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Modeling Monetary Policy Decisions in a Discrete Framework, the case of Mexico, 2004-2012

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Abstract

This research seeks to explain how Banco de México (Banxico) monetary policy responds to information from relevant macroeconomic variables, as well as the performance of Mexico's Federal Treasury Certificates (zero-coupon bonds called Cetes) and variables in commercial bank financing, to achieve price stability. For this purpose, we develop an ordered multinomial probit model to calculate the probabilities of three possible movements in the target interest rate (that the interest rate increase by 25 basis points [bps] or more, remain unchanged, or fall by 25 bps or more). Jumps are calculated through lags in the dependent variable. Finally, we simulate the dependent variables through probability graphs for Mexico between 2004 and 2012.

JEL **Classification**: C18, E52, E58.
Key words: monetary policy, central bank behavior, ordered multinomial probit model.

Introduction

In this article, we identify three principle macroeconomic and financial variables that determine the probability of movements in the Banco de México's target interest rate. This is relevant for economic agents (companies, families, and the government) because with knowledge of how monetary policy reacts to new information, all agents will have more information on which to base their decisions about production, consumption, saving, and expenditure.

This research seeks empirical evidence using the ordered multinomial probit model to ascertain how monetary policy responds; this is an innova-

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tion in how a model is specified on the basis of a monetary policy rule. Other works on monetary policy rules include McCallum (1988), Taylor (1993), Judd and Rudebusch (1998), Dueker (1999), Orphanides (2007), Orphanides and Williams (2002), Woodford (2003), and Hu and Phillips (2004).

Based on the specification of the monetary policy rule in Taylor (1993), presented for the United States, numerous theoretical and empirical research papers on monetary policy rules have replaced the output gap with the unemployment gap (the deviation from the natural rate of unemployment). However, evidence exists of some problems in the estimation of output and unemployment gaps and inflation because they consider unknown information. Taking this into account, we propose a probit model version, examining differences rather than levels (see Orphanides and Williams, 2002). This offers a specification advantage because it avoids mismeasurements of amounts produced by the use of gaps (mismeasurement in the sense of incorporating uncertainty with regard to the true value of potential output or the natural rate of unemployment).

Therefore, factoring in the limitations of ex-post information, the variables used in this study fully overcome the limitations of estimating output, unemployment, and inflation, because the variables used do not incorporate stochastic components, but instead are observed. In other words, they eliminate the uncertainty associated with calculating gaps, and this has been theoretically proven by Orphanides and Williams (2002).

Also, Staiger, Stock, and Watson (1997) have shown that estimates of the natural rate of unemployment change over time, and as a result are very imprecise; Orphanides and van Norden (2002) show that estimates of potential output are also imprecise; and Laubach and Williams (2003) report that estimates of the natural interest rate have inaccuracies because it is not observable (the natural interest rate is the real interest rate plus an adjustment on account of long-term inflation). For policy makers, an accurate estimate of the potential measures is essential[1] because otherwise they could give policy recommenda-

1 In the original presentation of Taylor rule, it is seen that each percentage point of error in the estimate of the natural interest rate is translated into one percentage point of change in the optimum target rate; similarly, a change of one percentage point in the potential output allows for half a point of change in the target. Deepankar and de Jong (2007) mention that, in practice, the Federal Reserve changes the federal funds rate by small amounts (25 or 50 basis points) since mismeasurements in the natural rate would produce very large errors in monetary policy decisions.

tions that might affect the central bank's efforts to maintain stability, as explained by McCallum (1988), Orphanides and Williams (2002; 2007).

To tackle the issue of mismeasurement, as examined in the literature on the topic, requires a strategy of adopting "difference rules" as monetary policy guidelines; for example, see: Orphanides and Williams (2002; 2007). These rules imply that the federal funds' nominal rate is defined in response to inflation and changes in economic activity, instead of the levels of the series. These rules are immune from mismeasurements of the natural rate and are robust by ensuring that there is no knowledge error caused by uncertainty about natural rates.

The results found in the estimates of the classic ordered multinomial probit model show that, on average, there was an 83.3% probability of maintaining the target rate during the sample period. In this sense, the results found in relation to the greater weight of changes in the target rate are due to inflation lags, inflation expectations, and changes in financial variables, and these results are in line with the empirical evidence of an efficient steering of monetary policy to achieve price stability.

This article is structured as follows: a review of relevant literature; a presentation of the methodology and discussion of the probability modeling for movements in Banxico's target rate; a concise description of the operating procedures and instruments of Banxico's monetary policy; an examination of the ordered multinomial probit model for the study of monetary policy through the short-term interest rate; an empirical analysis of the ordered multinomial probit models applied to monetary policy in Mexico; conclusions; appendices that provide analytical and empirical results of this research.

Review of the literature

The literature on the dynamic of discrete choice models covers three different ways of characterizing them: the first relates to the latent variable solely on the basis of stationary exogenous variables in each period; the second considers the latent variable on the basis of stationary exogenous variables and their lags; and the third specification contains a latent variable that is the function of variable stationary exogenous variables and lags of the choice variable.

The first specification has been widely used in the unordered discrete study, for example, in the sequential decision-making models of Keane (1994); in the models for studying the probability of a country going into default by

Hajivassiliou and MacFadden (1994); and in the choice of a place of residence in Hajivassiliou, McFadden, and Ruud (1996), among others.

The second specification has been used to analyze the inertia of monetary policy with time-series features by Dueker (1999). This author's work has three outstanding aspects: firstly, the specification of his model shows the latent variable based on independent variables and their lagged values; secondly, in his specification (1999) strict stationarity is not a problem given that the choice variable is a function of the latent variable and the lags are stationary; and thirdly, his model specification is not immune to problems derived from mismeasurements of the potential output series and natural rates.

The third specification is found in Deepankar and de Jong (2007): these authors indicate that this type of specification had not been explored empirically.[2] They estimate an ordered multinomial probit model based on the specification of a monetary policy rule for the United States. The data in their study have a monthly frequency from 1990 to 2006. In line with the above proposal, this research estimates an ordered multinomial probit model derived from the monetary policy rule for Mexico that considers interest rate movements (as jumps) in $t-1$ due to its importance in the decision of the next movement of the target rate.

The first studies that estimate a model on the basis of the monetary policy rule (Taylor, 1993) with changes in the federal funds' target rate consider it a continuous random variable as in Judd and Rudebusch (1998). Later, Dueker (1999) attempts to broaden the empirical analysis of the aforesaid rules of monetary policy to include the explicit knowledge of the discrete changes to the federal funds' rate, since in practice the U.S. Federal Open Market Committee (FOMC) changes the target rate only by discrete amounts (in exact multiples of 25 basis points [bps] since January 1990) and not continuously.

One study, by Duport, Mirzoev and Conley (2004), has analyzed the actions of the United States' central bank, using the information from the previous FOMC meeting. These authors have analyzed whether the Federal Reserve (Fed) does what it says it hopes to do, through an analysis of FOMC actions considering the possible directional bias of monetary policy in the subsequent

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[2] Although Duport, Mirzoev and Conley (2004) had already attempted to introduce lagged information of the dependent variable that influences the subsequent monetary policy decision, their estimated models are bivariate (restricted and unrestricted).

meeting. The authors include measurements of economic activity (output and unemployment) and inflation; nevertheless, the measurements of economic activity for its sample are inconsistent. Below we can see the methodology and the model used to calculate the probability that Banxico's target rate reacts to information about macroeconomic and financial variables.

A paper by Cuevas (2003) on this issue examines Mexico's specific case, estimating a binary probit model that identifies the determinants of decisions to increase monetary restriction through the *corto* (an operational target for daily balances); the author observes that from May 1996 to March 2003 the monetary restriction policy was more likely to occur with an increase in the inflationary gap and demand pressures.

