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THE IMPLEMENTATION OF MONETARY POLICY IN AN EMERGING ECONOMY: THE CASE OF CHILE*

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Abstract

Central bank authorities base implementation of monetary policy on an analysis of multiple variables known as monetary policy indicators. In a small open economy such as Chile, these indicators may include inflation misalignments, unemployment, GDP growth, money growth, the current account balance, exchange rate volatility and international reserves. A neural network approach is used to establish the corresponding weights considered by the Board of the Central Bank of Chile during the period 1995-2003. GDP growth and the difference between the actual and the target inflation were found to be among the variables of greatest weight in the monetary policy decision-making process of the Central Bank of Chile during this period.

Keywords*: Monetary Policy, Neural Network.*

JEL Classification*: E52, C45.*

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I. Introduction

One of the most challenging tasks for any central bank is to choose the indicators to be used in the implementation of monetary policy. In short, the question is: what are the variables that would help the board make its policy decision in order to achieve its objective?

For modern central banks, the main policy objective is price stability. The literature on inflation target[1] has emphasized that monetary policy indicators have to be those that help anticipate inflation in the future. To be more precise, an inflation equation is estimated and projections are made for two or three years. If the projected values are not within the range of the inflation target, it is supposed that the monetary authority should change its monetary policy stance. If this were the case, the basic indicators would be those variables that are contained in the inflation equation. However, the long and variable lags in monetary policy (Friedman, 1968) make things more complicated in practice. It has been documented, for instance, that the choice of the set of indicators also depends on the particular preferences of the board members[2]. On the other hand, as countries face different situations and have different data available, the choices they make are different.

One approach that has gained particular popularity in the last decade has been the so-called "Taylor's rule." According to this rule, central banks have a reaction function that depends on certain variables. In particular, Taylor argues, the policy rule of the Federal Reserve includes both lagged inflation and the deviation of real GDP from its potential (the so-called "output gap")[3]. Of course, there are some practical problems with this simplistic rule. Indeed, it is difficult to know ex ante what the level or the growth rate of the potential GDP is. At the same time, it is difficult to believe that lagged inflation is always a good leading indicator or even that a given structure of lagged inflation remains invariable over time. Finally, the monetary policy discussions that take place in central banks, as documented by the published memorandums of those same central banks some time after the discussions take place, make it clear that the implementation of monetary policy is much more sophisticated than a simple policy rule. This simple rule can describe, generally and ex post, the past behavior of the monetary authority during a period of time, but it cannot take into account the several variables that actually occur when there is a change in the monetary policy stance[4].

In the case of Chile, since it became independent in 1989, the Central Bank has implemented its monetary policy by focusing mainly on one objective: a low inflation rate. As the inflation rate had been around 25% during the 1980s, initially the objective was to gradually lower the inflation rate. In 2000, a long-term objective for the Central Bank was adopted, which is an inflation rate, as measured by the CPI, within the range of 2%-4%.

While the final objective is clear, the indicators that lead to monetary policy decisions, as it is always the case, are much less precise. In the case of a small open economy such as Chile, other indicators besides the output gap and lagged inflation become important. Among them it is possible to mention the current account of the balance of payments, the exchange rate and international reserves.

The purpose of this paper is to investigate what have been the major forces behind changes in monetary policy since the mid-nineties. We use a non-linear function model that uses neural network structures, especially designed to generate the corresponding macroeconomic weights that emerge during the learning process. In other words, using this procedure we can give weights to different variables that have influenced monetary policy during this period. These weights will tell us what major forces have been influencing the monetary policy stance and whether there have been changes in these major forces over time. Note that the approach is positive rather than normative; that is, we obtain the variables (and their corresponding weights) that were used as indicators in the different subperiods, but we do not say anything about the optimality of the policy decisions.

The paper is organized as follows: In the second section, we briefly describe monetary policy in Chile in the nineties. The objective is to understand, from a qualitative point of view, what the relevant issues were during this period and how they were changing over time. The third section briefly discusses the artificial neural network methodology. The application of this methodology in the case of monetary policy in Chile is contained in section four. Section five concludes.

II. Monetary Policy in Chile: 1990-2003

In December 1989, just days before the presidential election that led to a transition from an authoritarian to a democratic government, the Central Bank of Chile (BCCH) became independent from the government. The election of the first five board members involved a series of negotiations between the government and the opposition, which was essential in order to assure that the independence of the central bank would not be impugned by the government that would take office in March 1990[5].

One of the first tasks of the board was to stop the inflationary pressures that were mounting since the previous year. Indeed, inflation had risen from 12% in the fourth quarter of 1988 to 21% one year later. On the other hand, the board wanted to gain credibility as an inflationary hawk as soon as possible. The timing was perfect. In January 1990, a drastic increase in interest rates was announced[6]. The decision was very controversial. It was criticized on at least three grounds: (i) that it produced too severe of a real shock (growth went from almost 10% in mid-1989 to 0% in mid-1990), (ii) that it induced large capital inflows[7], (iii) that these capital inflows produced a significant appreciation of the domestic currency.

It is not the purpose of this paper to make an assessment of the costs and benefits of the policy decisions of the BCCH during this period but rather merely to see which variables were among the most influential when deciding on monetary policy actions. However, it is widely accepted that this episode helped the newly independent BCCH gain credibility in its goal of price stability.

In September 1990, the BCCH issued its first annual report to the Senate[8]. This included an inflation target range of 15%-20% for 1991. Thus, in a move that has been considered to be accidental (Morandé, 2002), the Central Bank of

Chile became one of the first central banks in the world to adopt an inflation targeting (IT) framework. It was accidental in the sense that there was no clear awareness that IT would become a new and very popular approach to monetary policy in the world in the years to come.

