non-Tradable Prod.* GDP	–3.76 *–2.43*		–3.33 *–2.40*			
Non-Tradable Prod.* GAP		–1.81 *0.45*				–3.45 *–2.65*
Lagged Inflation					0.68 *6.83*	0.40 *2.65*
Adjusted R-squared	0.96	0.95	0.96	0.95	0.96	0.98

The t-test is under each coefficient (Newey-West HAC matrix). Not reported coefficients are statistically not significant.

GRAPH 4
SAMPLE VARIANCE AS A FUNCTION OF STRUCTURAL BREAKS IN THE NER PASS-THROUGH COEFFICIENT



III.3. Model and Estimates

In general terms, using data for Chile 1986-2001, the theoretical microeconomic restrictions enumerated in section II are rejected (we don't find reasonable structural parameters), however it is necessary to highlight that in all the estimates the null hypothesis of perfect competition is rejected. Therefore we can say that the model developed an explanatory variable correctly, leaving a perfect market paradigm, but we did not find the right restriction set sustained by the data.

III.4. Analysis of Pass-through Parameter Stability

Another important issue is if the NER pass-through parameter has been constant in all periods of analysis. Focusing on the NER parameter and trying to find a structural break date in an endogenous way, Hansen (2001) shows a sequential search of the change in some parameter. The chosen structural break time will be the episode that minimizes the sum of squared errors.

Graph 4 shows how sample variance changes when breaks are allowed in the pass-through coefficient (using the specification described in the 5th column of Chart 1), starting from each particular moment (search was restricted between 1989:3 and 1999:1 quarters).

The structural break dates that best fit are: 1991:4 and 1993:2. The fourth quarter of 1991 was considered because of econometric properties[9] and estimated minimum variance value. The results are in Chart 3, where the first 2

9 1993's pass-through estimates had worse econometric properties than the 1991 ones.

CHART 3
ESTIMATES WITH A NER PASS-THROUGH STRUCTURAL BREAK IN 4TH QUARTER 1991

	1	2	3	4	5	6
Trend	–0.0004 *–3.78*	–0.0003 *–3.26*	–0.0004 *–3.67*	–0.0003 *–2.96*		
NER	0.24 *4.41*	0.18 *2.85*	0.27 *5.52*	0.22 *3.55*	0.19 *2.38*	0.41 *4.56*
+NER after 4:91	–0.17 *–3.05*	–0.13 *–2.07*	–0.19 *–3.57*	–0.16 *–2.62*	–0.15 *–1.75*	–0.31 *–2.99*
CPI	0.84 *5.53*	0.69 *6.37*	1.05 *6.92*	0.90 *6.25*	0.69 *2.63*	
CPI*GAP			–8.15 *–7.87*	–6.86 *–4.89*		–6.45 *–2.08*
GDP					–0.41 *–4.55*	
Wages	0.58 *18.47*	0.46 *5.41*	0.42 *12.77*	0.33 *5.27*	0.61 *9.54*	0.54 *9.63*
Wages*GDP	–1.69 *–5.75*	–1.45 *–4.21*				
Tradable Prod.	0.29 *3.11*	0.30 *2.95*	0.59 *5.38*	0.53 *4.34*	0.76 *4.18*	0.55 *3.33*
Tradable Prod*GDP	6.15 *5.32*	5.16 *4.26*				
Tradable Prod*GAP			6.84 *6.33*	6.27 *5.30*		
Non-Tradable Prod.	–0.13 *–3.85*	–0.13 *–5.17*	–0.35 *–5.12*	–0.34 *–5.27*	–0.39 *–3.54*	–0.26 *–2.42*
Non-Tradable Prod.*GDP	–4.28 *–4.34*	–4.17 *–4.10*				
Non-Tradable Prod.*GAP			–4.50 *–4.65*	–4.40 *–4.21*		
Lagged Inflation		0.21 *1.72*		0.19 *1.68*		
Adjusted R-squared	0.97	0.97	0.97	0.97	0.95	0.94

The t-test is under each coefficient (Newey-West HAC matrix). Not reported coefficients are statistically not significant.

columns were estimated by OLS, both using GDP growth, in static (1) and dynamic (2) specifications. Columns 3 and 4 use the gap between potential and effective GDP. Columns 5 and 6 are TSLS static estimates (using GDP and GAP respectively), with the same instruments already mentioned.