Methodology and modeling

To examine the probability that the short-term interest rate moves in three intervals, given the information of some macroeconomic and financial variables in Mexico, a multinomial probit model is estimated on the basis of a monetary policy rule with jumps, given the evidence observed about the type of information used in estimating the movements of Banxico's target interest rate.

Because of this, one of the contributions to this research is to propose an ordered multinomial probit model that estimates the probability that the target rate drops by 25 bps or more, remains at the same level, or increases by 25 bps or more. This model also incorporates some Federal Treasury Certificates (Cetes) yields in the commercial banking system's estimates and financing variable.

Previous studies of this issue estimate interest rate movements, but most of them consider the latent variable (defined in this research as changes to the optimum target rate) only on the basis of certain exogenous variables (such as installed capacity and the price index) or as a function of those independent variables and their lags. However, recently Deepankar and de Jong (2007) found that under certain conditions, there is consistency and asymptotic normality of the maximum likelihood estimator for a probit specification of the model with latent variable based on exogenous variables and lags of the choice variable. The justification of these properties is found in Appendix.

To create the database that will be used to estimate the multinomial probit model, the following monetary policy documents issued by Banco de México will be reviewed: *Programas de Política Monetaria* (Monetary Policy Programs)

2000-2012; the *Informes de Política Monetaria* (Monetary Policy Reports) 2000-2012; the statement on *Conducción de la Política Monetaria del Banco de México a través del Régimen de Saldos Acumulados y el de Saldos Diarios* (Banco de México's Monetary Policy Actions through the Accumulated Balance Regime and the Daily Balance Regime); the bulletin on *Instrumentación de la Política Monetaria a través de un Objetivo Operacional de Tasa de Interés* (Implementing Monetary Policy through an Operating Interest Rate Target), and los *Informes sobre la Inflación* (Inflation Reports), July-September 2007 and April-June 2011. This review is described briefly in the following section of this article.

Considering the above, a monthly database was created that contains the macroeconomic variables of Mexico and the U.S., principally the Global Indicator of Economic Activity (GIEA) by sectors, the National Consumer Price Index (NCPI) by components, the national unemployment rate, industrial output by sectors (both in Mexico and the U.S.), the exchange rate, variables in commercial bank financing in Mexico, the U.S. Consumer Price Index, the U.S. unemployment rate, U.S. construction permits, the yield of 1-, 28-, 91-, 182- and 364-day Cetes bonds, the performance of the Fed's one- and six-month EuroDollar deposit rates and its interest rate. The data were obtained from Banco de México's *Sistema de Información Económica* (Economic Information System) with a monthly frequency from April 2004 to June 2012, except for the series of data obtained from Valuación Operativa y Referencias de Mercado S.A. de C.V. (VALMER) and Banxico; the unemployment rate, obtained from the *Encuesta Nacional de Ocupación y Empleo* (National Survey of Occupation and Employment) (ENOE) of Mexico's statistics institute, the Instituto Nacional de Estadística y Geografía (INEGI); and U.S. variables that were obtained from the U.S. Federal Reserve, Department of Labor, and Department of Commerce.

In Mexico's case, the ordered multinomial probit model, set up on the basis of a monetary policy rule in differences, considers three outcomes: that the rate decreases by 25 bps or more, remains at the same level, or increases by 25 bps or more, taking the value of 0, 1, and 2, respectively, for the dependent variable. The exogenous variables included, both in time t as in $t-1$, are the growth rates of: GIEA by sector, the underlying NCPI (inflation of all items minus food and energy) by components, national unemployment, and lags in the dependent variable (to simulate previous jumps in the short-term interest rate), which clearly influence the movement of Banco de México's target rate in time t, among other variables.

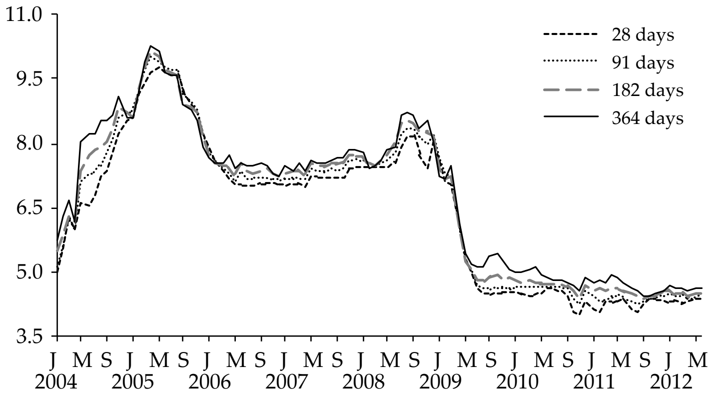
The parameters of the probit models are estimated by applying the method of maximum likelihood, see Greene (2008). The first-order conditions for the obtained likelihood function are non-linear, and therefore require numerical methods (in this article we used the Quadratic hill-climbing method) to find the value of the estimators that maximize the likelihood function.

Monetary policy operating procedures and instruments

The steering of monetary policy considers it important for the movement of short-term interest rates to be transmitted to longer-term ones, because the latter are those that mainly affect companies' and families' decisions on production, consumption and savings. Therefore, Banxico has improved the market regulation of government bonds.[3]

Figure 1

Interest rates on zero-coupon bonds (Cetes) at different periods, 2004-2012*



Note: */ Averages of daily observations.
Source: Developed by the authors using Banxico data.

Figure 1 shows the average monthly yields of Cetes (zero-bond coupons) with various maturities in Mexico. This Figure contains valuable information about the economy in the following sense: when the economy is enjoying moderate

[3] Bonds with a maturity of over one year were issued for the first time in 2000, and 30-year bonds were issued in October 2006.

growth within a framework of controlled inflation with low expectation levels, the short-term interest rate is expected to be at appropriately low levels and the long-term interest rate at a comparatively high level.

Based on this analysis, the technical chapter of the April to June 2011 Inflation Report argues that inflation expectations are anchored and that the changes to monetary policy over the economic cycle are reflected in the slope of the temporary structure of interest rates; we can observe that Banxico has shown a commitment to maintaining both price and macroeconomic stability.

Below we provide a concise explanation of Banxico's operating procedures and instruments to reach its priority target.

Initially, the Accumulated Balance Regime (in effect from September 13, 1995 to April 9, 2003) and the Daily Balance Regime (valid from April 10, 2003 to January 20, 2008) were the central bank's signal monetary policy, so called because the target balance of the banking sector's current accounts was used by Banxico to indicate its monetary policy intentions.

In essence, the mechanism worked as follows: the rates at which the surpluses in current accounts were paid or the overdrawn amounts charged must respectively be at zero and twice the target overnight rate. Specifically, the way of operating a *corto* or a negative balance target would indicate the central bank's intention to provide the banks with the resources demanded, but if the banks had overdrafts, the charging mechanism triggered an event: the central bank would not provide the entirety of resources at the market rates, thus causing an increase in interest rates since the institutions would try to avoid paying the overdraft rate, seeking to obtain these resources on the money markets even when this might involve paying higher interest rates, leading to a withdrawal of liquidity from the system. A *largo* is expansion that operates inversely, as it has the effect of creating greater liquidity.

