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Inflation Targeting Regime:  
Two Instruments to Control Inflation

The Mexican Experience, 1996-2013

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# Sterilized Interventions in an Inflation Targeting Regime: Two Instruments to Control Inflation. The Mexican experience, 1996-2013

Ignacio Perrotini and Santiago Capraro\*

## Abstract

This paper investigates the effectiveness of Banco de Mexico interventions to move the exchange rate in its desired direction. We use a time series model and an event study methodology to analyze the relationship between the exchange rate and the interventions. We find that interventions were effective in the period under study. Banco de Mexico almost totally sterilizes its exchange rate interventions, which means that sterilization is an independent instrument of Banco de Mexico monetary policy. The exchange rate, in turn, is an intermediate objective to accomplish low and stable inflation, which is Banco de Mexico's unique final goal. We briefly survey the specific instruments that Banco de Mexico uses to intervene and the recent evolution of the Mexican exchange rate market.

*Keywords: sterilized intervention, exchange rate, monetary policy, central bank.*

*JEL Classification Codes: E58, F31, F42, G15, O24.*

## 1.- Introduction

Central banks that apply inflation targeting regimes do not recognize that they often carry out sterilized interventions to control the exchange rate. This means that interventions are an additional instrument of the central banks beside the interest rate, while the exchange rate is an intermediate objective to achieve their final goal, which is the inflation target. The lack of transparency about this crucial issue is explained,

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in part, due to the orthodox stance that an inflation targeting regime is only consistent with a free floating exchange rate and the belief that sterilized interventions are not an effective instrument to control the exchange rate.

The present paper studies the effectiveness of Banco de Mexico sterilized interventions to control the exchange rate during the application of an inflation targeting regime during 1996-2013. The paper finds that Banco de Mexico has used several mechanisms to intervene in the exchange market. The main contribution of this investigation is that it produces econometric results, with two methodologies, which show that interventions were effective in the period studied and that they were sterilized by Banco de Mexico. These characteristics of Banco de Mexico sterilized interventions transform them into an independent instrument. The work also highlights, contrary to the official position of Banco de Mexico, that the exchange rate is an important part of the monetary policy to control inflation. More specifically, the results imply that it is an intermediate objective of the monetary policy used exclusively to reach the inflation target.

The rest of the paper is organized as follows. In the next section, we briefly survey the evolution of sterilized intervention in developed countries and the transmission mechanisms through which the sterilized intervention affects the exchange rate. The third section studies Banco de Mexico exchange rate policy. Specifically, we analyze the instrument used to intervene in the market and accumulate international reserves. In addition, we survey the recent evolution of Mexican exchange rate market. The fourth section develops a series of econometric models that study the relationship between the exchange rate and interventions in Mexico to determine if these were effective. We also assess the extent of the sterilization of these interventions. In the final section we present some concluding remarks.

## **2.- Sterilized interventions: origin and transmission mechanisms**

The modern history of Central Bank interventions (CBI) in the exchange rate markets started after the collapse of the Bretton Woods monetary institutions and the beginning of floating exchange rate regimes in the 1970s. This instrument has been controversial especially with regards to its effectiveness to move the exchange rate in the central banks' desired direction. In the G10 economies we can identify at least five stages in the praxis of CBI: the first started after the Bretton Woods crisis and finished at the end of 1970s; in this period central banks intervened regularly, individually or collectively, to appreciate or

depreciate their currencies. The second period started at the beginning of the 1980s and it ended in 1985; in these years central banks diminished their presence in the exchange rate market. The third period emerged in the second half of the 1980s and was characterized by the signing in 1985 and 1987 of the Plaza and Louvre Treaties, respectively. These treaties inaugurated a period of cooperation between countries in an attempt to control their currencies (Edison, 1993; Sarno and Taylor, 2001).

The fourth period began in the second half of the 1990s and came to an end at the beginning of the 2007-2008 crisis. The main characteristic of this period is that central banks intervened individually and less frequently than in the past. The Bank of Japan was the most active central bank in this period. Finally, the last and current period began during the crisis 2007-2008. It is characterized by an abnormal increase in the monetary base in the G10 economies due to an expansion in liquidity to support the financial sector during the crisis and the implementation of the policy known as quantitative easing (QE). Although the prime goals of these policies have been the normalization of financial markets and a decrease in the long-term interest rate, they have also produced in the short-run a depreciation of the US dollar and other major currencies (Palley, 2014).

In developing economies, interventions started in the mid 1990s due to the embrace of flexible exchange rates in these countries, in many cases after a balance of payment crisis generated by the impossibility of sustaining a fixed exchange rate. This article centers its attention on the case of Mexico, which adopted a flexible exchange rate (FX) after the balance of payments and financial crises of 1994-1995.

Central bankers are almost certain that interventions have a positive effect on the exchange rate (Neely, 2005; BIS, 2005). Among them there is a consensus that interventions are a useful instrument to move the FX and do not increase FX volatility. This is not the case within the private sector. Cheung and Chinn (2001) shows in a sample of US financial brokers that 61% believe that interventions increase FX volatility and central banks cannot move the FX in its desired direction. Something similar happens between economists: there is not a consensus on the effectiveness of interventions to control the exchange rate. But also, there is a lack of agreement over the optimal way to carry out interventions, in the sense that they can be done secretly or publicly, in the spot or forward market, etc. (Archer, 2005; Dominguez and Panthaki, 2007; Vitale, 2006)

Any study of CBI effectiveness must start by analyzing a simple central bank balance sheet. Suppose that it has three accounts: net foreign assets (NFA) and net domestic credit (NDC) –constituted by credit to the private and public financial institutions- on the assets side; and, the monetary base (MB) is the only account on the liabilities side, which includes currency held by the public and financial institution deposits

in the central bank. Equations (1) and (2) show the changes in the relevant variables that define when an intervention is sterilized -expression (1)- and when it is not –expression (2). The main difference is that when a central bank sterilizes an intervention the MB remains constant.

$$(1) \Delta NFA_t >/< 0; \Delta NDC_t = -\Delta NFA_t; \Delta MB_t = 0, \text{ where } \Delta \text{ is the nominal variation of the variable during the period.}$$

$$(2) \Delta NFA_t >/< 0; \Delta NDC_t >/< \Delta NFA_t; \Delta MB_t >/< 0.$$

Given the definition of sterilized intervention (SI), the monetarist theory sustains that it cannot be effective because it does not affect the MB, so it cannot alter the exchange rate. Monetarism reaches this conclusion by supposing that purchasing parity power (PPP) and the quantity theory of money (QT) both hold; that is if we have:

$$(3) P = eP^*,$$

$$(4) PY = MV,$$

$$(5) P^*Y^* = M^*V^*$$

where M is the monetary base, V is money velocity, P is a national price index, e is the exchange rate (expressed as units of national currency per unit of foreign currency), Y is the level of production and a star indicates a foreign variable. Equation (3) is the simplest version of PPP, and equations (4) and (5) are the equilibrium conditions in both money markets (Gandolfo, 2000). If we replace equations (4) and (5) in (3) and solve for the exchange rate, we obtain the monetarist determinants of the exchange rate:

$$(6) e = \frac{M V Y^*}{M^* V^* Y}$$

It is clear why monetarists are of the opinion that sterilized intervention cannot modify the exchange rate: if this instrument leaves M constant and it does not affect V or Y, there is no reason to expect that it affects e. Nevertheless, theoreticians against the use of sterilized interventions in the context of an inflation targeting regime cannot use monetarist arguments to deny the effectiveness of this instrument due to the fact that according to monetarism money is exogenous, while in inflation targeting theory money is endogenous. This means that equations (4) and (5) only apply ex-post. Thus, we have to analyze other theories in order to assess the effectiveness of this instrument.

Edison (1993) and Dominguez and Frenkel (1993) try to explain how sterilized interventions affect FX through two transmission mechanisms: the equilibrium portfolio and the signal channel. Nevertheless, these approaches did not create a consensus between economists, and theorists proposed a new

mechanisms based on the existence of bounded rationality agents (BRA) or noise-traders (Harvey, 2009; Fatum and Hutchinson, 2010). Finally, it is important to mention recent empirical results based on the information inherent in the order flow or microstructure of the exchange rate market (Breedon and Vitale, 2010).