Table 1 shows the inflation target and the actual inflation rate since 1991. Judging by the results, the IT scheme has been a success. Corbo *et al.* (2002) suggest that IT makes a difference in terms of monetary policy in the sense that it helps reduce inflation expectations. Morandé (2002) considers that the inflation target regime has proved to be flexible and helpful in achieving the objectives of the BCCH.

TABLE 1

INFLATION TARGET (IT) AND ACTUAL INFLATION (AI)

Year	IT	AI
1991	15-20	18.7
1992	13-16	12.7
1993	10-12	12.2
1994	9-11	8.9
1995	9.0	8.2
1996	6.5	6.6
1997	5.5	6.0
1998	4.5	4.7
1999	4.3	2.3
2000	3.5	4.5
2001	2-4	2.6
2002	2-4	2.8

Source: BCCH.

Despite the severity of the January 1990 monetary policy shock, inflation rose to 27% that year (from 21% the previous year) because of the increase in the oil price induced by the Gulf War. Nonetheless, by mid 1990, it became apparent that inflationary pressures had ceased and that at least in this respect, the policy had achieved its objective. The economy, which was growing at two digit rates in 1989, experienced a significant slowdown and grew 3.7% in 1990. The board of the BCCH decided to gradually return to a more “normal” policy stance. The first interest rate reduction took place within three months after the January shock. By the end of the year, the interest rate was below the pre-shock level, at a point that was considered expansionary. By 1991, the economy again showed strong signs of recovery. Output and aggregate demand growth were both approaching 10% by the end of that year. Concerned about the effects of the accelerating output and demand on inflation, and about the expanding current account deficit, the BCCH began to tighten monetary policy. In 1992, the 90-day central bank bond real interest rate went from 4.7% to 6.5%. One year later, output and demand slowed down and the BCCH relaxed again in 1994.

In May 1995, the BCCH changed the way in which it implemented monetary policy. It moved its operating target from the real interest rate of the 90-day central bank bond to the real interbank interest rate[9]. The change aimed at allowing longer term interest rates to move with the market. It was conceived as a way to modernize monetary policy by focusing (in terms of operating target) only on the very short-term interest rate, a common practice in central banks in advanced countries.

In the same year (1995), aided by a very favorable external scenario, the economy picked up again and monetary policy was tightened. Real interbank interest rates reached 7.5% in mid-1996.

Some authors have interpreted these stop-and-go cycles in the early years of BCCH autonomy as evidence of the lack of a proper and credible monetary policy (Fontaine, 2001). According to this view, the BCCH was very sensitive to the government's criticism, and it therefore relaxed monetary policy before it was advisable, causing volatility in real output. Under this hypothesis, the reduction in the inflation rate has been more the result of policies (both monetary and fiscal) that produced a real appreciation of the domestic currency than of a really credible monetary policy (Fontaine, 2001; and Rosende, 1998).

Most of the discussion in the BCCH during those years had to do with aggregate demand, the current account deficit, the output gap and inflation itself. The exchange rate was not a real factor since it had shown a steady decline (real appreciation of the peso). Hence, it was not posing any risk to the inflation target. Moreover, the concern regarding the exchange rate was exactly the opposite. As the peso appreciated about 30% in real terms between 1990 and 1997, the authorities were concerned that this would damage exports. This, together with the desire to maintain an independent monetary policy, meant that as early as 1991, the BCCH imposed capital account restrictions[10]. The exchange rate policy during this period was that of an exchange rate band. As pressures towards the appreciation of the peso were persistent during these years (until 1997), there were several episodes when the band was adjusted downwards (towards the most appreciated peso side). In addition, the band was gradually widened from ±3% in 1988 to ±12.5% in 1997.

Inflation dropping throughout the period and the preoccupation of the monetary authority regarding the potential inflationary effect of an expanding aggregate demand had a positive impact on the credibility of the BCCH. It must be noted that this enhanced credibility was also helped by the fact that the period between 1990 and 1997 was one of the most outstanding periods in terms of economic performance of the Chilean economy. The average GDP growth was 7.8% and unemployment fell to 6% in 1997, its lowest level in more than two decades.

Things started to change in mid-1997. The economy had been expanding at rates that were clearly unsustainable. The current account deficit had been above the level that the central bank would consider reasonable for more than a year[11]. As inflation was falling, the central bank started easing up on the monetary policy in the last quarter of 1996. The process continued for almost all of 1997, despite

the widening of the current account deficit and the strong expansion in demand. When the Asian crisis erupted in mid-1997, the authorities thought that the Chilean economy was invulnerable to it, as it had been to the Mexican crisis of 1995. They did not realize that both internal and external conditions were now much less favorable than before, and that this crisis would eventually hit all emerging economies. The continued rapid expansion of GDP during the rest of 1997 helped strengthen the view that Chile would not suffer the consequences of the Asian crisis. In September 1997, the central bank projected an economic expansion of 6.5%-7% for 1998.

The first sign that things would not go as well as expected was the increase in the exchange rate. In the last quarter of 1997, the peso depreciated 6% in nominal terms, something not seen in several years. The BCCH, concerned about the high rates of growth in aggregate demand and about the effects of the depreciation of the peso on inflation, decided to tighten monetary policy significantly. The real interbank rate increased from 6.5% at the end of 1997 to 8.5% at the beginning of 1998. The peso, however, continued its gradual depreciation.