On April 10, 2003, Banxico replaced the regime of Accumulated Balances (AB)[4] with one of Daily Balances (DB). Therefore, on April 9, 2003, the AB target for the 28-day period (*corto*) corresponded to Mex$700 million divided by 28 days from this date, giving a total of Mex$25 million per day; 49 *cortos*

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[4] The Accumulated Balances Regime (AB) began on September 13, 1995, with 25 million pesos (a *largo*). During the AB period, from September 13, 1995 until March 28, 2003, 11 *largos* were announced, sometimes twice or even six times per month (for example in November 1995); meanwhile, 32 *cortos* were announced.

were announced during the Daily Balances Regime; this amount remained unchanged until February 20, 2004, when it was increased by Mex$4 million, with gradual increases until March 23, 2005, when the daily balances target was held at Mex$79 million.

The bulletins began to show concern at the direction being taken by the short-term interest rate:[5] the April 23, 2004 bulletin mentions, "It would be undesirable to relax internal conditions"; the following bulletin, April 27, 2004, stated, "A significant reduction in the short-turn funding rate has been observed [...]. In response, Banco de México has decided to increase the *corto*, as from today, to Mex$37 million." From August 26, 2005, its statements began to explicitly indicate the interest-rate level that Banco de México considered appropriate for the prevailing *corto* level, and the indication up until the April 21 bulletin was for "easing by no more than 25 basis points." It gave no further indication on the interest rate until April 27 and October 26, 2007, when it stated, "It is restricted at 25 basis points." The monetary policy can be considered neutral or contractionary from July 2001, except from January to August 2009 (when the target rate fell on average by 0.5%).

Since January 21, 2008, the operational target of daily balances was substituted by a target overnight rate. With this operational target, Banco de México injects or withdraws missing or surplus liquidity directly from the system through Open Market Operations (liquidity auctions).[6]

In our ordered multinomial probit model of the monetary policy rule, the changes in the average monthly interbank rate are used to create a categorical variable, which can be assigned three values: 0, 1, and 2, following the methodology of Dueker (1999).

The ordered multinomial probit model

An ordered multinomial probit model is estimated on the basis of a type of discrete monetary policy rule, proposed by Dueker (1999).

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[5] The rate at which banks lend money to each other is known as the interbank rate and has the same purpose as the interest rate at which the central bank lends money. As an operational objective, since January 2008 the Banco de México has sought an *overnight rate*.

[6] Information taken from Appendix 3 of the *Informe sobre la inflación* (Inflation Report), July-September 2007 of the Banxico.

Reason for using probit models

In the family of limited dependent variable models, probit and logit models are most frequently estimated on account of their statistical properties, raising the question: Why estimate a probit and not a logit, if qualitatively speaking they would produce similar results? However, the probit model tends to be used more frequently than the logit since the former has a latent variable of interest. Another reason to estimate a probit is that the error of the truncated dependent variable is generated by a normal distribution. It is important to indicate that the variant of multivariate probit model is not used often because it tends to show convergence problems.[7]

One way of generalizing the binary probit model is to allow more than two discrete results, as shown in equation [1]:

$$y_t = \begin{cases} 0 & \text{if} \quad y_t^* \leq k_0 \\ 1 & \text{if} \quad k_0 < y_t^* < k_1 \\ \quad . \\ \quad . \\ \quad . \\ q & \text{if} \quad y_t^* \geq k_{q-1} \end{cases} \qquad [1]$$

where y_t is the discrete choice variable that can take some of the possible q values $\{0,1,2,\ldots,(q-1)\}$; y_t^* is a continuous latent variable; and $k_0, k_1, \ldots k_{q-1}$ are parameters that affect choice behavior at the threshold. In the next section, we examine the specification of the ordered multinomial probit model that considers three cases of short-term interest rate movement.

[7] It is important to remember the difference between the multinomial probit model and the multivariate probit model: the latter is used to model the results of binary correlation, and it enables an estimation of the results of various correlated binaries together. The multinomial probit model, meanwhile, is a generalization of the probit model, since it allows more than two discrete results: it is a model used to predict the probabilities of different possible results of a dependent variable, given a set of independent variables.

The probit multinomial model for studying monetary policy through the short-term interest rate

The ordered multinomial probit model analyzed in this article shall be specified on the basis of a Mexican monetary policy rule; it is a dynamic choice model because it considers the variables over time, and can be represented as follows:

$$y_t = \begin{cases} 0 & \text{if} \quad y_t^* \leq k_0 \\ 1 & \text{if} \quad k_0 < y_t^* < k_1 \\ 2 & \text{if} \quad y_t^* \geq k_1 \end{cases} \qquad [2]$$

Similarly, the likelihood function for the ordered multinomial probit model with three answers is given by:

$$f(\beta|y_t) = \begin{cases} \Phi(k_0 - x_t'\beta) & \text{if} \quad y_t = 0 \\ \Phi(k_1 - x_t'\beta) - \Phi(k_0 - x_t'\beta) & \text{if} \quad y_t = 1 \\ [1 - \Phi(k_1 - x_t'\beta)] & \text{if} \quad y_t = 2 \end{cases},$$

$$L(\beta) = \prod_{t=1}^{T} f(\beta|y_t) \qquad [3]$$

To record the dynamic nature of the choice behavior, it is allowed that a latent variable y_t^* may depend linearly on a set of stationary regressors x_t and z_{t-1} (this captures the direct dependency of the current choices on past choices) and of stationary shocks in each period u_t, so that:

$$y_t^* = x_t'\beta + \rho z_{t-1} + u_t \qquad [4]$$

where x_t is a matrix of $(l \times T)$ of stationary regressors; β is a vector of parameters $(l \times 1)$; y_t^* and z_{t-1} are vectors of $(T \times 1)$; and ρ a parameter to be estimated. $z_{t-1} = f : \Re^n \rightarrow \Re$ is defined using the following functional relationship:

$$z_{t-1} = f(y_{t-1}, y_{t-2}, \ldots, y_{t-n}) \qquad [5]$$

For example, $z_{t-1} = I(y_{t-1} \geq 0.25)$, $I(y_{t-1} > -0.25) < z_{t-1} < I(y_{t-1} < 0.25)$ or $z_{t-1} = I(y_{t-1} \leq -0.25)$, where $I(\cdot)$ denotes the indicator function; we observed that z_{t-1} can take only one finite number of values.[8]

To analyze the properties of this model's stationarity, a new error term is defined as:

$$\varepsilon_t = x_t^{'}\beta + u_t \tag{6}$$

Note that ε_t is stationary because it is the sum of two stationary variables, $x_t^{'}\beta$ and u_t. The dynamic multinomial ordered choice model can now be represented as:

$$y_t = \begin{Bmatrix} 0 & \text{if} \quad \rho z_{t-1} + \varepsilon_t \leq k_0 \\ 1 & \text{if} \quad k_0 < \rho z_{t-1} + \varepsilon_t < k_1 \\ 2 & \text{if} \quad \rho z_{t-1} + \varepsilon_t \geq k_1 \end{Bmatrix} \tag{7}$$

where the shock in each period ε_t is taken to have a cumulative distribution function $F(\cdot)$. Without a loss of generality, the unknown threshold parameters k_i have been chosen to satisfy:

$$k_i < k_{i-1},\ i = 0,1,2,\ldots,(q-1) \tag{8}$$

The dynamic multinomial ordered choice model represented in [7] is a relatively new specification in econometric literature similar to that introduced by Deepankar and de Jong (2007). The relevance of this model consists of allowing a latent variable, y_t^*, which depends on an arbitrary (but known) function of the lagged dependent variable. This leads to changes in the econometric specification, since the latent variable is a function of the lagged dependent variable, making the dependent variable a non-linear function of its own lags.

The non-linear dependency of the dependent variable on its own lags suggests the existence of a strict stationary solution of the model. Also, the stimulator $\hat{\theta}_{MLE}$ is consistent and asymptotically normal (the details of these tests can be found in Appendix).

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[8] This is due to the fact that z_{t-1} is a function of a finite number of lags of the choice variable, which can in itself take only a finite number of values for each period.