The perspective of the equilibrium portfolio is similar to the monetarist approach but it changes the assumption of risk-neutral investors. This means that national and international assets are not perfect substitutes.<sup>1</sup> This approach argues that when a central bank intervenes to appreciate its currency and sterilizes it, the central bank changes the current equilibrium relation between national and foreign assets. In this case, the proportion of international assets increases in relation to national assets.

Investors could return to the initial ratio if they sell international assets from their portfolio, which will provoke two effects: on the one hand, an increase in the interest rate of the foreign assets, and on the other hand a depreciation of the foreign currency or an appreciation of the national currency, which was the objective of the central bank. Although this mechanism shows a plausible way in which interventions could affect the FX, this channel has not been supported by empirical studies. An important issue of this mechanism is that it is based on a variation in the stocks of national and international assets, but the volume of interventions is negligible compared to the turnover on the exchange rate market (Sarno and Taylor, 2001). Thus, it is not clear how a small variation in the central bank's NFA could move the FX.

The signaling channel states that when a central bank carries out sterilized interventions, it sends a signal concerning its future monetary policy posture and, as a consequence, affects the FX. This channel has at least two important problems: first, it does not explain why central banks would carry out sterilized interventions in secret if the very aim is to signal their future policy stances. In other words, central banks

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<sup>1</sup>Gandolfo (2000) explains that "The monetary approach assumes perfect substitutability between domestic and foreign bonds, so that asset holders are indifferent as to which they hold, and bond supplies become irrelevant. Conversely, in the portfolio approach domestic and foreign bonds are imperfect substitutes, and their supplies become relevant.

To avoid confusion it is as well to recall the distinction between (perfect) capital mobility and (perfect) substitutability. Perfect capital mobility means that the actual portfolio composition instantaneously adjusts to the desired one. This, in turn, implies that –if we assume no risk of default or future capital controls, etc.- *covered interest parity* must hold. Perfect substitutability is a stronger assumption, as it means that asset holders are indifferent as to the composition of their bond portfolios (provided of course that both domestic and foreign bonds have the same expected rate of return expressed in a common numeraire). This, in turn, implies that *uncovered interest parity* must hold.

It is important to note that according to some writers the condition of covered interest parity itself becomes a theory of exchange-rate determination (the *interest parity model*, where interest parity may be expressed either in nominal or real terms), if one assumes that the forward exchange rate is an accurate and unbiased predictor of the future spot rate: it would in fact suffice, in this case, to find the determinants of the expected future spot exchange rate to be able to determine, given the interest rates, the current spot rate." (p. 227).

do not actually appear to signal at all. Second, this approach also does not explain why central banks partially or totally sterilize their interventions.

The proposed mechanisms up to now are based on rational agents and perfect markets; nevertheless, those are not plausible assumptions for the current behavior of market agents. First of all, many financial traders can be defined as bounded rationality agents (BRA), because their position in the market are not defined by the available information, but instead are based on their beliefs or sentiments (Hung, 1997; Harvey, 2009). This characteristic has been used to explain the persistent difference between the exchange rate and its predicted value by the uncovered interest rate parity relation. In an inflation targeting scheme the sterilized interventions could be interpreted as an instrument to avoid the negative effects of the BRA without affecting the interest rate.

The BRA approach is useful to explain the effectiveness of interventions. A key characteristic of the BRA is that they make decisions based on exchange rate trends. Hence, the goal of the central bank is to break a risky trend, by provoking a cascade effect that spreads the initial effect of the sterilized intervention, in turn moving the exchange rate.

Recently economists interested in the determinants of the exchange rate started to study the microstructure characteristics of the exchange rate market due to the availability of a new kind of information, Breedon and Vitale (2010) mention that “Until the late 1990s no detailed data on foreign exchange transactions were available to researchers and it was not possible to conduct any empirical study of microstructure aspects of FX markets with detailed information on the trading activity of their participants. More recently, however, improved data capture by trading platforms and data vendors has given researchers and practitioners access to detailed information on individual transactions between FX traders” (pp. 505, 504). With this new set of information for the euro/USD market Breedon and Vitale (2010) find that interventions made by the European Central Bank affect the exchange rate through the equilibrium portfolio mechanism. Evans and Lyons (2001) using the microstructure approach find strong support for the portfolio mechanism to explain how sterilized interventions affects the exchange rate (see also Lyons (2001)).

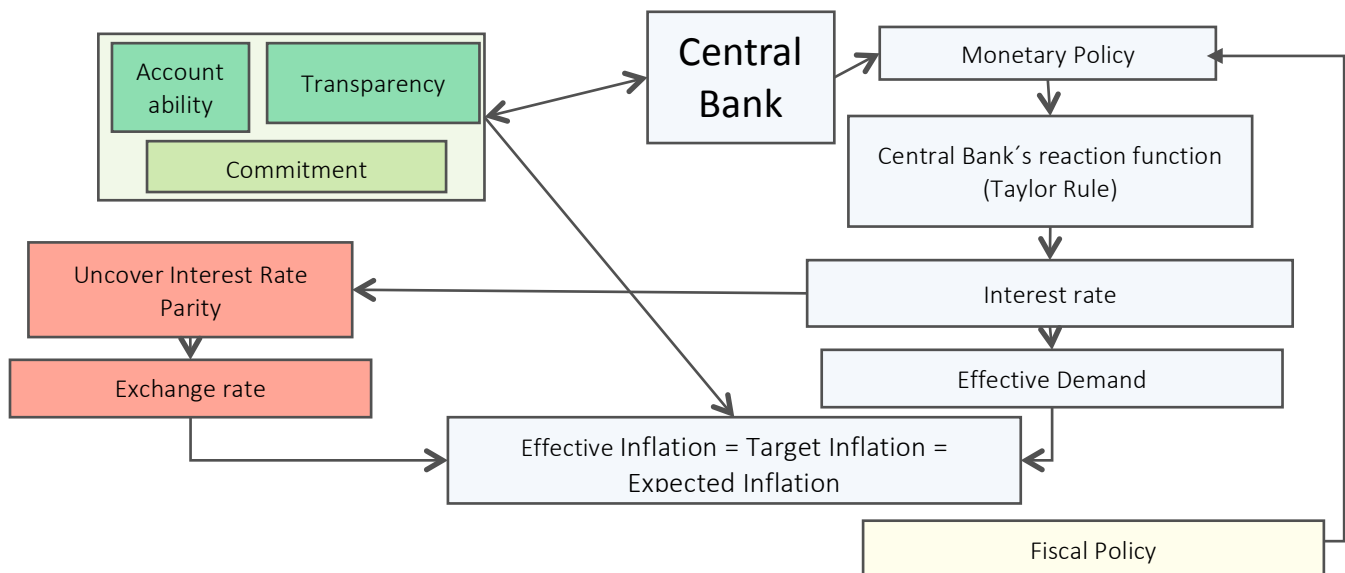
Uncertainty concerning the effectiveness of sterilized interventions and its transmission mechanism is due to two factors: first, the lack of relevance of the sterilized interventions in orthodox but also in heterodox theory as an instrument to control the exchange rate (Dominguez and Frenkel, 1993); second are, the empirical and theoretical problems that are implied in the determination of the FX (Neely, 2005).

## 2.2.- Sterilized Intervention in an Inflation Targeting Regime

Many countries in the 1990s looked for a new monetary policy to replace the fixed exchange rate. Some applied a new regime that later would be known as inflation targeting. Taylor (1997) suggests that the only sustainable monetary policy that could be applied instead of a fixed exchange rate is one based on a flexible exchange rate, a monetary policy rule (a Taylor’s rule) and an inflation target. In fact these are the basic elements that defined an inflation targeting regime (ITR) according to the orthodox literature.

Svensson (2010) gives a more complex characterization: he stresses that an ITR is formed by “... (1) an announced numerical inflation target, (2) an implementation of monetary policy that gives a major role to an inflation forecast and has been called forecast targeting, and (3) a high degree of transparency and accountability. Inflation targeting is highly associated with an institutional framework that is characterized by the trinity of (1) a mandate for price stability, (2) independence, and (3) accountability for the central bank...”(p. 1). We summarize these characteristics in scheme figure 1; which highlights that the only instrument of this monetary regime is the interest rate and that there are no intermediate objectives to control inflation, like a monetary aggregate or the exchange rate. According to Taylor (2001) central banks must not respond to movements in the exchange rate, because it always adjusts through the uncovered interest rate parity to a level which is consistent with macroeconomic fundamentals. Also Svensson (2001) considers that interventions in general are not effective and thus he “...see[s] no reason why a transparent inflation-targeter should undertake foreign-exchange interventions.”(p.48).