After this third approach, we can say:

- In OLS static estimates, we could not reject the null hypothesis that the NER pass-through fell from 24% or 27% (before last quarter of 1991) to 7% or 8 (after that date).
- In OLS dynamic estimations, there is also evidence that short run NER pass-through decreased from 18% or 22% to 5% or 6%. The long run pass-through coefficients also decreased from a range between 23-27% to 6-7% range.
- In TSLS estimations, before 1991:4, NER coefficients are highly dissimilar (19% and 41%); however, after the structural break they became closer (between 4% and 10%).
- The international inflation pass-through coefficient decreased (estimated coefficients higher than 1 were no longer found). This coefficient was always different from the NER pass-through.
- There were not significant changes (statistical significance or coefficient sign) from previous charts in the other variables.

It is necessary to point out that the last estimates were obtained, after allowing a structural break in the NER pass-through. In theoretical terms it is hard to justify a structural break at some arbitrary date. *A priori* undiscarded hypothesis is based on Taylor (2000). This paper shows how an economic agent perception of a price stability environment diminishes the cost pass-through, if these cost variations are perceived as transitory movements.

IV. Conclusions

To study the nominal exchange rate pass-through to inflation, a microeconomic model of oligopolistic Cournot competition has been developed. We have obtained an explicit endogenous relationship between price level and the nominal exchange rate; which is based on a mark-up that varies endogenously with real consumer income and justifies a relationship between prices and economic cycle, abandoning the usual *ad-hoc* models in the literature on exchange rate pass-through; however we don't find reasonable structural parameters with the Chilean data.

The nominal exchange rates' pass-through to inflation was estimated under different econometric techniques, definitions of variables and specifications. As a result, the exchange rate pass-through in Chile (years 1986-2001) was 12% in the short run, while the long run total effect should be expected to be around 18%.

Regarding the pass-through evolution, we did a sequential search to find an endogenous structural break date. The evidence does not reject the hypothesis of a break in the last quarter of 1991, after which, the exchange rate pass-through decreased from coefficients of around 20% to values between 5-7%. Contrary to conventional wisdom, we find no evidence of procyclical pass-through.

In another result the firms had different reactions if the input price increase was caused by nominal exchange rate movements or international price movements. In the latter, a higher pass-through shows evidence of a special sensitivity to international inflation shocks.

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APPENDIX

Description of data:

1. **Domestic prices:** the National Institute of Statistics (INE) publishes the series of Chilean consumer price index (IPC). The frequency is monthly and through a simple 3 month average the quarter value is obtained. The inflation is the annual percentage variation of the price level.

2. **Nominal Exchange Rate (NER):** The series of observed dollar price (pesos/dollar) is published by the Central Bank of Chile (BCCh). The frequency is monthly and the quarter value is obtained through a simple 3 month average. The devaluation is the annual percentage variation of the observed price.

3. **USA inflation (CPI) and index of external prices for Chile (IPE):** There is no unanimous opinion about which indicator is closer to international inflation. There is an indicator of external prices concerning Chile (IPE), developed by the BCCh. The IPE average is figured by the commercial importance of the wholesaler price index of each trade partner of Chile. This index is expressed in dollars, so it is extremely sensitive to commercial partner devaluations. After exchange rate movements in the second half of the 90's, this index points out deflations of –5% and inflations near to 10%. That is why our estimates use U.S. consumer price index (CPI) which, although it includes non-tradable goods, is not susceptible to international devaluations.

4. **Geographical Product (GDP):** The quarterly GDP series is published by the Central Bank of Chile (BCCh).

5. **Gap Effective-Potential product (GAP):** The last concept is defined by referring to the gap between effective product and potential product. There are a lot of theoretical and methodological options. The present paper opted for the Hodrick-Prescott filter (HP). The difference in effective growth is denominated by the effective-potential product gap (abbreviated as GAP).

6. **Nominal Wage (WN):** The wage series is published by The National Institute of Statistics (INE). It has a monthly frequency and the quarter value is obtained through a simple 3 month average.