The Russian crisis of mid-1998 made things much worse. Capital inflows to emerging economies declined substantially and there were huge pressures on the exchange rate. The BCCH started losing international reserves, something that was new in the 1990s. Gross international reserves fell from more than US$ 18 billion at the end of 1997 to less than US$ 15 billion in mid-1998.

The BCCH attempted several measures to put a stop to an escalating exchange rate. First, it began a gradual process to eliminate the capital controls that still existed as a legacy from the crisis in the early 1980s. It also reduced and later eliminated the controls imposed in the 1990s (the reserve requirement). Then it decided to let the interbank interest rate go above the targeted level. This was a clear *de facto* abandonment of the way it used to run monetary policy. Indeed, for a short period of time, the interbank interest rate was no longer the operating target. Then, in an attempt to gain credibility on the exchange rate market, it decided, in June 1998, to shorten the exchange rate band from ±12.5% to +2%,–3.5%. This did not work[12] and in December, it partially reversed the measure and widened the exchange rate band to ±8%, also incorporating a factor that would gradually keep widening it[13]. Finally, in September 1999, the BCCH adopted a free floating exchange rate system.

Regarding monetary policy, in September 1998, as things were getting out of control (interbank interest rates on some days were above 50%), it decided to increase its monetary policy rate to 14% and to sustain that level with an active monetary policy. Thus, the interbank interest rate again became the operating target of the BCCH.

Hence, at least for a while in the second half of the 1990s, the exchange rate and the international reserves seem to have played a more important role in the conduct of monetary policy. The BCCH was widely criticized for its attempts to target the exchange rate with the effect of skyrocketing interest rates. On the other hand it has to be mentioned that it is likely that the BCCH was just trying to avoid the effects on the inflation rate of a massive depreciation of the currency.

The real economy started to feel the effects of the monetary tightening and of the worsening of the external scenario. The last quarter of 1998 showed the first negative growth rate since the first half of the eighties. In 1999, the GDP fell 0.8%, the first recession since 1983. Unemployment climbed to 9.8% on average during 1999 —the highest level in more than a decade— and the government decided to implement an emergency program aimed at hiring the unemployed.

With a free floating exchange rate policy, the BCCH focused more directly on the rate of inflation itself and the output gap to make its monetary policy decisions, in a move that resembles its policy prior to the Asian crisis. The difference is that now the effective GDP was below its potential and aggregate demand was very weak. As there was no sign of inflation despite the depreciation of the peso, it began to lower interest rates, a process that continued until 2003[14]. Monetary policy was relaxed for the first time just about a month after the huge tightening of September 1998. By the end of 1998, the rate was already below its pre-September level. In 1999, the rate fell from 7.8% at the beginning of the year to 5% at the end of the year. The inflation rate in 1999 was 2.3%, the lowest level in 60 years. In 2000, inflation was 4.5%, above the upper limit of the BCCH range; however, it was mostly explained by the huge increase in the price of oil. Core inflation (which excludes oil and perishable foods) was 3.4%.

Despite the changes in emphasis dependent upon the changes in circumstances, it is clear that inflation itself and the output gap have been at the core of the monetary policy decision-making process in Chile during this period. It also seems that some "external variables" such as the exchange rate and international reserves gained relative importance during 1998-1999.

Various issues have arisen in recent years regarding the implementation of monetary policy by the BCCH[15]. One of them is whether the target should be headline inflation or core inflation (García *et al*., 2002). The BCCH targets headline inflation but it uses core inflation as an indicator. Moreover, when the inflation rate went above the upper limit of the IT range in 2000, the BCCH constantly argued that the core inflation was within the limits of the range. As regards the inflation forecasts, the BCCH has been using a two-year forecast of inflation in the last few years to guide its monetary policy decisions.

The very limited effect of the depreciation of the peso on the inflation rate since late 1997 has raised the question as to whether there is a structural change in the pass-through coefficient (Morandé, 2002, and BCCH, Monetary Policy Report, various issues). Although this is not yet settled, it seems, at least in the short run, that the pass-through is minimal.

The role of money supply has also been a matter of discussion (Rosende, 2001; García and Valdés, 2003; De Gregorio, 2003; and Vergara, 2003). The BCCH uses money supply merely as an indicator for monetary policy, not as any kind of target. And as an indicator, it does not seem to be one of the most relevant ones used by the BCCH. If money supply is growing above or below what a standard money demand function indicates, the usual reaction of the BCCH is to argue that there has been a structural change in the money demand function. It is worth noting, however, that money demand was very stable in the 1990s and only in the last few years is there an unexplainable volatility.

Finally, in mid-2001, the BCCH changed its operating target from a real to a nominal interest rate. This aimed at improving the effectiveness of monetary policy. It was also seen as a new move toward what is common practice in central banks in most countries. The change has not been easy for a country accustomed to financial indexation for more than three decades, although there has been increasing acceptance by the market of the "nominalization" of monetary policy. In any case, this issue is beyond the scope of this paper.

III. Artificial Neural Networks: Applications and Analysis

A neural network model is an artificial structure reflecting the idea of parallel processing. Traditional linear methods of fixing a data set are based on the causal effect mechanism in which a set of variables influences a dependent variable, usually acting simultaneously. The neural network approach explores this characteristic, extending the methodology to include non-linear relationships among variables[16].