Scheme 1.- An Orthodox view of Inflation Targeting Regime

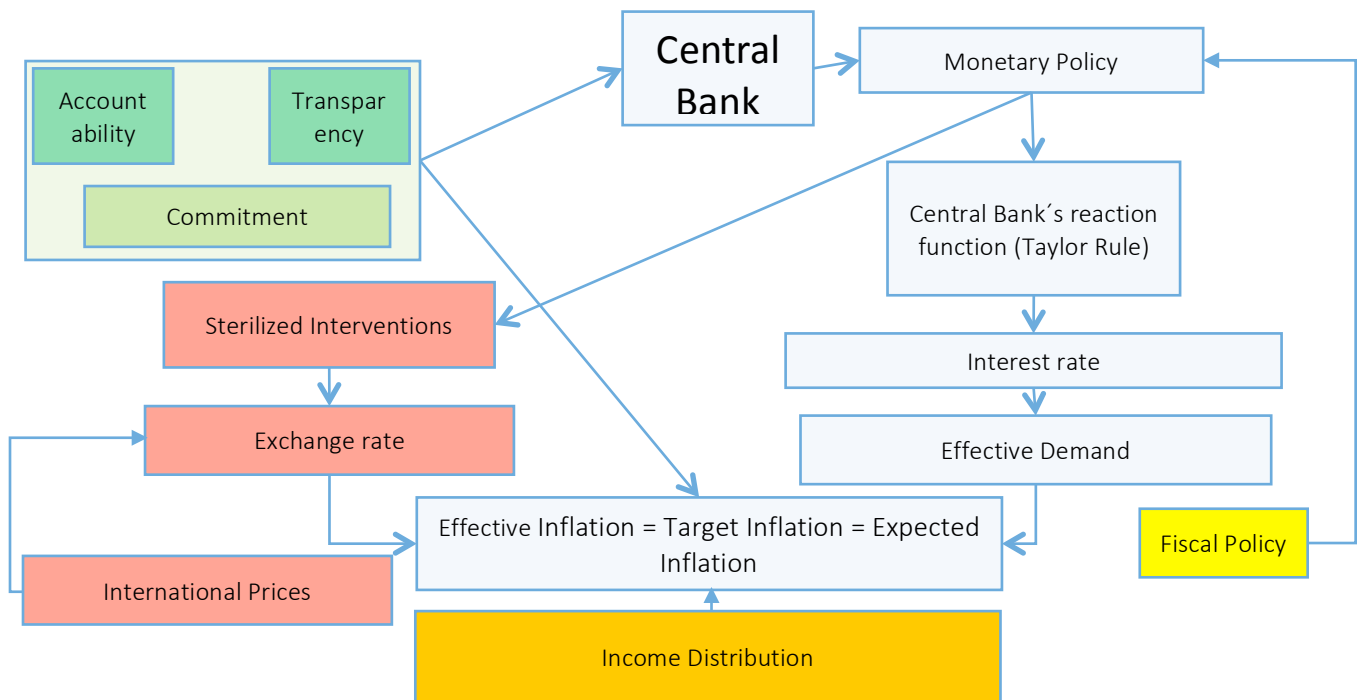


Source: Authors own elaboration based on Hüfner (2004).



Nevertheless many central banks do not practice what they preach, especially when it is about the exchange rate. For example, in an ideal description of a flexible exchange rate regime the central bank's stock NFA would be constant and not an important variable of monetary policy. But this is not the case in developed or in developing countries that called themselves "floaters" in the last 20 years (Calvo and Reinhart, 2002; Huffner, 2004; Epstein and Yeldan, 2008). In particular, there is evidence that countries that apply an ITR use sterilized interventions to control the exchange rate. A structure closer to what central banks actually do is shown in scheme 2. It shows that there are two instruments, one intermediate objective and a final target. The instruments are the interest rate and sterilized interventions; the former is used by central bank to control aggregate demand and ultimately the inflation rate; central banks manage the exchange rate through sterilized interventions, which becomes an intermediate objective to control inflation. The final target is the same in both schemes. Scheme 2 presents an ITR where fiscal policy plays a secondary role: particularly it must be consistent with the monetary policy stance. Thus, it is not independent of the central bank's dictates. Finally that scheme establishes that there is a relationship between inflation and income distribution that could be represented through social conflict. This is an issue that is not mentioned in the ITR literature but has an overwhelming importance as a determinant of inflation (see for example Panico and Rizza, 2014).

Scheme 2.- A real Inflation Targeting Regime



Source: Authors own elaboration based on Hufner (2004).

The use of intervention as a second instrument and the exchange rate as an intermediate target does not come without a cost for the orthodox ITR framework, principally in terms of transparency and accountability. A central bank that intervenes in the exchange rate market is not able to be as transparent as regards its interest rate policy as it is with the exchange rate policy. For example, the central bank cannot say that it wants the exchange rate to reach a particular level because it puts itself in a position where it can be the victim of a speculative attack. This is obvious when there is a capital outflow but it is also true when there is an inflow. Atish et al. (2012) stress that "... the central bank should not be viewed as defending a specific level of the exchange rate, and should be perceived as willing to let it depreciate when inflow pressures abate. Such short-run volatility in the return to investors can help counteract the perceptions of one-way bets" (p. 19). This means that central banks cannot explain openly and thoroughly its exchange rate policy; and also citizens cannot evaluate the central bank's behavior because there is not an objective to use as a reference to check when the policy is successful or not. Also, it is difficult to measure the cost of the intervention policy (Mántey, 2009; Chakraborty and Dasgupta, 2010).

Atish et al. (2012) propose that central banks can eliminate the contradiction between sterilized interventions and ITR principles by subordinating the use of it to achieve a low and stable rate of inflation. According to Atish et al. (2012) if central banks constrain the utilization of the second instrument to only achieve the inflation target, it will be easier to achieve macroeconomic stability –namely low output gap and inflation and a stable real exchange rate around the level consistent with fundamentals. For example, they mention that "In response to a destabilizing increase in capital inflows, the central bank can both lower the policy rate and intervene in the FX market to limit appreciation, in much the same way as it would do under unconstrained full discretion, but while avoiding the inflationary bias that would otherwise result from discretionary policies. Far from being reticent to use the second instrument, central banks should embrace its use as being fully consistent with the IT framework." (p. 22).

When a central bank carries out a SI to appreciate the exchange rate a necessary condition for its effectiveness is that the central bank's international reserves stock has to be big enough in order to signal to the market that it could effectively intervene if the level of the exchange rate is not consistent with the inflation target. Thus, independently of the specific channel through which the SI affects the FX, we need an intervention regime in the sense that it is not enough to study SI in an isolated fashion; instead, we need to study it as a process that includes a period in which the central bank accumulates NFA as well as punctual interventions to avoid undesired appreciation or depreciation of the FX. In this sense, SI is an

instrument to manage the exchange rate when a central bank applies an inflation target. The next section studies the intervention regime in Mexico.

### **3.- The Exchange Rate Market and Sterilized Interventions in Mexico, 1996-2013.**

One of the most important consequences of the Mexican 1994-1995 balance of payments crisis was the abandonment of the semi-fixed exchange rate and the adoption of a flexible exchange rate in 1995 (Banco de Mexico Annual Reports, 1995-1997). The regime is consistent with the fundamental tripod proposed by Taylor (1997). Mexico is a good example of a central bank that says that it lets the exchange rate float, even though, as is shown below, it actually accumulates international reserves when the FX market is tranquil and intervenes when a depreciation of the exchange rate puts at risk the achievement of its inflation target. Table 1 shows the most obvious sign of the contradiction between what Banco de Mexico says that it does and what it actually practices. Since its currency started to “float” in 1995, the NFA has accumulated from \$US6.3 billion in 1996 to \$186.6 billion in 2013. In this section we explain the recent evolution of the Mexican FX market, the instruments Banco de Mexico has used to intervene in the FX market, and finally, we estimate three econometric models to study the effectiveness of the Banco de Mexico interventions and the degree of sterilization of those interventions.