Specification of the ordered multinomial probit model based on the monetary policy rule

The monetary policy rule of Taylor (1993) has been used as the basis for many research papers on the reaction function that models how central banks move interest rates, as an instrument of monetary policy, in response to shifting macroeconomic conditions. Taylor suggested that the macro-economy of the United States could be reasonably understood as the gap between: 1) current inflation and a target inflation rate, and 2) the gap between real and potential output. Its original formulation is:

$$f_t = \pi_t + r_t^* + 0.5\left(\pi_t - \pi^*\right) + 0.5\left(y_t - y^*\right) \qquad [9]$$

where f_t is the central bank's interest rate; r_t^* is the natural (real) natural interest rate; π_t is the inflation rate; π^* is the central bank's target inflation rate; y_t is the logarithm of the real Gross Domestic Product (GDP); and y^* is the logarithm of the potential GDP. The above monetary policy rule (in real time) was modified by Dueker (1999), who proposed a model derived from the monetary policy rule, but in a discrete version.

Dueker (1999), working on the basis of Taylor's specification, proposed that the explanatory variables are inflation, the output gap, and an intercept. If, given the evidence of smoothing,[9] we add a lagged latent variable and the lagged changes in the latent variable, we have the following specification:

$$f_t^* = \rho f_{t-1}^* \pi_t + \lambda_0 + \lambda_1 \pi_t + \lambda_2 y_t + \delta \Delta f_{t-1}^* + \varepsilon_t \qquad [10]$$

The observable variable, Δf_t, is related to the latent variable (f_t^*) as follows:

$$\Delta f_t \text{ is in category } j \text{ if } \left(f_t^* - f_{t-1}^*\right) \in \left(c_{j-1}, c_j\right), \left[j = 1, \ldots, 3\right] \qquad [11]$$

The specification of the monetary policy rule [10] is referred to in literature on the subject as the *discrete version of a difference monetary rule* widely referred to

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[9] The inertia factor is closely related to the performance taken into account by Banxico when steering its monetary policy. Also the persistency aims to smooth the interest rate.

both in Dueker (1999) and in Orphanides and Williams (2002), in this sense within a discrete choice framework that considers the problems of mismeasurements of gaps or natural rates.

However, based on the specification of the discrete-choice version of a monetary policy rule proposed by Deepankar and de Jong (2007), the changes to the central bank's optimum target rate are the latent variable. Similarly to standard literature on discrete-choice models for the interest rate, we will look at short-term changes to the interest rate as the latent (or non-observable) variable. The discrete changes observed are determined by the sign and size of the latent variable. In order to find the specification of the multinomial probit model to be estimated for Mexico, the modified specification of the Taylor rule proposed by Orphanides and Williams (2002) is used:

$$f_t^* = r_t^* + \pi_t + \theta_\pi \left(\pi_t - \pi^*\right) + \theta_u \left(u_t - u^*\right) \qquad [12]$$

where the unemployment rate's deviation from its natural rate is used as the output gap. In equation [12], f_t^* is the optimum nominal target rate; r_t^* and u^* are the natural interest and unemployment rates, respectively;[10] π_t is the inflation rate; and u_t is the unemployment rate. Using the first difference of equation [12] we have:

$$\Delta f_t^* = \left(1 - \theta_\pi\right) \Delta\pi_t + \theta_u \Delta u_t + \left(\Delta r_t^* - \theta_u \Delta u^*\right) \qquad [13]$$

where Δ refers to the first difference, *i.e.*, $\Delta x_t = x_t - x_{t-1}$. Following Gordon (1997) and Ireland (1999), natural variables such as stationary difference will be used. Therefore:

$$\Delta r_t^* - \theta_u \Delta u^* = \varepsilon_t \qquad [14]$$

where ε_t is a stationary stochastic process. After substituting [14] in equation [13], we find:

$$\Delta f_t^* = \left(1 - \theta_\pi\right) \Delta\pi_t + \theta_u \Delta u_t + \varepsilon_t \qquad [15]$$

[10] The natural unemployment and the interest rates are the rate of unemployment and the real interest rate, which are compatible with the stable inflation rate.

Equation [15] is the basis that controls the evolution of the optimum target rate. In order to factor in the inertia policy,[11] it is allowed that in a previous period the choice variable determines the current latent variable. To formalize this dependency, three dummy variables are included in the equation:

$$\begin{gathered} d_{1t} = I(\Delta f_{t-1} \leq -0.25) \\ d_{2t} = I(-0.25 < \Delta f_{t-1} < 0.25) \\ d_{3t} = I(\Delta f_{t-1} \geq 0.25) \end{gathered} \qquad [16]$$

The dummy variables capture the effect of previous choices in the latent variable (and therefore in the choice of current monetary policy): d_1 refers to the negative changes less than or equal to 0.25; d_2 represents the changes within –0.25 and 0.25; and d_3 considers the positive changes greater than or equal to 0.25. All changes refer to those that happened in the previous period. With dummy variables included, we find the following specification of our model's latent variable:

$$\Delta f_t^* = \left(1-\theta_\pi\right)\Delta\pi_t + \theta_u \Delta u_t + \gamma_1 d_{1t} + \gamma_2 d_{2t} + \gamma_3 d_{3t} + \varepsilon_t \qquad [17]$$

where ε_t is *i.i.d.* normal with zero mean and standard unitary deviation. A dependent variable (DF_t) is defined as an ordered categorical variable that considers the values 0, 1, and 2 which takes y_t. This variable is defined in terms of the sizes and signs of the changes in the target rate observed as follows:

$$DF_t = I(-0.25 < \Delta f_{t-1} < 0.25) + 2 * I(\Delta f_{t-1} \geq 0.25) \qquad [18]$$

The model estimated in this research belongs to the ordered multinomial choice family, a version of the model shown at [7], where the observable categorical variable DF_t, and the latent non-observable variable are related as follows:

$$DF_t = \begin{Bmatrix} 0 & \text{if} \ \ \Delta f_t^* \leq k_0 \\ 1 & \text{if}\ k_0 <'' f_t^* < k_1 \\ 2 & \text{if} \ '' f_t^* \geq k_1 \end{Bmatrix} \qquad [19]$$

[11] Theoretical studies of this issue have proven that including the inertial policy in the models can improve the stabilization of central banks; see, for example, Rotemberg and Woodford (1999).

where k_0 and k_1 are unknown but constant threshold parameters which can be estimated. It is necessary to estimate the following parameters: θ_π, θ_u, γ_1, γ_2 and γ_3. Note that [17], [18], and [19] together define a new alternative of the Taylor rule, which best capture how the central bank decides monetary policy, with decisions in discrete time, through the target rate.

Data

We created a monthly database that contains macroeconomic and financial variables of Mexico and the United States. For Mexico, the database contains the following Mexican macroeconomic variables: GIEA) by sectors; general and underlying NCPI (inflation of all items minus food and energy); national unemployment rate; industrial output by sectors; and the exchange rate. For the United States variables the database included industrial output by sectors; the Consumer Price Index; and the unemployment rate; construction permits. For the financial variables, we included variables of commercial bank financing in Mexico; the yield of 1-, 28-, 91-, 182- and 364-day Cetes bonds; and the yield of the Fed's one- and six-month EuroDollar deposit rates. The notation of the variables used in the models is shown in Table 1.