White (1992) and Kuan and White (1994) popularized the neural network approach in economics. Since then, it has been used to analyze bank lending decisions (Witkowska, 1999; Olmedo and Fernandez, 1997; Zurada, 1999), corporate outcomes (Wilson *et al*., 1995), customer profiles (Goss and Ramchandani, 1995; Church and Curram, 1996), educational spending (Baker and Richards, 1999), and macroeconomic or financial forecasting (Moshiri *et al*., 1999; Martin *et al*., 1997; Qi, 1999; Yao *et al*., 1999; El-Shazly and El-Shazly, 1999; Fu, 1998)[17]. Wu and Wang (2000) use a neural network to classify loan applications into groups suitable for acceptance or rejection, and compare model results with actual decisions made by loan officers. They found that neural network models can be highly predictive and very useful in enhancing lending decisions.

This approach has also been very useful in the field of finance. Given the high frequency of data available, this field has several artificial neural network applications that focus mainly on forecasting asset prices or returns or on studying spillover effects across different asset indexes. Lim and McNelis (1998) analyze the influence of shocks in the Nikkei (Japan) and Standard and Poor's (US) stock indices on the Australian All-Ordinaries Index. Based on forecast statistics, they found that neural network models outperform traditional econometric structures such as linear OLS and GARCH-Ms models[18].

In macroeconomics, applications have focused primarily on exchange rates, inflation, money demand and growth[19]. Evidence of non-linearities in Chilean macroeconomic data can be found in Soto (1995) and McNelis (1998). Both examine money demand in Chile, revealing that there is a high degree of non-linearity in the long-run demand for money.

For the US, Smith and MacLin (1995) examined the behavior of the Federal Reserve Board of Governors as it reflected different presidential mandates. The authors found evidence suggesting that FOMC decision-making has been influenced by the presidential administration of the day, especially the more relaxed policies preferred by the Kennedy-Johnson administrations.

Tkacz and Hu (1999), from the Bank of Canada, use macroeconomic data from 1985-1998 to estimate an artificial neural network for forecasting GDP, concluding that these models performed better (proving to be 15% to 19% more accurate) than traditional, linear regression, time series models.

3.1 Analytical neural network

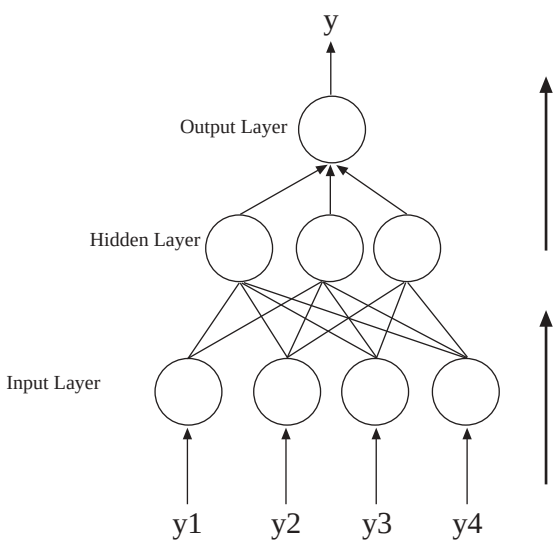
Analytically, a neural network can be represented by the equation (1), where y is the dependent variable (which could be a vector of variables), y_j for $j = 1,2...$ are independent variables, and f represents a non-linear function.

$$y_t = f(y_{1t}, y_{2t}, ...) + \varepsilon_t \tag{1}$$

In the classic regression model, f represents a linear function but in this setup f denotes any non-linear form. Let us consider the typical feed-forward neural network depicted in Figure 1. A traditional neural network consists of a collection of inputs and processing neurons, arranged in interconnected layers known as input, hidden, and output layers. The input layer only receives information, without processing it. Once in the hidden layer, this information is processed, analyzed, and then passed on to the output layer using transfer functions, which are functions in the processing neurons that define the system's output. To provide some insight, let us assume that we have four time series (y_1, y_2, y_3, y_4) to explain our dependent variable y.

FIGURE 1

FEED-FORWARD NEURAL NETWORK



Each network node is linked through a mathematical function:

$$y_j = f(Neural\ Net) + \varepsilon_j$$
$$y_j = f\left(\sum_i \omega_{ij} x_i\right) + \varepsilon_j \tag{2}$$

where ω_{ij} represents the parameter between input i and neuron j. Function f corresponds to the transfer function, usually modeled using a sigmoid or tangent hyperbolic function[20], represented, respectively, by:

$$f = \begin{cases} \dfrac{1}{1+e^{-\sum \omega_{ij} x_i}} \\ \dfrac{e^{\sum \omega_{ij} x_i} - e^{-\sum \omega_{ij} x_i}}{e^{\sum \omega_{ij} x_i} + e^{-\sum \omega_{ij} x_i}} \end{cases} \tag{3}$$

Neural network literature offers two basic learning procedures. The first is unsupervised learning, where output is not defined and the network classifies inputs according to the characteristics of the problem to be solved. In supervised learning, the second, and by far the most popular, methodology in this area, the network is tested with both inputs and the required output, thus allowing the learning procedure to minimize errors or differences among variables.

The methodology used in the estimation is called back-propagation (BP). It calculates difference signals from the last layer by back-propagating them along the path of steepest descent in the network. Standard BP uses the gradient descent method to map inputs to output.

3.2 Back-propagation learning using gradient descent methods

Let us define the neuron's squared error as:[21]

$$\varepsilon_p = \frac{1}{2}\left(y_p - \hat{y}_p\right)^2 \tag{4}$$

where the subscript p refers to the pth pattern or data point, y represents the actual or desired output, and $\hat{y}$ the network prediction. Equation (4) represents an approximation to the general error term $\sum_p \varepsilon_p$.