7. **Tradable Productivity:** In previous papers, the product per worker has been a proxy of productivity. The ratio is built with the tradable outcome (published by BCCh) and the tradable sector number of workers (published by INE). The following have been considered as tradable sectors: agriculture, fishing, mining and the manufacturing industry. Given the technology assumed, the outcome-workers ratio implies that the imported input-workers ratio remains constant in the period 1987-2001. Formally:

If $Q_T = A(M)^{\alpha}(L)^{1-\alpha} \Rightarrow \frac{Q}{L} = A(\frac{M}{L})^{\alpha}$; Then $\left(\frac{\hat{Q}}{L}\right) = \hat{A} + \alpha\left(\frac{\hat{M}}{L}\right)$

8. Non-Tradable Productivity: Applying the same methodology indicated for the non-tradable sector, we consider the following to be non-tradable sectors: construction, hotels and restaurants, transport and communications, trade, energy, financial, community and personal services.

9. Model Budget restrictions:

1) Tradable Firms: $P_t^T Q_t^T = wL_t^T + sM_t^T + F_t^T$

2) Non Tradable Firms: $P_t^N Q_t^N = wL_t^N + sM_t^N + F_t^N$

3) Balance in Non Tradable Market: $Q_t^N = C_t^N$

4) Consumers: $\dot{b}_t = rb_t + \frac{1}{e_t}(w_t^N + F_t^N + L_t^T w_t^T + F_t^T - P_t^N C_t^N - P_t^T C_t^T)$

5) Aggregate Economy: $\dot{b}_t = rb_t + \frac{1}{e_t}(P_t^T Q_t^T - P_t^T C_t^T - sM_t)$

10. Adjustment speed procyclical condition:

$$P^0 < P^1 \Leftrightarrow \lambda > \left[\frac{Y^0 Q^F - Y^F Q^0}{Y^0(Q^F - Q^0)}\right] \quad \text{where} \quad Q^j = \left(\frac{\varepsilon Y^j - \sqrt[2]{F\varepsilon Y^j}}{CMg}\right)$$

11. Relationship between Income and each firms quantity:

It can be derived directly from equation 15 and 19:

$$\frac{\partial q}{\partial Y_R} = \frac{1}{2CMg_R}\left(\sqrt{\frac{\varepsilon F_R}{Y_R}}\right) > 0$$

12. Money in the model:

We believe that long term inflation is a monetary phenomenon. The model developed does not include money, since it assumes that movements in money quantity determine nominal prices of inputs. So that:

$$\hat{w}_t = \hat{D}_t + \eta_t \quad \text{and} \quad \hat{e}_t = \hat{D}_t + \zeta_t$$

Where D is quantity of money, η and ξ are shocks of each nominal price (wages and the nominal exchange rate, respectively). We do not replace these equations because we are looking for a NER pass-through coefficient.

13. CHART 4: OLS Estimates, using the BCCh International Price Index (IPE):

	1	2	3	4
Constant	0.09 *3.75*	0.08 *3.27*		0.04 *1.80*
Trend	–0.0014 *–3.87*	–0.0014 *–3.83*		–0.0007 *–1.86*
NER	0.16 *3.18*	0.23 *4.36*	0.08 *1.71*	0.14 *2.59*
NER*GAP				–2.01 *–3.26*
IPE	0.34 *5.22*	0.18 *3.25*	0.10 *1.46*	0.09 *1.57*
IPE* GDP	–3.28 *–4.63*			
IPE*GAP		–4.32 *–6.26*		–2.21 *–2.37*
GDP	–0.41 *–6.26*			
GAP		–0.36 *–4.76*		
Wages	0.38 *5.00*	0.29 *3.87*	0.28 *4.65*	0.11 *2.37*
Wages * GDP			–1.20 *–4.49*	
Tradable Prod.	0.85 *6.73*	0.69 *5.23*	0.35 *2.62*	0.39 *3.42*
Tradable Prod.* GDP			2.38 *2.13*	
Tradable Prod.* GAP		3.01 *2.19*		
Non-Tradable Prod.	–0.35 *–4.82*	–0.32 *–3.90*	–0.20 *–3.97*	–0.23 *–3.41*
Non-Tradable Prod.* GDP			–2.47 *–2.35*	
Lagged Inflation			0.58 *6.08*	0.52 *5.45*
Adjusted R-squared	0.95	0.96	0.97	0.97

The t-test is under each coefficient (Newey-West HAC matrix). Not reported coefficients are statistically not significant.