Table 1: Evolution of Banco de Mexico's Stock and Flow of Net Foreign Assets (NFA) -millions of dollars, 1996-2013-

Year	Stock of NFA	Flow of NFA	Origin of the flow			
			PEMEX	Government	Interventions	Others Flow of NFA
1996	6,312.8	6,347.5	9,047.4	-2,706.5	864.0	-857.5
1997	19,823.7	13,511.0	8,469.5	859.3	3,821.0	361.4
1998	23,479.8	3,656.2	5,429.8	-3,307.3	310.0	1,223.6
1999	27,379.7	3,900.0	7,426.0	-6,506.1	1,820.0	1,159.8
2000	35,628.9	8,249.3	11,172.1	-6,802.2	1,794.0	2,085.4
2001	44,856.9	9,228.0	8,905.2	-2,400.5	1,363.0	1,360.2
2002	50,722.1	5,865.2	10,018.6	-6,211.9	0.0	2,058.6
2003	59,058.9	8,336.9	15,380.2	-5,823.2	-3,218.0	1,997.7
2004	64,233.4	5,174.4	13,832.1	-3,240.2	-6,712.0	1,294.6
2005	74,114.8	9,881.5	20,378.0	-7,290.3	-4,402.0	1,195.7
2006	76,303.9	2,189.0	26,697.9	-20,191.8	-8,014.0	3,697.2
2007	87,234.7	10,930.7	12,899.5	-3,648.2	-4,240.0	5,919.6
2008	95,231.7	7,997.1	22,753.8	-4,772.4	-18,674.0	8,689.7
2009	99,870.1	4,638.4	11,528.9	5,902.8	-16,246.0	3,452.6
2010	120,620.5	20,750.5	16,036.7	274.1	4,466.0	-26.3
2011	149,242.3	28,621.7	18,692.4	2,181.2	4,614.0	3,134.4
2012	167,081.9	17,839.6	16,933.1	391.2	-645.9	1,161.4
2013	180,232.3	13,150.4	17,297.2	-425.1	0.0	-3,721.6

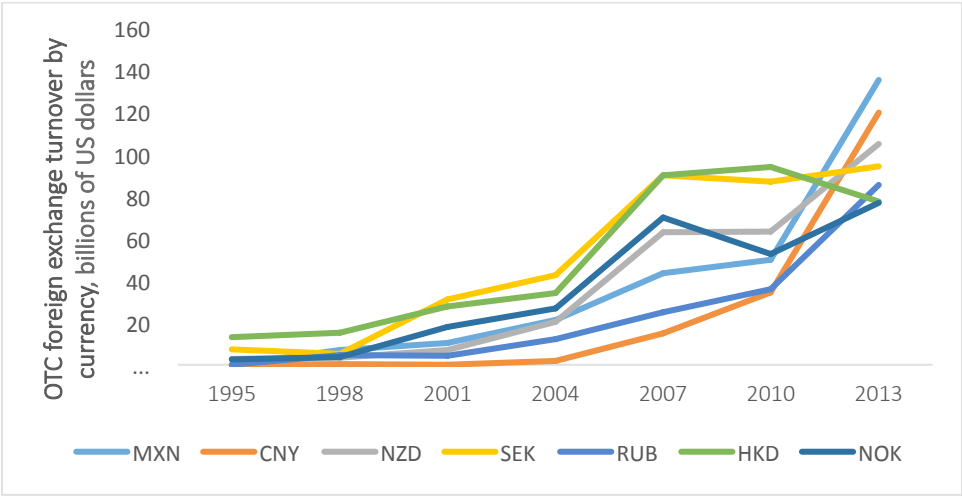
Source: Own elaboration based on Banco de Mexico's information. Reference: Banco de Mexico defines NFA as the international reserves (bonds, currency, etc.) and gold stock owned by Banco de Mexico that are free of any lien and whose availability is not subject to any restriction; Mexico's favorable position with the IMF derived from contributions made to said organization; currencies from financing related to IMF foreign currency regulation and other international financial cooperation organizations, or which group central banks, and central banks and other foreign corporations that exercise authority in financial areas. Buy/sell transactions involving local currency pending receipt are not considered, and Banco de México's liabilities in currencies and gold are deducted except for those with a more than 6-month term at the time when reserves are calculated, and those corresponding to funding obtained as part of the previously mentioned foreign exchange regulation.

### 3.1.- Some Stylized Facts about the Mexican Exchange Rate Market

The Mexican peso is the most traded currency among developing economies and is the eighth most traded in the world. The BIS Triennial Survey (2013) stresses that "Turnover in the Mexican peso reached \$135 billion [per day] in 2013, raising the peso's share in global FX trading to 2.5%. The Mexican peso has

thus become part of the group of the world’s 10 most actively traded currencies, ahead of well-established currencies such as NZD [New Zealand Dollars] and SEK [Swedish Krona]” (p. 3, own comments between []). The local market had a turnover of \$32 billion in April-2013; the rest of the transactions are made in international markets, especially at the Chicago Board of Trade (CBOT). Graph 1 shows the evolution of the turnover of different currencies. It is clear that recently the Mexican peso has experienced a boom in international markets, and it is expected that this level of turnover will be maintained in the future (BIS, 2013).

Graph 1.- Turnover of the Mexican Peso and other currencies markets, 1995-2013 –billions of dollars-



Source: BIS. References: OTC: Over the Counter. MXN: Mexican Peso; CNY: Chinese Renminbi; NZD: New Zealand Dollar; SEK: Swedish Krone; RUB: Russian Ruble; HKD: Hong Kong Dollar and NOK: Norwegian Krone.

The evolution of the Mexican peso exchange rate market (MERM) is a consequence of the Mexican authorities and institutions’ desire to develop a financial market after the 1994-1995 crisis. In this process there are three important milestones: first, the creation in 1998 of the Mexican market for derivatives called MexDer, which started to offer products based on the exchange rate and the interest rate. Now this market has more than 20 instruments. Another key development was the inclusion in 2006 of the Mexican peso in the CLS Bank’s system. The CLS Bank is a private bank created in 2002 which is owned by 73 international banks and was “...established by the private sector in cooperation with a number of

central banks as a “PvP”<sup>2</sup>, to reduce the settlement risk arising from foreign exchange (FX) transactions, which involve separate payment instructions in two different currencies. CLS Bank began settling FX transactions in 7 currencies in September 2002, and now does so in 17 currencies.” (CLS Bank, 2011). In 2008, the CLS Bank made 55% of the total FX transactions in the world (Lindley, 2008). The CLS Bank has succeeded by reducing risk in FX markets, especially through close cooperation with the monetary authorities whose currencies are traded. CLS Bank (2011) explains that “The central banks of these currencies have contributed to the effectiveness of the CLS system by maintaining central bank accounts for CLS Bank, and by creating a “window period” during which all of the central banks’ RTGS<sup>3</sup> systems are open at the same time, to accommodate the funding necessary for the settlement of payment instructions. The benefits of participation in a PvP system such as CLS Bank are maximized, and the liquidity implications of such participation are mitigated, by funding in central bank money using this window period of overlapping RTGS opening hours.”<sup>4</sup> (p. 7)

The last significant event that we want to highlight is Mexico’s incorporation in 2010 into the World Government Bond Index (WGBI). Banco de Mexico and the Secretary of Finance and Public Credit highlight that “The World Government Bond Index (WGBI), created by Citigroup, is part of a series of benchmark indices that track the market for government debt in the currencies of each of the countries included. This type of index serves as a global reference on government bonds that meet the following requirements. 1) Size: to be eligible, issues must total at least 20 billion dollars, and each issue should have a minimum outstanding value of 1 billion dollars. 2) Credit grade: the WGBI has a rating equivalent to investment grade, a minimum of BBB- for S&P and Baa3 for Moody's. 3) Access: The local market must facilitate the involvement of foreign investors, make sure issue policies are followed, and guarantee the free movement of capital. The WGBI is made up of close to 800 bonds with maturities of longer than a

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<sup>2</sup> PoP is the short title for “Payment versus Payment” which is a “Mechanism in a foreign exchange settlement system which ensures that a final transfer of one currency occurs if and only if a final transfer of the other currency or currencies takes place.” (Bis, 2003).

<sup>3</sup> RTGS is the short title for “real-time gross settlement”, which means the continuous (real-time) settlement of funds or securities transfers individually on an order by order basis (without netting) (Bis, 2003).