The weight modification for any neuron will be proportional to the impact of the weight from that neuron on the previous difference ε_p, expressed by the following equation:

$$\Delta\omega_k = -\gamma \frac{\partial \varepsilon_p}{\partial net_k} \frac{\partial net_k}{\partial \omega_{ki}} \tag{5}$$

Similarly, the contribution of the weighted sum of inputs to output error from any neuron arises from:

$$\lambda_{ko} = -\frac{\partial \varepsilon_p}{\partial y_p} \frac{\partial y_p}{\partial net_k} = \left(y_p - \hat{y}_p\right) f'_k\left(net_k\right) \tag{6}$$

For the hidden unit *h* connected to the neuron *n*, this contribution is the product of:

$$\lambda_{hn} = -\sum_n \lambda_{no} \omega_{np} \tag{7}$$

3.3 Extracting the monetary policy reaction function

The parameters established in the section above help us design an algorithm to estimate the contribution of a set of macroeconomic variables to changes in domestic monetary policy. A change in policy is represented by the real overnight interest rate which is the dependent variable. A previous correlation analysis was implemented to include a set of non collinear set of variables as explanatory variables in the neural net. Multicollinearity is also a potential identification problem in neural net models, especially because the impossibility to solve the set of non lineal equations involved in the optimization process.

We calculate the proportional contribution of different macroeconomic variables using the contribution of the weighted sum of inputs to output error shown in equation (6). This contribution is obtained from the weights generated for each macroeconomic variable and the interpretation is not in signs but in absolute magnitude. The gradient of the variable to explain the movement of the dependent variable is imposed from our personal experienced and previous literature about the sensibility of monetary policy to each variable involved in the vector of explanatory variables[22].

Of course, there is the possibility that some relevant variables will be excluded in the estimations. However, given our previous discussion, we are confident that our analysis has considered the most relevant monetary policy indicators used in the monetary policy decision-making process in Chile during this period.

IV. The Results

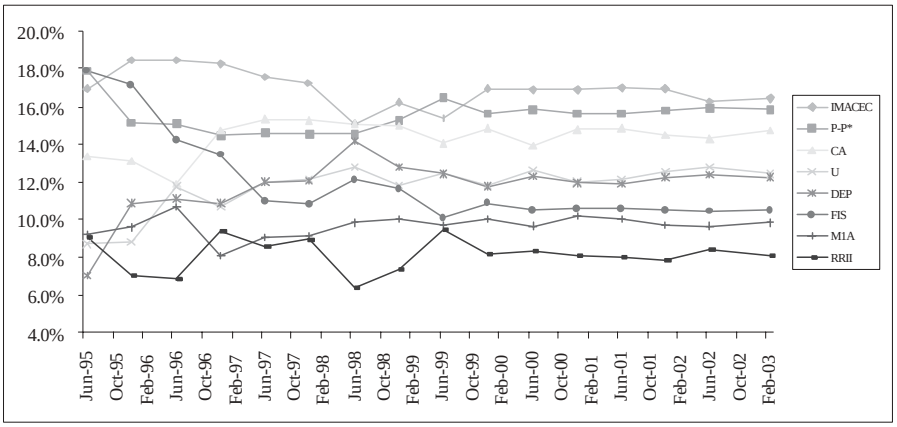
Figure 2 contains the main results of the neural network approach applied to monetary policy in Chile. The vertical axis represents the weight of each variable in the monetary policy decision. The results are shown starting in June 1995. In other words, we start the estimation in June 1991 and end on different dates beginning in June 1995. Then we move forward through February 2003.

We use monthly data and the estimations are made three times each year, for June, October and February. We use February so that the last estimation coincides with the end of the sample period. Every line in the figure represents the weight that each variable has had in different periods of time. The policy variable is the change in the BCCH monetary policy interest rate, measured in real terms[23]. The 4-months estimation period instead of choosing quarter frequency was to consider a dynamic feeling of the variables, but also enough degrees of freedom to estimate the parameters of the neural net model. Given its high non-linearity and number of parameters to estimate, the availability of having a large sub sample is relevant in the estimation process.

The explanatory variables are the difference between the effective and target inflation (P–P*), monthly rate of growth in economic activity (IMACEC), current account balance as a percentage of GDP (CA), unemployment rate (U), nominal depreciation (DEP), the fiscal balance as a percentage of the GDP (FIS), growth rate of M1 (M1A), and the change in international reserves (RRII). The sources of the data are the Central Bank of Chile and the Ministry of Finance.

FIGURE 2

NEURAL NETWORK ESTIMATION: RESULTING WEIGHTS



The first result seen is the importance of GDP growth in the monetary policy decisions of the BCCH. It is the variable with the largest weight throughout almost the entire period. It should be no surprise since the output gap is a key variable in the inflation models of the BCCH (Central Bank of Chile, 2003). Hence, it is natural to view a higher GDP growth as an event that will reduce the output gap and then increase inflationary pressures[24]. It is also interesting to see that its weight has marginally declined in recent years. This might be explained by the change in growth performance since the late 1990s. Until 1998, the "problem" of the Chilean economy was too much growth, which eventually overheated the economy. Between 1991 and 1997, the average annual GDP growth was 8.2% while in 1998-2003 it was only 2.6%. Given this fundamental change and the events that were explained in Section II, it seems reasonable that GDP growth marginally lost some importance in monetary policy decisions.

It is important to bear in mind that the estimation in each period is an accumulated estimation for the whole period through that date. In other words, it is an average for the whole period until the end of that specific estimation period. Hence, the difference in the estimated weight between the beginning and the end of the period underestimates the change at the margin. This implies that although the change in the weights over time seems small, it is greater at the margin.