Table **1**

Notation of the variables used in the models

Notation	*Variable*	*Units*
i_iTARGET	Target interest rate of the Multinomial probit model	%
*ITARGET*_0	Estimate of the dependent variable if $y_t = 0$	%
*ITARGET*_1	Estimate of the dependent variable if $y_t = 1$	%
*ITARGET*_2	Estimate of the dependent variable if $y_t = 2$	%
Δ*NCPI*	General inflation	%
Δ*NCPI*(–1)	General inflation lagged by one period	%
Δ*NCPI*(–2)	General inflation lagged by two periods	%
Δ*NCPI*(–3)	General inflation lagged by three periods	%
Δ*SUBNCPI*(–1)	Inflation of all items minus food and energy, lagged by one period	%
Δ*GIEA*	Growth of GIEA	%
Δ*GIEA*(–1)	Growth of GIEA lagged by one period	%
Δ*GIEA*(–2)	Growth of GIEA lagged by two periods	%
Δ*GIEA*(3)	Growth of GIEA lagged by three periods	%
Δ*SERGIEA*(–4)	Growth of GIEA of services lagged by four periods	%

Table **1, continuation…**

Notation	*Variable*	*Units*
$\Delta NATMU$	Change in national unemployment rate	%
$\Delta NATMU(-1)$	Change in national unemployment, lagged by one period	%
$\Delta NATMU(-2)$	Change in national unemployment, lagged by two periods	%
$\Delta NATMU(-3)$	Change in national unemployment, lagged by three periods	%
$\Delta NATMU(-4)$	Change in national unemployment, lagged by four periods	%
$\Delta MINP$	Growth of industrial mining output	%
$\Delta MINP(-1)$	Growth in industrial mining output lagged by one period	%
$\Delta MINP(-2)$	Growth in industrial mining output lagged by two periods	%
$\Delta RCB(-1)$	Growth of financing for the country's non-banking sectors, provided by commercial banks resident in the country, for private portfolios of companies, and individuals engaged in business activities	%
$\Delta TFCB$	Growth of the total financing of commercial banking; financing for the country's non-banking sectors	%
$\Delta TFCB(-4)$	Growth of total financing of commercial banking; financing for the country's non-banking sectors, lagged by four periods	%
$\Delta DBRB$	Growth of financing for non-banking sectors in the country, by development banks, for private portfolios of companies and individuals engaged in business activities, provided by banks resident in the country	%
ΔDB	Growth of financing for non-banking sectors in the country, by development banks, for private portfolios of companies and individuals engaged in business activities	%
$\Delta YIELD28(-1)$	Change in Cetes 28-day yields, lagged by one period	%
$YIELD91$	Cetes 91-day yield	%
$\Delta YIELD91(-3)$	Change in Cetes 91-day yield, lagged by three periods	%
$\Delta YIELD182(-1)$	Change in Cetes 182-day yield, lagged by one period	%
$\Delta YIELD364$	Change in Cetes 364-day yield	%
$\Delta YIELD364(-3)$	Change in Cetes 364-day yield, lagged by three periods	%
ΔNER	Change in nominal exchange rate	%
$\Delta NER(-1)$	Change in nominal exchange rate lagged by one period	%
$\Delta CPIUSA(-5)$	U.S. inflation, lagged by five periods	%

Table 1, continuation…

Notation	*Variable*	*Units*
Δ*USMANP*(–1)	Growth of U.S. manufacturing output, lagged by one period	%
Δ*USAMU*(–6)	Change in U.S. unemployment, lagged by six periods	%
Δ*US-CONSPER*(–1)	Increase in number of U.S. construction permits, lagged by one period	%
Δ*USIP*	Growth of U.S. industrial output	%
Δ*DEP1EURODL*(–2)	Change in the yield of 1-month EuroDollar deposits (Federal Reserve), lagged by two periods	Annualized %
Δ*DEP6EURODL*	Change in the yield of 6-month EuroDollar deposits (Federal Reserve)	Annualized %
Δ*FED*	Change in the Federal funds rate (Federal Reserve)	Annualized %
Δ*FED*(–3)	Change in the Federal funds rate, lagged by three periods	Annualized %

The data were obtained from Banco de México's Economic Information System with a monthly frequency from April 2004 to June 2012.[12] Except for the series of yields obtained from VALMER and Banxico, the unemployment rate that was obtained from the ENOE of Mexico's statistics institute, the INEGI, and U.S. variables obtained from the United States Federal Reserve, Department of Labor, and Department of Commerce.

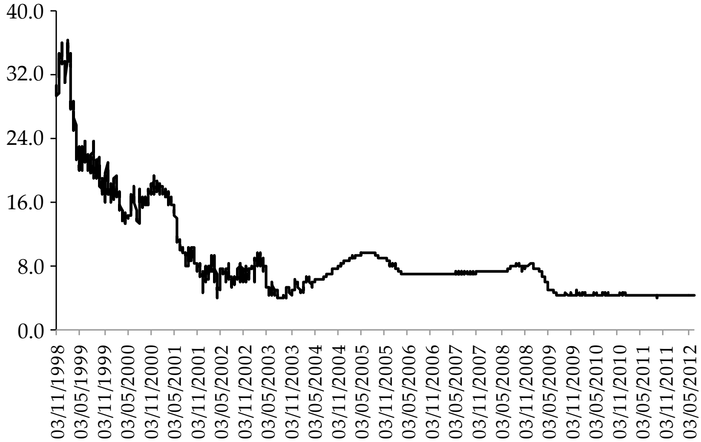
To create the categories of the dependent variable in the proposed model, Banco de México statements were reviewed to observe the changes in Banxico's short-term interest rates, the current monetary policy instrument.

Based on the April 27, 2004 bulletin[13] and Figure 2, it can be seen that the central bank managed stabilize the rate's performance approximately from April 2004, but this activity was explicitly referred to in Banco de México's statements from August 26, 2005, since the bulletins refer to the rate considered consistent with the existing *corto* level. On January 21, 2008, the overnight rate was established as a direct instrument of monetary policy.

[12] This period of analysis was chosen because since April 2004, it was observed that Banxico directly guides the overnight rate, a dependent variable of the estimated models.

[13] The April 27, 2005 bulletin states, "A significant decrease in the short-term bank rate has been observed […]. In response, Banco de México has decided to increase the *corto*, as from today, to Mex$37 million."

Figure **2**
Weighted average interbank rat, 1998-2012
(annual percentage)



Source: Created by authors using Banxico data.

We have estimated the models for April 2004 to June 2012 taking into account that the one-day interbank interest rate behavior has offered a guideline since April 2004, and the implicit comments in Banxico's bulletins about monetary policy movements. This is also backed up by the empirical evidence found in Benavides and Capistrán (2009), who find that the daily volatility of the short-term interest rate in Mexico fell substantially when Banxico changed from the Daily Balances (DB) to the interest-rate regime in April 2004.

Dependent variable of the ordered multinomial probit model

In the case of the ordered multinomial probit mode, the changes in one-day interbank rates are used to create a categorical variable similar to that of Dueker (1999). The dependent variable considers three results: that the rate decreases by 25 bps or more, remains at the same level, or increases by 25 bps or more, taking the value of 0, 1, and 2 as the dependent variable, respectively. We interpreted that the latent variable is the change in the optimum target rate. In each period, this latent variable is determined by three sets of other variables: inflation's current or lagged changes; the current and lagged changes in the increases of the unemployment rate and of the GIEA; and a known function of the lagged dependent variable. These three sets of variables, together with a random sample of shocks, determine the value of the latent variable in each period, and this in turn determines the value taken by the choice variable.

Descriptive statistics of the dependent variable

Table 2 summarizes the statistics of the dependent variable, considering solely the overnight rate for the period between April 2004 and June 2012.