<sup>4</sup> Also central banks have organized an oversight committee for CLS as is explained by the FED: “The Federal Reserve and other central banks have established a cooperative oversight arrangement for CLS, a foreign exchange settlement system. The Protocol for the Cooperative Oversight Arrangement of CLS (Protocol) provides a mechanism for the central banks of issue of currencies eligible for settlement in the CLS system to fulfill their responsibilities to promote safety, efficiency, and stability in the local markets and payment systems in which CLS participates. The Protocol is designed to facilitate comprehensive oversight of CLS, enhance oversight efficiency by minimizing potential burden on CLS and duplication of effort by the participating central banks, foster consistent and transparent central bank communications with CLS, enhance transparency among the participating central banks regarding the development and implication of international and domestic policies applicable to CLS, and support fully informed judgments when participating central banks make their oversight assessments and decisions regarding CLS. The Federal Reserve organizes and administers the CLS Oversight Committee, which is the primary forum for the participating central banks to carry out their cooperative oversight of CLS. (FED, 2009).

year, issued by countries with developed markets. It currently includes bonds from Germany, Australia, Austria, Belgium, Canada, Denmark, Spain, the United States, Finland, France, Greece, Ireland, Italy, Japan, Malaysia, Mexico, Norway, the Netherlands, Poland, Portugal, Singapore, Sweden, Switzerland and the United Kingdom. On June 3, 2010, Citigroup announced that Mexico would be included in the index. Thus, on October 1 of this year, Mexico became the first Latin American country to join the WGBI, with fixed-rate federal government bonds totaling a market value of 116.8 billion dollars.” (Banco de Mexico Annual Report, 2010, p. 19).

The participation of Mexico in the CLS Bank and the WGBI shows the desire of the Mexican authorities to develop the Mexican financial markets. On this issue it is important to stress that the interest seems to be on speculative instruments because credit to private sector activities is very low. According to the World Development Indicators (WDI), the ratio of credit to the private sector to GDP, 27.7%, is a very low figure compared to Mexico’s own history and, also, compared with countries of similar development levels (for example, Brazil’s ratio is 68.4%, Chile’s is 99.8% and Colombia’s is 52.2%).

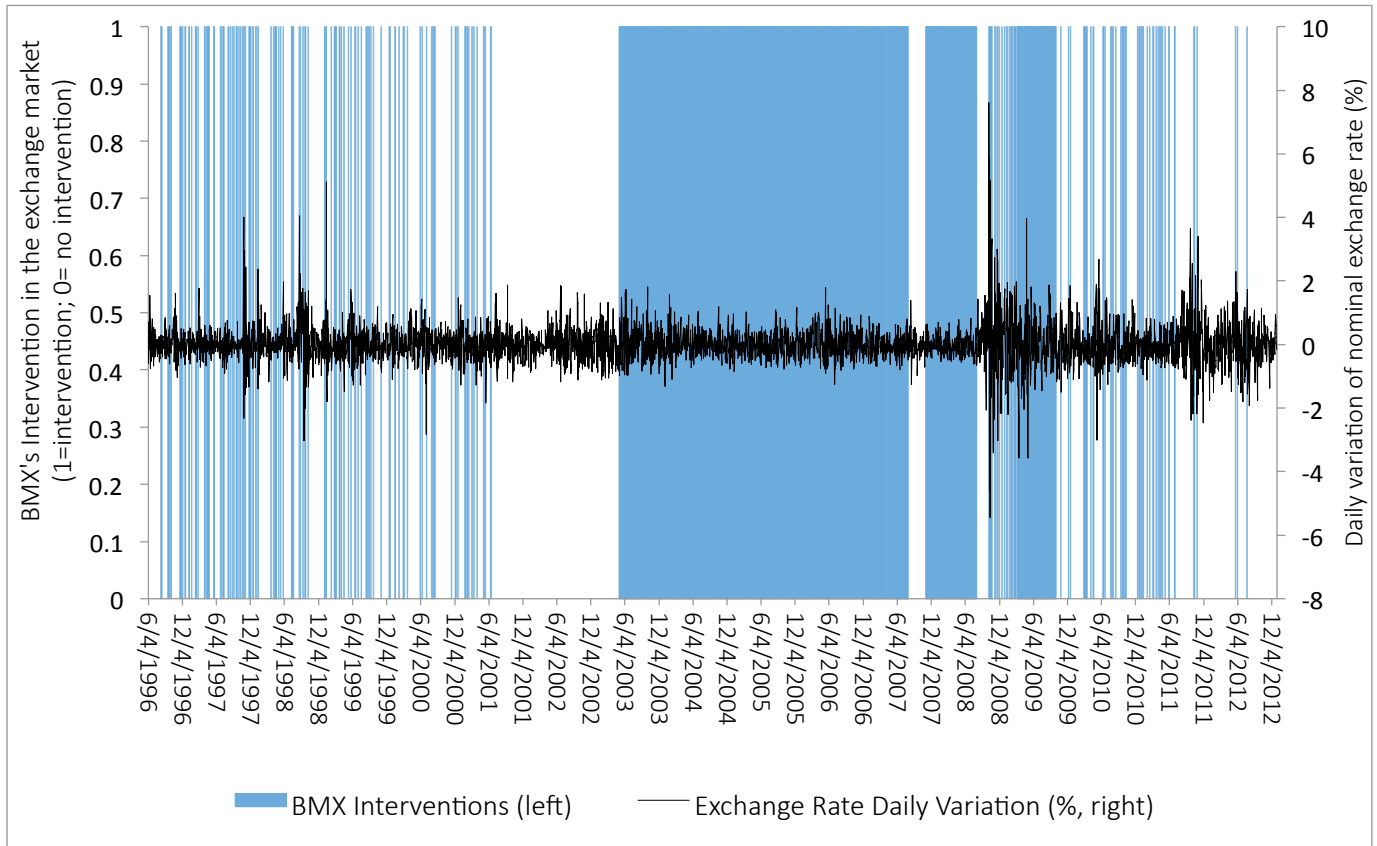
### **3.2.- Banco de Mexico’s Interventions in 1996-2013**

Graph 2 shows that between 1996 and 2013 Banco de Mexico had intervened almost continuously in the Mexican peso exchange market. Banco de Mexico has used 9 mechanisms to intervene:

1. Put auctions to sell dollars to Banco de Mexico used between August-1996 to September-2001 and from February-2010 to December-2010.
2. Auctions of dollars were active between February-1997 and June-2001.
3. Auctions to reduce the level of NFA used between May-2003 and July-2008.
4. Extraordinary auctions of dollars utilized in October-2008.
5. Auctions of dollars with minimum price used between October-2008 to April-2010.
6. Auctions of dollars without minimum price operated between March-2009 to September-2009.
7. Auction of credits in dollars through a financial swap with the US Federal Reserve. This was used once in April 2009.
8. Direct sale of dollars in the spot market were carried out in September-2008 and February-2009.

- In 2009 the Exchange Commission opened a flexible credit line with the IFM for \$48 billion that was available during 2009 and 2010. However, Banco de Mexico did not actively use this instrument.

Graph 2.- Exchange rate daily variation and Banco de Mexico Interventions



Source: Banco de Mexico.