The difference between actual inflation and the inflation target has the second largest weight. Again, this should be no surprise given that inflation is the objective of the BCCH and that in an inflation target scheme deviations from the target are key. Its weight declined somewhat between 1995 and mid-1998, which coincides with the period in which inflation fell to one digit, a major achievement for the Chilean economy. It increases again after 1998 when the Asian and Russian crises generated some concern regarding the possibility that the depreciation of the peso would produce inflationary pressures.

The current account has also been an important factor throughout the period. Interestingly, its weight increased in 1997-1998, which reflects the concern at that time regarding an increasing current account deficit[25]. It is worth remembering that there are, in the history of Chile, several financial crises preceded by large current account deficits. In addition, the Asian crisis had just erupted with the devaluation in Thailand and several of the initial analyses focused on the large current account deficit in this country.

The unemployment rate has a smaller weight than the previous variables, although it is interesting to note that its weight increased in the second half of the nineties. This result seems reasonable in a scenario where the unemployment rate became one of the top political priorities. In this context, what is really surprising is why its weight did not increase even further.

The depreciation of the domestic currency has a weight that is similar to the weight of the unemployment rate. It also increases in the second part of the nineties. As in the case of unemployment, this seems reasonable given the depreciations in Chile after the Asian crisis. As explained in Section II, the Chilean peso started a period of depreciation after a long period of appreciation. Indeed, between 1990 and 1997, the peso appreciated 30%, while between 1998 and 2002

it depreciated 25%. Our estimations show that its weight increased somewhat before the actual depreciation of the peso took place.

The weight of the budget balance has decreased significantly, from 18% in 1995 to close to 10% in 2003. Although the budget has, in recent years, shown a deficit after many years of surpluses, the public debt is quite moderate and there is a general appreciation that fiscal policy has been responsible throughout this period. Net public debt declined from 40% of GDP in the early 1990s to less than 15% of GDP nowadays.

Both M1 and international reserves have been assigned a smaller weight in monetary policy decisions than the rest of the variables. M1 has a similar weight throughout the period while international reserves show an interesting increase in weight in 1999 that coincides with the period in which there were pressures on the exchange rate and the BCCH lost a significant amount of international reserves.

From our previous analysis it is clear that although there have been some changes in the relative weights of the monetary policy indicators over this period and that these changes coincide with the change in emphasis in every sub-period, in general terms the process seems to be quite stable. In other words, overall, there do not seem to be major changes in the indicators used in the monetary policy decision-making process of the BCCH during this period. This does not come as a surprise since the path of inflation has been smooth, exhibiting a gradual decline without major swings. In some sense this also implies a relatively simple policy rule (in the sense that it changes little).

Given that the all set of parameters in the model were estimated, is necessary to remember that such a process involve uncertainties. These imprecisions, which are present in every econometric model, make clear that one of the tasks to be considered in future research must be to include confidence intervals for each weight of the model. This is left for future analysis[26].

V. Conclusions

This paper has used a neural network approach to establish the weights considered by the Board of the Central Bank of Chile in the implementation of monetary policy between 1995 and 2003. GDP growth and the difference between the actual and target inflation are the two variables with the greatest weight. This result is perfectly consistent with the fact that inflation is the main objective of the BCCH and also with the fact that the inflation model of the BCCH considers the output gap to be one of the main determinants of inflation.

The rest of the variables considered are weighed less, although in some periods they have become more important. For instance, both the unemployment rate and the exchange rate increased their weight marginally in the last few years. This is consistent with the increase in the unemployment rate and the depreciation of the domestic currency that hit the Chilean economy in the aftermath of the Asian crisis.

Besides these changes, our results highlight the stability of the monetary policy decision-making process during this period. They show that the BCCH has not changed this process significantly since the mid-nineties. The gradualism in the reduction of inflation combined with the absence of major swings in inflation, might be the keys that explain this phenomenon.

Notes

1 See Loayza and Soto (2002), and Mishkin and Schmidt-Hebbel (2002).

2 For instance, it has been widely documented that Greenspan uses all sorts of microeconomic data to make his decisions (Woodward, 2000).

3 Taylor (1993), Rosende (2001).

4 Estimation of Taylor's rules in Chile using conventional methodologies (OLS, GMM) include Calderón *et al*. (2003), Corbo (2002), Cabrera and Lagos (2002). Most of these studies find that both the output gap and inflation deviation have the expected sign and are statistically significant.

5 At that time, it was already clear that the opposition would win the election. The details of these negotiations and how the newly independent BCCH functioned in the aftermath of its independence can be found in Bianchi (1994). Fontaine (2001) discusses the fundamentals of the BCCH autonomy law.

6 Since the mid-eighties, the Central Bank of Chile had set its operating target as the 90-day real interest rate (in UF) on its own bills. However, during this episode, it switched temporarily and briefly to a long-term real rate (10 years), which rose from 6.9% to 9.7%. Short-term market rates went up even further given the expectations of a sooner rather than later relaxation in monetary policy.

7 The sterilization of these flows resulted in a significant increase in the BCCH internal debt and, hence, in the quasi-fiscal deficit.

8 A good description of major policies of the BCCH during this period can be found in Central Bank of Chile, "Informe al Senado", various issues. Since 1990 this annual report was changed for a quarterly inflation report ("Monetary Policy Report").

9 In fact this was an "imperfect" real rate since it was based on the lagged (one month) inflation rather than on expected inflation.

10 They took the form of a reserve requirement for capital inflows, with the exception of direct foreign investment.

11 The BCCH had said, on numerous occasions, that the range it considered sustainable for the current account deficit was 3-4% of GDP (using the kind of sustainability analysis developed in Edwards and Vergara, 2002). However, by mid-1997, it had been well above the upper limit for more than a year.