Table **2**
Dependent variable statistics

Concept			
DF_t	*Definition*	*Frequency*	*Category average*
0	$\Delta f_t \leq -0.25$	15/99	–0.4303
1	$-0.25 < \Delta f_t < 0.25$	74/99	0.0130
2	$\Delta f_t \geq 0.25$	10/99	0.3568

Table 3 shows the statistics of the dependent variable, considering the overnight rate for the period between April 2004 to December 2007 and Banxico's target overnight rate from January 2008 to June 2012.

Table **3**
Dependent variable statistics

Concept			
DF_t	*Definition*	*Frequency*	*Category average*
0	$\Delta f_t \leq -0.25$	14/99	–0.4426
1	$-0.25 < \Delta f_t < 0.25$	75/99	0.0095
2	$\Delta f_t \geq 0.25$	10/99	0.3580

It can be seen that the average within the category changes little when DF_t takes the value 1.

Empirical analysis of the ordered multinomial probit model applied to Mexico's monetary policy

The model proposed in this article, as well as the other specifications of the Taylor rule, record the dependency of policy-makers on the change of interest rates on account of inflation and the rate of growth of current economic activity; the proposal also takes into account the central bank's policy (inertial policy or changes at $t-1$ of the movement of the target rate).

Below we present the results of the estimation of the multinomial probit model derived from the monetary policy rule.

Results of the estimation of the ordered multinomial probit model of the monetary policy rule

We estimated three specifications of the multinomial probit model, describing them as follows: the *classic model*, which only takes values from exogenous variables in time t; the *extended model*, which includes lags of independent variables; and the *proposed model*, which jointly considers macroeconomic and financial information.

Table 4 shows that the best adjustment is found in the proposed model with a pseudo R-squared of 81.6%, while the classic and extended models have a goodness of fit of 64.7% and 71.3%, respectively.

Table 4
Model adjustment tests, information criteria and Log-likelihood

Criterios	*Classic model*	*Extended model*	*Proposed model*
Pseudo R-square	0.647212	0.713024	0.816479
Log likelihood	–22.62698	–17.95962	–10.29777
Schwarz	1.435068	1.765308	1.206862
Akaike	0.897410	1.010329	0.658647
Hannan-Quinn	1.114664	1.314639	0.879911

The Akaike, Schwarz, and Hannan-Quinn information criteria indicate the proposed model is the best compared to the set of models considered; it also offers the greatest value in the maximization of the likelihood function.

The results of the classic multinomial probit model specifications, as shown in Table 5, indicate that Banxico responds more to inflation expectations, generated by an expectation of changes in the demand for liquidity; this expectation of demand for liquidity is based on the analysis of indicators of real economic activity (Mexico's GIEA lagged by one period).

Specifically, if the monetary authority observes a demand shock that positively affects Mexico's economic activity, inflation expectancy increases, thus increasing the probability of changes to the interest rate, as indicated in the classic model. The extended model shows the weight of information of financial variables on the central bank's decision to change its monetary policy, through the reference rate. In both the classic and extended models, we can observe that the previous movements in the target rate have a relative influence on the current target rate.

Table **5**
Results of the Estimate of the Ordered Multinomial Probit Model

Slopes of the classic and extended ordered multinomial probit model					
Classic model: without lags of explanatory variables		*Extended model: with lags of explanatory variables*			
*D*1(–2)	–3.82663*	*D*1(–3)	–0.33772	Δ*DEP6EURODL*	–8.60537**
	(1.38032)		(1.05525)		(3.78499)
*D*2(–1)	2.57917*			Δ*YIELD*28(–1)	14.95904
	(1.02044)	*D*2(–1)	3.76777**		(15.88361)
*D*2(–2)	–1.29944		(1.56230)	Δ*YIELD*91(–3)	–16.10847
	(0.87708)				(14.95396)
*D*3(–1)	5.40269*	*D*3(–1)	9.59079*	Δ*YIELD*182(–1)	–7.67957
	(1.69586)		(3.33595)		(15.44867)
Δ*NCP*I	4.18068**			Δ*YIELD*364	27.14427***
	(1.78935)				(15.56137)
Δ*NCPI*(–1)	1.17043	Δ*NCPI*(–1)	1.429503	Δ*YIELD*364(–3)	6.69105
	(1.37586)		(2.02534)		(12.61830)
Δ*NCPI*(–2)	–2.07648	Δ*NCPI*(–2)	–2.71506	Δ*FED*(–3)	5.38159**
	(1.91575)		(2.24614)		(2.43476)
Δ*NCPI*(–3)	3.33307	Δ*NCPI*(–3)	5.45778**	k_1	0.957494
	(1.81181)		(2.71990)		(1.48231)
Δ*GIEA*	59.25498	Δ*GIEA*	46.63758	k_2	9.85989*
	(39.77609)		(32.91806)		(3.452697)
Δ*GIEA*(–1)	75.71715**	Δ*GIEA*(–2)	27.91070		
	(35.18014)		(45.28676)		
Δ*GIEA*(–2)	35.30425	Δ*MINP*	–10.93733		
	(24.86619)		(24.64574)		
Δ*GIEA*(–3)	–7.10594	Δ*MINP*(–1)	22.04328		
	(31.40099)		(19.39485)		
Δ*NATMU*	–3.84323	Δ*MINP*(–2)	31.72862		
	(6.72081)		(18.40333)		
Δ*NATMU*(–1)	10.78394	Δ*NATMU*(–1)	–8.19341		
	(8.08550)		(11.99681)		

Table 5, continuation…

Slopes of the classic and extended ordered multinomial probit model

Classic model: without lags of explanatory variables		*Extended model: with lags of explanatory variables*	
ΔNATMU(–2)	–5.13554	ΔURBMU(–1)	7.81740
	(7.20522)		(6.68446)
ΔNATMU(–3)	–1.75925	ΔRCB(–1)	–48.72264
	(6.42899)		(26.89125)
ΔFED	2.86502	ΔTFCB	–21.67759
	(1.98990)		(25.36913)
ΔNER(–1)	26.43831	ΔDBRB	–23.01087***
	(15.78847)		(12.38817)
k_1	0.70854	ΔNER	–3.42287
	(1.48813)		(16.17575)
k_2	7.02676*	ΔNER(–1)	18.46478
	(2.42799)		(13.64192)

Notes: At a 1% (*), 5% (**), and 10% (***) level of significance. Standard errors are placed in brackets. The letters *TFCB* refer to the total commercial bank financing of the country's non-financial sectors. *RCB* represents the funding of non-banking sectors in the country, provided by banks resident in the country from the commercial bank sector, for the private portfolios of companies and individuals engaged in business activities. *DBRB* considers the financing of the country's non-banking sectors, by development banks, for private portfolios of companies and individuals engaged in business activities, provided by banks resident in the country.

In short, the probability of movements in the target rate, as seen in the extended model, show an effect of the financial variables and inflation lags in the central bank's decision because it takes into particular account the changes in previous inflation, given its target, which is to maintain people's purchasing power, although it is desirable for Banxico to encourage growth with price stability, as found in the Federal Reserve's dual mandate. In this sense, the results found are consistent with the empirical evidence of efficient implementation of monetary policy to achieve price stability, because the greater weight of the probability of changes in the target rate is due to lags in inflation, inflation expectancies generated by the behavior of variables of real activity (which make it possible to foresee future changes in the demand for liquidity), and changes in financial variables.

Using the specifications of the ordered multinomial probit model, Table 7 shows the estimated probability of the rate decreasing by more than 25 bps remaining at the same level or increasing by more than 25 bps.