It is important to mention that the Exchange Commission (EXC) is in charge of exchange rate policy in Mexico. This commission is formed by 7 members, 3 from Banco de Mexico and 4 from the Minister of Finance. The EXC makes its decisions by simple majority and then the central bank executes them. This might lead to the risk of a conflict between Banco de Mexico and the Minister of Finance about the exchange rate policy. The former has a bias to appreciate the exchange rate to fulfill the inflation target and the latter has a preference for depreciating the exchange rate, which could generate economic growth. Nevertheless, Banco de Mexico and the Minister of Finance have not had contradictory goals in the period of study as both institutions have agreed that the first and foremost goal is to achieve the inflation target. Thus, the logic behind sterilized interventions in Mexico is different from other countries that use it to avoid undesired appreciations of their currencies (Adler and Tovar, 2011). More



importantly, it can be inferred, as we do below, that Mexican authorities have let the peso appreciate with the inflows of capital and have intervened when the outflows of capital depreciate the peso and put the inflation target at risk.<sup>5</sup>

The analysis of Banco de Mexico intervention policy has a growing literature. Mántey (2009) studies the importance of sterilized interventions to control the FX, nevertheless she centers the discussion on the cost of sterilization and not on the effectiveness of the interventions or the mechanism through which interventions affect the exchange rate. Domaç and Mendoza (2004) and Güimares and Karacadag (2004) study sterilized interventions in Mexico and conclude that they are not effective to control the exchange rate. Garcia-Verdu and Zerecero (2013) and Benavides (2011) study Mexican interventions but not as an instrument to control the exchange rate; Garcia-Verdu and Zerecero (2013) show that interventions (particularly Auctions of dollars without minimum price) affect the exchange rate market liquidity measured as the bid-ask price spread. Benavides (2011) finds that Banco de Mexico interventions during the 2008-2009 financial crisis affected the expected depreciation of the Mexican peso. He concludes that “Once the Central Bank intervened the expectations about a Mexican peso depreciation decrease. For a decrease in the implied skewness the interpretation is that the probability of large Mexican peso depreciation is getting smaller compared to a Mexican peso appreciation of the same magnitude. So, again the market participants are decreasing their expectations that the Mexican peso will depreciate more in the near future once the intervention occurred” (p. 18).

Central banks have several reasons to intervene in the exchange rate market. First, numerous empirical studies show that the uncovered interest parity (UIP) does not hold, which means that a central bank that wants to affect the exchange rate through the interest rate alone would not reach its objective. The UIP does not hold principally because capital flows do not respond exclusively to interest rate differentials, for example they depend on the risk premium, the flight to quality phenomena, etc. (For the Mexican case see Benevidez and Capistran, 2009). Also, regardless of whether the UIP holds or not a central bank intervenes in the exchange market because it is a direct way to affect the exchange rate without changing the interest rate. Thus the crux of the reason to intervene is to avoid the possible

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<sup>5</sup> There are many articles that study aspects of the exchange rate policy in Mexico; Ros and Galindo (2005) sustain that Banco de Mexico has an asymmetric exchange rate policy, in the sense that it increases the rate of interest when the exchange rate depreciates but it not decreases it when the exchange rate appreciates. Perrotini (2007) distinguishes between stable and unstable periods, in the later the monetary policy concentrates in the interest rate, but in the former the monetary policy concentrates in the exchange rate.

contradiction between the rate of interest that stabilize the aggregate demand or the product gap and the interest rate necessary to accommodate the exchange rate in a path consistent with the inflation target.

Our fundamental hypothesis is that sterilized intervention is an instrument independent of the interest rate, and that it is used to control the exchange rate to avoid depreciations of the exchange rate that are not consistent with the inflation target. Thus, the next section is dedicated to assessing whether SI in Mexico were effective in the period 1996-2013. We concentrate our efforts on evaluating whether the Banco de Mexico interventions in the form of dollar sales were an appropriate instrument to control the exchange rate. We use two methodologies: first, a Generalized Autoregressive Conditional Heterocedasticity time series model (GARCH) and, second, we then estimate a non-structural event study model.

### 3.3.- A GARCH model to analyze the impact of Sterilized Interventions on Exchange Rate

Graph 2 shows the daily variation in the nominal exchange rate between 1996 and 2013. It is easy to recognize periods of low and high volatility; for instance: the final part of 1997 and whole 1998 show an increase in volatility as does the period during the last world financial crisis in 2008-2009. Hence GARCH models are a good option for studying the impact of interventions because the exchange rate appears to be generated by a heterocedastic information process. Thus, we estimate the following GARCH model:

$$(7) s_t = \beta_0 + \beta_1 SI_{t-1} + \beta_2 difi_{t-1} + \beta_3 MxB_t + \beta_4 o_t + \varepsilon_t$$

$$(8) \varepsilon_t = v_t \sqrt{h_t}, \text{ where } v_t \text{ is a white noise with unity variance.}$$

$$(9) h_t = \psi_0 + ARCH(q) + GARCH(p) + \psi_1 IV_{t-1} + \psi_2 difti_t + \psi_t p_t$$

Where  $s_t$  and  $h_t$  are the endogenous variables of the model,  $s_t$  represents the daily variation of the exchange rate (measured as the natural logarithmic of the ratio of the exchange rate in period  $t$  over the exchange rate in period  $t - 1$ , hence  $s_t = \ln(q_t/q_{t-1})$ , where  $q_t$  is the nominal exchange rate expressed as units of pesos per dollar);  $h_t$  represents the conditional variance of  $s$ . The exogenous variables are: dollar sale interventions ( $SI_{t-1}$ ) in period  $t-1$ ; the variation of the difference between the national and the international interest rates ( $difi_{t-1}$ ); following Bonser-Neal and Tanner (1996) and Frenkel (2003), we include in the model the daily variation of the Prices and Quotations Index of the Mexican Stock Exchange

( $MxB_t$ ) to control for the impacts of economic or politic events that effect financial markets. Finally,  $o_t$  represents the variation of the oil price.

We suppose that sell interventions were effective in the period 1996-2013, and therefore we expect that  $\beta_1$  is different from zero. Independently of the mechanism through which SI affects the ER, a sell (buy) intervention must appreciate (depreciate) the exchange rate. Thus, we expect  $\beta_1 < 0$ . In the case of  $\beta_2$  we expect that it is not different from zero because the UIP does not hold in Mexico. We also expect  $\beta_4 < 0$ , which means that an increase (decrease) in the oil price appreciates (depreciates) the exchange rate. The reason is that Banco de Mexico's principal source of NFA in the 1996-2013 period has been PEMEX's oil exports (see table 1). Thus when oil price raises, agents know that Banco de Mexico's NFA would increase, which means that Banco de Mexico will have more international assets to intervene in the exchange market in the case of a depreciation. A decrease in oil price produces the opposite effect. Thus, oil price affects exchange rates through agent expectations about Banco de Mexico future behavior.

### 3.4.- Data and results

We use daily data between 06/04/1996 and 12/31/2013. Each series contains 4425 observations. We use information about exchange rates from Banco de Mexico; we choose the FIX<sup>6</sup> series, which is the price of the exchange rate in the wholesale spot exchange rate market, in which the vast majority of interventions have taken place. Banco de Mexico is one of the few central banks in the world that regularly releases information about its interventions<sup>7</sup>. Table 2 shows that during the studied period Banco de Mexico intervened 1636 days, which is an impressive figure compared to other central banks<sup>8</sup>. We can split the period of study into two phases based on Banco de Mexico monetary policy: the first period extended from 1996 to 2001 and is characterized by the stabilization of the economy after the peso crisis in 1994-1995. In this period BMX started to build the elements necessary to apply an inflation targeting regime. It

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<sup>6</sup> Banco de Mexico defines FIX exchange rate as "... as an average of quotes in the wholesale foreign exchange market for operations payable in 48 hours. Banco de México informs the FIX from 12 o'clock onwards each banking day. It is published in the Official Gazette (Diario Oficial de la Federación) one banking business day after its determination date, and is used to settle liabilities denominated in U.S. dollars payable in Mexico on the day after its publication in the Official Gazette." (<http://www.banxico.org.mx/portal-mercado-cambiario/foreign-exchange-markets--exc.html>).

<sup>7</sup> Japan did not report interventions until 2003, when it published data from 1991 to 2003. Since 2003 it publishes interventions data regularly (Fatum and Hutchinson, 2006; Sarno and Taylor, 2001).

<sup>8</sup> Between the Central Banks of developed countries Bank of Japan is the bank that does more intervention, with 159 event during the period 1991-2003 (Fatum, 2010).

also replenished the stock of NFA, as is shown in table 1. The second period extends between 2001 and 2013. Its principal feature is that Banco de Mexico applied a full-fledged inflation targeting regime, while, nevertheless, continuously accumulating NFA to intervene in the exchange rate market.