12 It should be no surprise that it did not work given the constant changes that the BCCH had made to the central parity and to the limits of the exchange rate band in previous years. In other words, the BCCH had gained credibility in regard to inflation (which is its final objective) but not in regard to the exchange rate.

13 The band had been previously expanded in September to ±3.5% and it was scheduled to reach ±5% by the end of the year.

14 We must mention that in the first quarter of 2000, there were a couple of small interest rate increases as it seemed that the economy was entering a new high growth period. The interest rate went from 5% to 5.5%. This move was reversed in August when the BCCH reduced the real interbank rate to 5% once again.

15 For a detailed description of the policy, see Central Bank of Chile (May 2000).

16 The ANN approach has benefits over the traditional OLS or even the GMM approaches in the dimension of considering non-linear causalities among the variables included in the model, and also it is not restricted to any structural model previously optimized such as the usual structures behind GMM models. This freedom is used to design a list of potential candidate variables that

help to explain the dynamic of monetary policy, without any concern to "deep" parameters behind any structural model.

17 See also Granger and Terasvirta (1993), Gately (1996), Campbell *et al*. (1997), and Franses and van Dijk (2000).

18 See footnote 14.

19 International evidence on growth can be found in Fu (1998) and Tkacz and Hu (1999).

20 Alternative transfer or "squashing" functions are identity, piecewise linear, sinusoidal, and Gaussian.

21 See Freeman (1994), Sargent (1993) and Kasabov (1996) for a broader treatment.

22 A point of interest to discuss is the potential stability of the model. Previous structural stability tests were performed on a linear OLS model and the instability was present. This result enlarge the methodology adopted in this paper in which a moving window of data is included in the estimations to get a flavor of the change in relevance of each of the variables involved in the analysis.

23 It corresponds to the interest rates in UF and the UF reflects the CPI. For the period after the nominalization of the monetary policy (2001), we use the nominal interest rate less expected inflation, which is supposed to be the mean of the inflation target of the BCCH (3%).

24 As the growth rate of potential GDP is relatively stable in the short run, changes in the output gap are basically explained by the rate of growth of actual GDP.

25 It reached almost 7% of GDP in the year, ending in the second and third quarter of 1998.

26 We thank the anonymous referees of the Journal for this comment.

References

BAKER, B. and C. RICHARDS (1999). "A Comparison of Conventional Linear Regression Methods and Neural Networks for Forecasting Educational Spending". *Economics of Education Review*, 18 (4), pp. 405-15.

CENTRAL BANK OF CHILE. "Informe al Senado", various issues.

CENTRAL BANK OF CHILE. "Monetary Policy Report", various issues. Available in: www.bcentral.cl

CENTRAL BANK OF CHILE (2000). *Monetary Policy of the Central Bank of Chile: Objectives and Transmission*. May. (In: www.bcentral.cl).

CENTRAL BANK OF CHILE (2003). "Modelos Macroeconómicos y Proyecciones del Banco Central de Chile". Available in: www.bcentral.cl

BIANCHI, A. (1994). "La Autonomía del Banco Central de Chile". *Testimonios sobre la Actuación de la Banca Central*, Centro de Estudios Monetarios Latinoamericanos, México D.F.

CABRERA, A. and L.F. LAGOS (2002). "Monetary Policy in Chile: A Black Box". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 197-245.

CALDERON, C. and R. DUNCAN (2003). "The Role of Credibility in the Cyclical Properties of Macroeconomic Policies in Emerging Economies", *Working Paper* Nº 237, Central Bank of Chile, November.

CAMPBELL, J. Y.; A. W. LO and A. C. MACKINLAY (1997). *The Econometrics of Financial Markets*. Princeton: Princeton University Press.

CHURCH, K. and S. CURRAM (1996). "Forecasting Consumers' Expenditure: A Comparison Between Econometric and Neural Network Models". *International Journal of Forecasting*, 12 (2), pp. 255-67.

CORBO, V.; O. LANDERRETCHE and K. SCHMIDT-HEBBEL (2002). "Does Inflation Targeting Make a Difference". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 221-269.

CORBO, V. (2002). "Monetary Policy in Latin America in the 1990s". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 117-165.

DE GREGORIO, J. (2003). "Dinero e Inflación: ¿En Qué Estamos?" *Economía Chilena*, 6 (1), pp. 3-19.

EDWARDS, S. and R. VERGARA (2002). "Fiscal Sustainability, Debt Dynamics and Debt Relief: The Cases of Nicaragua and Honduras". *Unpublished manuscript*, October.

EL-SHAZLY, S. and H. EL-SHAZLY (1999). "Forecasting Currency Prices Using a Genetically Evolved Neural Network Architecture". *International Review of Financial Analysis*, 8 (1), pp. 67-82.

FONTAINE. J.A. (2001). "Banco Central Autónomo: En Pos de la Estabilidad". In: F. Larraín and R. Vergara (eds.), *La Transformación Económica de Chile*, second edition, Centro de Estudios Públicos, Santiago, pp. 393-428.

FRANSES, P. and D. VAN DIJK (2000). *Non-linear Time Series Models in Empirical Finance*. New York: Cambridge University Press.

FREEMAN, J. A. (1994). *Simulating Neural Networks with Mathematics*. Addison-Wesley Publishing Company.

FRIEDMAN, M. (1968). "The Role of Monetary Policy". *American Economic Review*, 58 (1), pp. 1-17.

FU, J. (1998). "A Neural Network Forecast of Economic Growth and Recession". *Journal of Economics*, 24 (1), pp. 51-66.