Table 6
Results of the estimate of the proposed model of the ordered multinomial probit

Slopes of the ordered multinomial probit (proposed model)					
*d*1(–5)	–0.36134	Δ*CPIUSA*(–5)	2.94278***	*YIELD*91	6.92901**
	(–1.30240)		(1.87942)		(3.10556)
*d*2(–1)	7.77179**	Δ*USMANP*(–1)	–75.54673	*YIELD*182(–1)	–23.02001
	(–3.42597)		(58.72583)		(19.30147)
*d*3(–1)	16.71125*	Δ*USAMU*(–6)	0.47312**	Δ*DEP*1-*EURODL*(–2)	4.33513
	(6.46269)		(0.24184)		(3.91807)
Δ*SUBNCPI*(–1)	27.13102*	Δ*US-CONSPER*(–1)	16.24448**	*FED*(–3)	–0.64606***
	(10.46517)		(8.08490)		(0.39542)
Δ*NATMU*(–4)	0.39203***	Δ*USIP*	1.30721**		
	(0.22260)		(0.57786)	k_1	10.35692*
Δ*SERGIEA*(–4)	8.96931***	Δ*TFCB*(–4)	9.06766**		(–4.145645)
	(4.90741)		(4.48235)	k_2	25.47882*
Δ*NER*(–4)	–0.45517**	Δ*DB*	–0.41088*		(–8.880387)
	(0.19230)		(0.16619)		

Notes: At a 1% (*), 5 %(**), and 10 % (***) level of significance. Standard errors are placed in brackets. *DB* stands for financing of the country's non-banking sectors, by development banks, for private portfolios of companies and individuals engaged in business activities.

Table 7
Probability of jumps by type of ordered multinomial probit model

Models and categories				
DF_t	*Definition*	*Type of model*		
		Classic	Extended	Proposed
0	$\Delta f_t \leq -0.25$	0.1553	0.1225	0.9187
1	$-0.25 < \Delta f_t < 0.25$	0.8333	0.8122	0.0812
2	$\Delta f_t \geq 0.25$	0.0114	0.0653	0.0001

Table 7 shows the probabilities of jumps per type of model. In the classic model, the probability of the interest rate decreasing by more than 25 basis points is close to the observed frequency of the event (15.5% *vs.* 14.1%). However, the proposed model that contains the United States' macroeconomic and financial variables indicates a 90.9% chance that the central bank may reduce the reference rate, which strengthens the position of the analysts who consider that, under the right conditions (discussed in the Conclusions below), Banxico could reduce the target rate.

If the rate remains the same, the observed frequency in the extended model was 75.8% versus 83.3% as estimated in the classic model. When the rate increases by more than 25 basis points, the estimated probability of the extended model was 6.5% versus that observed of 10.1%.

Although the classic and extended models approximate better the frequency observed in each of the dependent variable categories, because since July 17, 2009, Banxico has maintained the reference rate at 4.5%, under current macroeconomic and financial conditions, which are considered in the proposed model, a change in Banxico's monetary policy is foreseen.

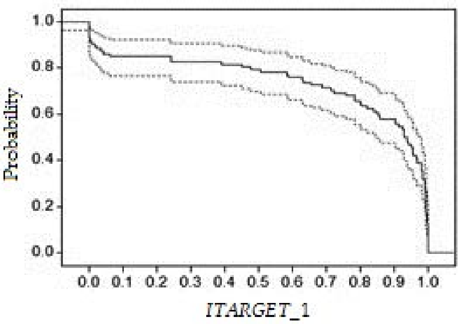
Figure 3 (a, b, and c) shows the estimated probabilities of choosing each one of the categories of dependent variable for the classic model, the extended model (with lags), and the model proposed here.

Figure **3**

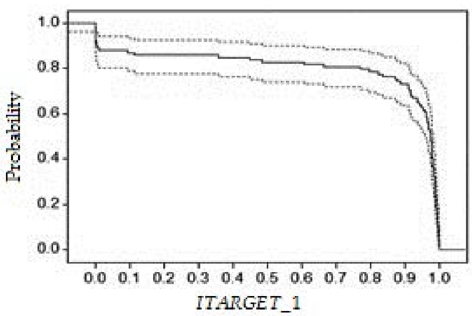
Estimated Probabilities for Each Estimated Model

for $-0.25 < \Delta f_t < 0.25$

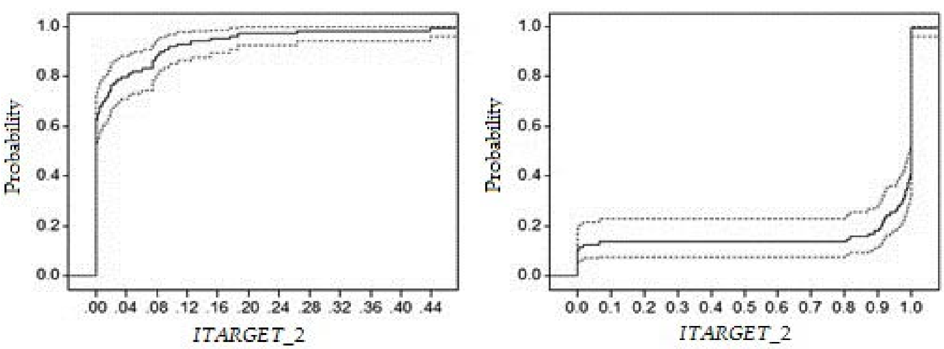
3a. Classic model



3b. Extended model



3c. Proposed model



Figures 3a and 3b show a high probability that Banxico may change the target rate by small amounts. In other words, if Banxico were to decide to change monetary policy, it would do so gradually and in prudent amounts. Figure 3c shows the probability of a decrease or increase in Banxico's target rate, which indicates that it is highly probable that the central bank could reduce its reference rate due to the empirical distribution presented by estimated probabilities with regard to the threshold value, set at y_t.

The econometric results and the expectation observed through reading Banco de México's reports therefore indicate that it foresees lowering its interest rates to encourage economic growth, because inflation is on a downward trend and the economy is showing signs of slowing down. However, given the pressure of the depreciation of the exchange rate on inflation, it is hard to believe that Banxico will reduce the target rate.

Conclusions

The monetary authority faces a great dilemma given such disparate macroeconomic indicators and the global economic signs. Those in charge of monetary policy could make one of three decisions: reduce the target interest rate, maintain it at the same level, or increase it. Banco de México is currently leaving the reference rate unchanged at 4.5%, but let us look more closely at the reasons why it could move it.

A reason to relax the current monetary policy would be to boost economic growth, if growth expectancy is under 4%, but ensuring that the real interest rate is positive, if inflation is between 3 and 4 percent. An accommodative monetary policy would make loans more accessible and the opportunity costs between financial savings and productive investment lean toward the latter, which could increase the demand for goods and services. This would have two positive effects: on the one hand, it would stimulate the domestic market, compensating for the weakness of the external market; and, on the other, reducing the interest rate creates exchange-rate competitiveness and boosts exports, but this can carry an inflationary risk due to excessive exchange-rate depreciation, affecting prices. Therefore, until conditions in the foreign exchange market change, it would be difficult for the central bank to reduce its interest rates.

Banxico could raise its interest rates if permanent increases were observed in prices that prefigure inflationary pressures and therefore affect the official target, since uncontrolled inflation is bad for the economy. Some economists even consider inflation worse than tolerating an economic slowdown because it harms families' purchasing power, especially if the authorities fall into the monetary trap and create an inflationary spiral. Workers tend to lose much more with runaway inflation, as happened in the 1970s and 1980s, specifically in 1986 and 1987 when annual inflation hit levels of 105.7 and 159.2 percent.

If the central bank decides to maintain its reference rate at 4.5%, it is highly likely that it is keeping an eye on economic and financial conditions in order to react swiftly.