Table 2: Phases of Banco de Mexico's Intervention Policy -1996/2013-

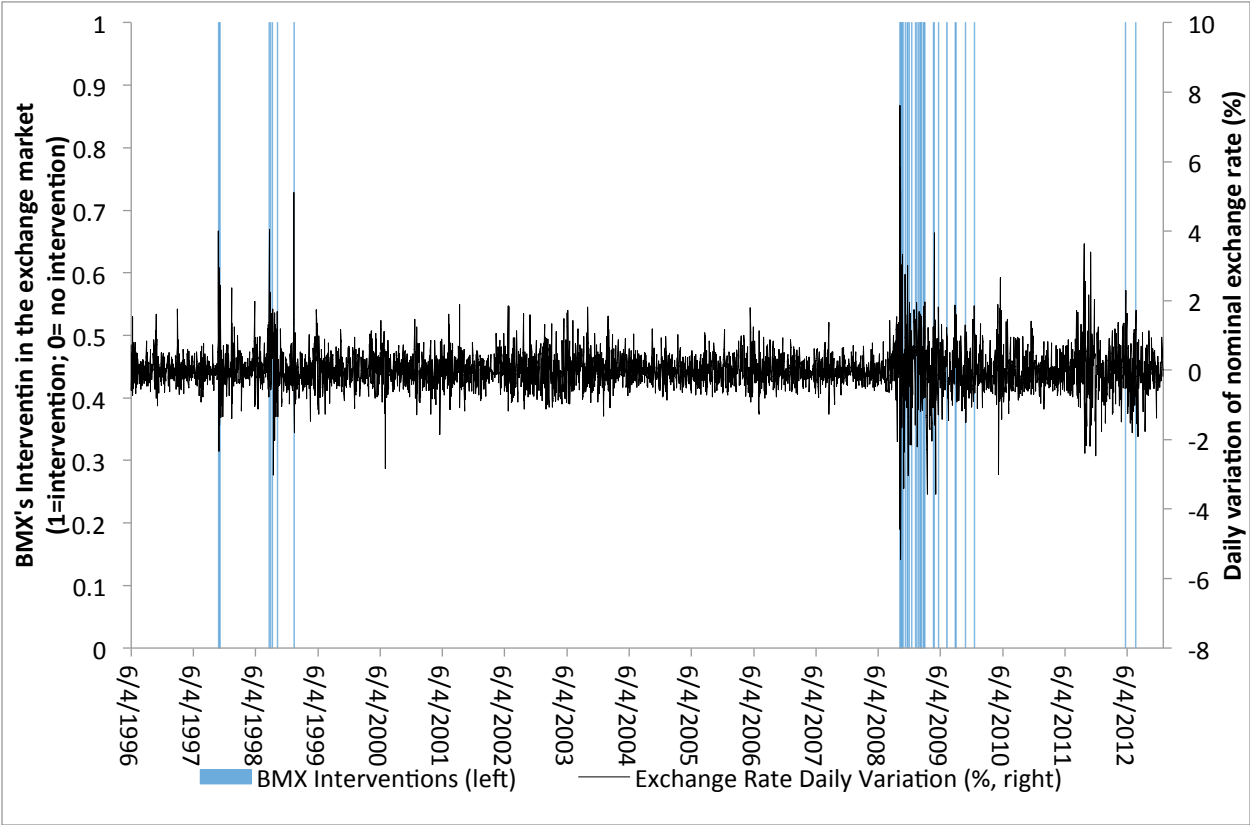
	All days	Stabilization	Inflation Targeting Regime	Crisis
	July/1996- December/2013	July/1996- June/2001	July/2001- December/2013	October/2008- December/2009
Market days	4,425	1,253	3,172	314
Days without Interventions	2,789	1,107	1,682	141
Days with Interventions	1,636	146	1,490	173
Intervention ratio (x100)	37.0	11.7	47.0	55.1
Non-Intervention ratio (x100)	63.0	88.3	53.0	44.9
Purchase Intervention (SI)	182	132	50	0
Sell Intervention (PI)	1,454	14	1,440	173
SI ratio (x100)	11.1	90.4	3.4	0
PI ratio (x100)	88.9	9.6	96.6	100
Less than 99.9 millions of dollars	1515	86	1429	140
100-199.9 millions of dollars	42	33	9	0
More than 200 millions of dollars	79	27	52	33

Source: Own elaboration based on BMX's information. Reference: SI: sell intervention. PI: purchase intervention.

In the first period Banco de Mexico only intervened in 146 days out of 1253, with 14 dollar sell interventions and 132 dollar purchase interventions. In the second period intervention skyrocketed and BMX intervened 1490 out of 3172 market days. The majority of these interventions were relatively small (less than 100 million dollars per day) and had the goal of reducing the stock of international reserves. We started modeling by using every sell intervention, but we did not reach significant or coherent results; then we experimented using only interventions of bigger amounts with the intention of establishing a threshold of the amount necessary for an intervention to be effective. The best model in terms of tests and results is obtained with sell interventions of 200 millions of dollars or more (SI). We dichotomize this variable and incorporate it into the model with a value of one (1) the days with interventions and zero (0)

in other cases.<sup>9</sup> In the first period there were only 8 events of this nature, but in the second were 35, of which 33 occurred during the turmoil generated by the international financial crisis between October 2008 and December 2009. The evolution of the exchange rate and the SI are shown in graph 3.

Graph 3.- Exchange rate daily variation and Banco de Mexico Interventions of 200 millions of dollars or more



Source: Banco de Mexico.

The interest rate differential was constructed with the annualized Mexican Bonds interest rate of 28 days (CETES-28) as a reference rate for Mexico and the federal funds rate of US as the international rate. We use the West Texas Intermediate (wti) presented by Federal Reserve Economic Data as the crude oil price because we could not construct a series of Mexican oil blend price for the entire period. Finally, the source of the Mexican stock index price is the National Institute of Statistics, Geography and Informatics (NISGI).

<sup>9</sup> The models not reported here are available upon request.

Table 3 shows the estimated GARCH model. The coefficient in the conditional mean of SI is statistically significant at the 1% level and has the expected sign. The point estimate is -0.28, which means that a SI provokes a daily exchange rate appreciation of 0.28% during the analyzed period. This outcome shows that interventions could be used to lean against the wind; thus it can offset a devaluation process. With this result it is important to analyze two phenomena. First, on three consecutive days, October 8<sup>th</sup>, 9<sup>th</sup>, and 10<sup>th</sup> of 2008, Banco de Mexico intervened in the exchange rate market with \$9.98 billion, \$1.502 billion and \$6.400 billion, respectively, to offset a daily depreciation of the peso of 6% and 3% on October the 6<sup>th</sup> and 7<sup>th</sup>, respectively. The day after the first intervention the FX appreciated 4.7% daily; thus the model underestimates the effect of intervention in this case. In the second round of interventions the FX depreciated 5%; in this case the model overestimates the effect of intervention on FX. The day after the last intervention the exchange rate appreciated 5.6%, once again in this case the model underestimates the effect of intervention. Thus it seems that the model cannot gauge accurately the effect of intervention on FX. Nevertheless, when the FX of the day after the third intervention is compared with the FX of October 8<sup>th</sup>, 2008, it shows an appreciation of 0.6%, and the model predicts after three days of interventions an appreciation slightly bigger of 0.8%. Thus when we compare the whole process, the model makes a more precise prediction.

Table 3: A GARCH Model of the Exchange Rate Daily Variation.

Media Equation	$s_t = -\frac{0.277 *}{(0.086)}SI_{t-1} - \frac{0.003 ***}{(0.002)}difi_{t-1} - \frac{0.089 *}{(0.004)}MxB_t - \frac{0.016 *}{(0.003)}o_t$
Conditional Variance Equation	$s_t = -\frac{0.177 *}{(0.01)} + \frac{0.166 *}{(0.011)}ARCH_{t-1} - \frac{0.152 *}{(0.017)}AF_{t-1} + \frac{0.104 *}{(0.017)}AF_{t-2} + \frac{0.967 *}{(0.003)}GARCH_{t-1}$ $+ \frac{0.403 *}{(0.048)}SI_{t-1} - \frac{0.008 *}{(0.002)}difi_{t-1} - \frac{0.048 *}{(0.003)}MxB_t - \frac{0.006 *}{(0.003)}o_t$

References: Standard Errors between ( ). \*\*\*, \*\*, \* indicates statistical significance at 10%, 5% y 1% respectively. AF: Asymmetric factor.  $s_t$  is the daily variation of the exchange rate,  $h_t$  is the conditional variance of  $s$ ,  $SI_{t-1}$  is a sell intervention of 200 millions of dollars or more;  $difi_t$  represents the variation of the difference between the national and international interest rates;  $MxB_t$  is the daily variation of the Prices and Quotations Index, and  $o_t$  represents the variation of oil price.