GARCIA, P.; L.O. HERRERA and R. VALDES (2002). "New Frontiers for Monetary Policy in Chile". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 627-649.

GARCIA, P. and R. VALDES (2003). "Dinero e Inflación en el Marco de Metas de Inflación". *Economía Chilena*, 6 (1), pp. 21-47.

GATELY, E. (1996). *Neural Network for Financial Forecasting*. New York: John Wiley and Sons.

GOSS, E. and H. RAMCHANDANI (1995). "Comparing Classification Accuracy of Neural Networks, Binary Logit Regression and Discriminant Analysis for Insolvency Prediction of Life Insurers". *Journal of Economics and Finance*, 19 (3), pp. 1-18.

GRANGER, C. W. J. and T. TERASVIRTA (1993). *Modelling Nonlinear Economic Relationships*. New York: Oxford University Press.

KASABOV, N. (1996). *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering.* Cambridge: *MIT Press.*

KUAN, C. M. and H. WHITE (1994). "Artificial Neural Networks: An Econometric Perspective". *Econometric Review*, 13, November, pp. 1-91.

LIM, G. and P. McNELIS (1998). "The Effect of the Nikkei and the S&P on the All-Ordinaries: A Comparison of Three Models". *International Journal of Finance and Economics*, 3 (3), pp. 217-28.

LOAYZA, N. and R. SOTO (2002). "Inflation Targeting: An Overview". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 1-21.

MARTIN, V.; E. CHOO and L. TEO (1997). "Exchange Rate Forecasting Models". In: Creedy, J. and V. Martin (eds.), *Nonlinear Economic Models: Cross-Sectional, Time Series and Neural Network Applications*. Cheltenham, UK, and Lyme, N.H.: Elgar.

McNELIS, P. (1998). "Money Demand and Seigniorage-Maximizing Inflation in Chile: Approximation, Learning, and Estimation with Neural Networks". *Revista de Análisis Económico*, 13 (2), pp. 3-24.

MISHKIN. F. and K. SCHMIDT-HEBBEL (2002). "A Decade of Inflation Targeting in the World". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*. Central Bank of Chile, Santiago, pp. 171-219.

MORANDE, F. (2002). "A Decade of Inflation Targeting in Chile: Development, Lessons and Challenges". In: N. Loayza and R. Soto (eds.), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp. 583-626.

MOSHIRI, S.; N. CAMERON and D. SCUSE (1999). "Static, Dynamic, and Hybrid Neural Networks in Forecasting Inflation". *Computational Economics*, 14 (3), pp. 219-35.

OLMEDO, I. and E. FERNANDEZ (1997). "Hybrid Classifiers for Financial Multicriteria Decision-Making: The Case of Bankruptcy Prediction". *Computational Economics*, 10 (4), pp. 317-35.

QI, M. (1999). "Nonlinear Predictability of Stock Returns Using Financial and Economic Variables". *Journal of Business and Economic Statistics*, 17 (4), pp. 419-29.

ROSENDE, F. (1998). "Política Monetaria en Chile en los Noventa. Un Ejercicio No Neutral". *Perspectivas*, 2 (1), pp. 157-189.

ROSENDE, F. (2001). "La Nueva Síntesis Keynesiana: Análisis e Implicancias de Política". *Unpublished manuscript*, November.

ROSENDE, F. (2003). "¿El Fin del Monetarismo?". *Cuadernos de Economía,* 40 (121), pp. 681-689.

SARGENT, T. (1993). *Bounded Rationality in Macroeconomics.* Oxford University Press.

SMITH, P. and O. MACLIN (1995). "Have Presidents Influenced Monetary Policy: New Evidence from an Artificial Neural Network". *Studies in Economics and Finance,* 16 (1), pp. 23-45.

SOTO, R. (1995). "Non-Linearities in the Demand for Money: A Neural Network Approach". *Unpublished manuscript*, Georgetown University.

TAYLOR, J. (1993). "Discretion versus Policy Rules in Practice". Carnegie-Rochester Conference Series on Public Policy 39.

TKACZ, G. and S. HU (1999). "Forecasting GDP Using Artificial Neural Networks". *Working Paper* Nº 99-3, Bank of Canada.

VERGARA, R. (2003). "El Dinero Como Indicador de Política Monetaria en Chile". *Cuadernos de Economía,* 40 (121), pp. 707-715.

WHITE, H. (1992). *Artificial Neural Networks: Approximation and Learning*. Cambridge: Blackwell.

WILSON, N.; K. CHONG, M. PEEL (1995). "Neural Network Simulation and Prediction of Corporate Outcomes: Some Empirical Findings". *International Journal of the Economics of Business,* 2 (1), pp. 31-50.

WITKOWSKA, D. (1999). "Applying Artificial Neural Networks to Bank Decision Simulations". *International Advances in Economic Research,* 5 (3), pp. 350-68.

WOODWARD, R. (2000). *Maestro: Greenspan's Fed and the American Boom*, Touchstone Books, Simon & Schuster, New York.

WU, C. and X. WANG (2000). "A Neural Network Approach for Analyzing Small Business Lending Decisions". *Review of Quantitative Finance and Accounting,* 15 (3), pp. 259-76.

YAO, J.; C. TAN and H. POH (1999). "Neural Networks for Technical Analysis: A Study on KLCI". *International Journal of Theoretical and Applied Finance,* 2 (2), pp. 221-41.

ZURADA, J. (1998). "Neural Networks versus Logit Regression Models for Predicting Financial Distress Response Variables". *Journal of Applied Business Research,* 15 (1), pp. 21-29.