This is a reflection of the options available to the central bank under certain circumstances, given the current uncertainty facing the global economy. Based on the results obtained from the proposed model and in common with other analysts, we can foresee the central bank reducing its interest rates in the case of worsening international economic conditions that may affect Mexico. For example, with a sharper deceleration in trade following the crisis of some eurozone countries or even if the United States were to enter into a recession, Banxico would lower its interest rate this year, after remaining at 4.5% for a little over two years.[14] In the last quarterly inflation report, Banxico mentioned that currently its monetary policy, rather than controlling inflationary pressures, could be oriented toward stimulating economic growth, because its underlying inflation (inflation of all items minus food and energy) expectancy for the next year is below 3% and could fall even lower, and at around the 3% mark a reduction of the target rate undoubtedly becomes possible. However, given the current state of the global economy, Banco de México has decided to maintain its reference interest rate, even for the rest of 2012. This will depend on the development of inflation expectations and growth, as well as the expectancies generated by the decision announced by the U.S. Federal Reserve through its last FOMC statement, indicating that it would possibly maintain its federal funds rate between the range of 0% and 0.25% until 2014.

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[14] After the global crisis triggered by the bankruptcy of Lehman Brothers on September 15, 2008, Mexico's central bank began a series of cuts to the one-day interbank interest rate, lowering it from 8.27 to 4.50 percent, and maintaining it there since July 17, 2009.

Given global macroeconomic circumstances, due to the crisis of some countries in the euro zone, on the basis of the proposed model, we suggest that monetary authorities adopt a strategy of bolstering the domestic market as an alternative given a possible drop in demand for Mexican exports, as well as looking for medium- and long-term measures to help improve purchasing power.

In econometric terms, this research provided further analysis of the use of probit models applied to the study of monetary policy. Based on the Taylor rule, we configured a dependent variable multinomial model with three discrete categories. This was prompted by the work of Dueker (1999) and Orphanides and Williams (2002), who model the short-term interest rate as a discrete variable instead of a continuous random variable. Given the discrete nature of changes made by central banks to the target rates, a discrete specification appears to be more realistic. Furthermore, the proposed ordered multinomial probit model can be considered as falling within the discrete category of the robust version of the *difference models* proposed by Orphanides and Williams (2002); the advantage is that they take into account the growth rates of the variables and therefore avoid the problems derived from mismeasurements of unknown quantities, such as natural rates and output and inflationary gaps.

Apart being able to capture the effects of discrete choices in current decisions, the proposed specification, through the ordered multinomial probit model, reveals the following small asymmetries in Banxico's behavior: positive (negative) changes in the target rate in the previous period lead to a greater probability of negative (positive) changes in the current period, as found by Deepankar and de Jong (2007) for the Fed.

The technical innovations incorporated into this paper are in response to relevant literature, because there is empirical evidence that the macroeconomic and financial variables offer an improved specification based on the information criteria of Akaike, Schwarz and Hannan-Quinn. In particular, the goodness of fit for the ordered multinomial probit model is improved. Therefore, these models provide more information that make it possible to find out the probability of a jump in the target rate by incorporating the perceptions of participants in the government bond market, and including macroeconomic variables that reflect the rhythm of economic activity.

Therefore, monetary policy reacts to the available macroeconomic and financial information to achieve price stability although it is desirable that it encourages price stability (as found in the Federal Reserve's dual mandate).

We found that Banxico reacts more strongly to lagged inflation, changes in financial variables, and inflation expectancies generated after an expectation of changes to the demand for liquidity; this expectancy of changes in the demand for liquidity is based on the analysis of indicators of real economic activity.

In particular, if the monetary authority observes a demand shock that may have a positive effect on Mexico's real economic activity, the expectation of inflation rises. Thus the results we found that lagged inflation, changes to financial variables, and inflation expectancies have the greatest effect on changes to the target rate, which is in line with the empirical evidence of an efficient steering of monetary policy to achieve price stability.

Future research could incorporate other variables to reflect the interrelation of the financial systems of Mexico and the United States. Also, we could increase the multinomial model order, with the purpose of estimating a model with more limits on possible monetary policy changes. Further studies could also examine possible asymmetries in central banks' behavior.

Appendix

Properties of the General Probit Model Specification

The general probit model, the properties of which will be analyzed, is the following:

$$y_t = \begin{Bmatrix} 0 & \text{if} & \rho z_{t-1} + x_t^{'}\beta + u_t \le k_0 \\ 1 & \text{if} & k_0 < \rho z_{t-1} + x_t^{'}\beta + u_t \le k_1 \\ & & \cdot \\ & & \cdot \\ & & \cdot \\ q-1 & \text{if} & \rho z_{t-1} + x_t^{'}\beta + u_t > k_{q-2} \end{Bmatrix} \quad \text{[A1]}$$

where $z_{t-1} = f(y_{t-1}, y_{t-2}, \ldots, y_{t-n})$ and the error have a normal distribution. With the true vector a parameter denoted by $\theta_0 = (\beta_0', \rho_0)'$, where $\beta_0 \in \Re^l$ and $\rho_0 \in \Re$. The space of the parameter is denoted by Θ with $\theta = (\beta', \rho)' \in \Theta$. To concisely express the conditional likelihood function:

$$P\left(y_{n+i}=0\right)=p_0^{n+i}=\Phi\left(k_0-\rho z_{n+i-1}-x_{n+i}^{'}\beta\right)$$
$$P\left(y_{n+i}=j\right)=p_j^{n+i}=\Phi\left(k_j-\rho z_{n+i-1}-x_{n+i}^{'}\beta\right)$$
$$-\Phi\left(k_{j-1}-\rho z_{n+i-1}-x_{n+i}^{'}\beta\right),\ j=1,\dots,q-2 \qquad [A2]$$
$$P\left(y_{n+i}=q-1\right)=p_{q-1}^{n+i}=\Phi\left(k_{q-2}-\rho z_{n+i-1}-x_{n+i}^{'}\beta\right)$$

The likelihood function, conditional on $(y_1, y_2,\dots, y_n)$, is given by:

$$\ln L_T(\theta)=\sum_{i=n}^{T}\sum_{j=0}^{q-1}1\left(y_{i+1}=j\right)\ln p_j^{i+1} \qquad [A3]$$

The estimator of maximum likelihood, $\hat{\theta}_{MLE}$, is the value of θ which maximizes [A3]. We used the following notation: $\|x\|$ denotes the Euclidean norm of $x\in\Re^l$; $\rightarrow_p$ indicates convergence in probability; and $\rightarrow_d$ denotes convergence in distribution. For consistency of $\hat{\theta}_{MLE}$ the following assumptions are required:

Assumption A

1) x_t is a strictly stationary sequence, strongly mixed random variables, where $x\in\Re^l$ for $l\geq 0$ and $(E\|x\|^2)<\infty$. The distribution of $w_t=(x_t', y_1, y_2,\dots, y_{t-n})'$ is not contained in any linear subspace of $\Re^l$.
2) $u_t\,|\,x_t, y_{t-1}, y_{t-2},\dots, y_{t-n}\sim iid\ N(0,1)$.
3) y_t is given by [A1].
4) θ_0 is an element inside Θ, which is a convex set.

Theorem 1: Under the assumption A, $\hat{\theta}_{MLE}\rightarrow_p\theta_0$. For asymptotic normality, we need an additional assumption.

Assumption B

1) $u_t\,|\,(x_t,y_1), (x_{t-1},y_{t-2}),\dots\sim iid\ N(0,1)$

Theorem 2: Under the assumption A and B, $T^{1/2}(\hat{\theta}_{MLE}-\theta_0)\rightarrow_p N(I^{-1})$, where I is the information matrix given by $I=E(\partial/\partial\theta)(\partial/\partial\theta')\ln L_T(\theta)$.

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