The second phenomenon occurred between February 3 and February 6, 2009. In those days Banco de Mexico intervened in the exchange rate market. After the last day of interventions the FX appreciated 3%, while the model predicts an appreciation of 1.1%. Thus, in the first case the model overestimates and in the second underestimates the effect of interventions; nevertheless the important goal accomplished by the model is that it shows that the effect of sell interventions has the expected sign and is statistically significant.

These results contradict those reported by Domaç and Mendoza (2004) and Guimaraez and Karacadag (2004), in terms of the conditional mean equation -equation (7)- because they estimate a GARCH model and conclude that the coefficient of interventions is not statistically different from zero. Nevertheless, our results coincide in terms of the implied volatility equation, because, as it is shown in table 3, SI increases volatility by a factor of 0.4. The mentioned works analyze the period 1996-2001; hence differences could arise because naturally they ignored the data generated after that period, especially during years 2008-2010, in which there were 33 SI. These new events could explain the change in the significance of the SI coefficient in the mean equation.

With regard to the variable  $difi_{t-1}$ , it has the sign expected by the neoclassical theory, which implies that some mechanism postulated by the UIP holds, despite the fact that the coefficient is statistically significant only at 10%. Clearly this result needs further study. The coefficients on the other variables of the model are significant at the 5% level and have the expected signs. Finally, it is important to mention that other works (Nelly, 2005) use EGARCH (1,1), but our best model is an EGARCH (2,1) with a unity asymmetric coefficient, which means that depreciations have a bigger impact on exchange rate volatility than appreciations. This model has a key weakness: it does not capture the contemporaneous effect of intervention on the exchange rate; instead it studies the effect of intervention on the exchange rate of the day before. With the objective of gauging the contemporaneous effects of intervention on the exchange rate in the next section we estimate an average treatment effect model.

### **3.4.- Average Treatment Effects of the Intervention on the Exchange Rate**

This section studies the relationship between FX and interventions through an event study methodology, specifically we estimate an average treatment effect model (ATE). This methodology was used to analyze the effect of intervention in Japan by Fatum and Hutchinson (2006) and is part of the new wave of studies that have applied non-parametric methodologies to prove the effectiveness of interventions. The exploration of new techniques responds to the doubts about exchange rate determinants and the lack of consistence of the results obtained with traditional time series models (Nelly, 2005).

There are three aspects of the ATE methodology that are relevant to analyzing the relationship between exchange rate and interventions: first, there is no structural model using time series techniques that perfectly adjust to the characteristics of the variables considered, there are problems of endogeneity

between variables, heteroscedasticity of the variables, and structural problems regarding the determinants of the FX. Second, there is a counterfactual argument in the relationship between interventions and the exchange rate: as long as we only observe the effective variation of the exchange rate when the central bank intervenes it is impossible to know what would have been the variation of the exchange rate if the central bank had not intervened (Calvo and Reinhart (2002) mention this phenomenon). However, the ATE is a method to build an efficient set of counterfactuals observations with which we could compare what would have happened if the CB had not intervened. Third, this methodology does not need the utilization of structural relationships, so it avoids the problems regarding the structural determinants of exchange rates.

The ATE estimation utilizes a propensity score function (PS) to study the relationship between interventions and exchange rates in a counterfactual way; this means that it compares the evolution of the exchange rate in days when there was an intervention with days without intervention, which are similar to each other in term of the PS. This method has two interesting characteristics: first, the PS is an instrumental variable of the model, which consists of the conditional probability that the Central Bank makes an intervention, which depends on a set of exogenous variables; thus, the method estimates a reaction function of the central bank. Second, the method arranges days with and without interventions based on the value of the PS, which means that the difference between observations could only be imputed to interventions. To understand these characteristics of the method, suppose the daily variation of the exchange rate can be defined by the next equation:

$$(10) s_t = F(X_t) + w_t g(I_t).$$

Where  $s_t$  is the exchange rate daily variation in moment  $t$ ;  $F(X_t)$  is a function of exogenous variables;  $w_t$  equals 1 if in the moment  $t$  Banco de Mexico intervenes and 0 in the other case; and,  $g(I_t)$  is a function that depends on intervention that could take the form:

$$(11) g(I_t) = \beta I_t \text{ with } \beta > 0.$$

Suppose that we have two moments  $t = (i, j)$ , with  $w_j = 1$  and  $w_i = 0$ . Thus, we have:

$$(12) s_j = F(X_j) + w_j g(I_j),$$

$$(13) s_i = F(X_i)$$

If we calculate the difference between moment  $i$  and  $j$ :

$$(14) s_j - s_i = F(X_j) - F(X_i) + g(I_j)$$



Expression (14) shows that the difference in the daily variation between days with and without intervention is not only due to the presence of central bank in the market  $-g(I_j)$ - but also depends on other variables ( $F(X_t)$ ).

What the ATE does is to arrange data in a way that:

$$(15) F(X_j) - F(X_i) = 0.$$

This means:

$$(16) s_j - s_i = g(I_j)$$

Expression (16) shows that if the ATE is efficiently applied the difference between observations must only depend on the intervention. Finally, equations 10-16 show that the method does not need a structural form for the exchange rate but it does not suppose that it does not exist; in fact the method supposes that it exists and is equal to  $F(X_t)$ , but it is eliminated in the process to calculate the effect of intervention on exchange rate  $-g(I_t)$ - (Woldridge, 2004).

In our case Banco de Mexico interventions are the treatment that is applied to the daily variation of the Mexican peso exchange rate. The exogenous variables that we consider in Banco de Mexico reaction function or PS are: the daily exchange rate variation lagged one period; a variable that indicates how Banco de Mexico reacts to deviations of the exchange rate with regards to its annual moving average (also lagged a period). Finally it is likely that after Banco de Mexico intervenes in period  $t$  it intervenes also the next day. Thus the model includes the intervention lag of one period. We expect the sign of the exchange rate coefficient to be positive, which means that the probability of an intervention increases when the exchange rate depreciates; thus Banco de Mexico tries to lean against the wind and offsets a rise of the exchange rate. Also, the sign of the coefficient of the deviation from the annual moving average is expected to be positive because through this variable we study if Banco de Mexico not only tries to avoid exchange rate devaluation but also whether it has an exchange rate target; in this case the target is the annual moving average, which means that Banco de Mexico's objective is to smooth the evolution of the exchange rate.

In the estimation of the PS we use a logit model. The variable intervention takes the following form:

$$(17) I_t = \begin{cases} 1, & \text{wether there was an intervention} \\ 0, & \text{wether there was not an intervention.} \end{cases}$$

We estimate the following logit model:

$$(18) I_t = \beta_0 + \beta_1 s_{t-1} + \beta_2 \delta_{t-1} + \beta_3 I_{t-1} + \varepsilon_t.$$

Where  $s_{t-1}$  is the daily variation of the exchange rate and  $\delta_{t-1}$  is the deviation of the exchange rate respect to its annual moving average, both variables lagged a period. We calculate the ATE of those days with interventions (ATET) through a nearest-neighbor matching algorithm (NN). We estimate the ATET for time  $t$ , but we also estimate the effect of intervention 4 days after the intervention, because it is not clear at all if the intervention has an immediate effect on the exchange rate or if the effect tends to happen days after Banco de Mexico intervenes.

### 3.4.1.- Data, software, and results

Our information on interventions and exchange rates is the same as utilized in the GARCH model. We include a new variable to study if Banco de Mexico has an exchange rate target policy, which means that it responds to deviations of the exchange rate from an exchange rate target. This policy is represented by  $\delta$ :

$$(19) \delta_t = e_t - E[e_t].$$

Where  $e_t$  is the natural logarithmic of the exchange rate in period  $t$  and  $E_t$  is the natural logarithm of the annual moving average of exchange rate. In (19) we suppose that the target is the annual moving average of the exchange rate. We use two software packages developed for Stata: *pscore* to analyze if the PS is balanced or not (Becker and Ichino, 2002) and *psmatch2* to estimate the ATE (Leuven and Sianesi, 2003).

The Banco de Mexico reaction function was calculated based on the equation (18); table 4 reports the results of the estimated model. The three variables of the model are statistically significant at 1%. Their coefficients are complex to interpret at face value, and thus we estimate how Banco de Mexico reacts to a standard deviation change in the independent variables. An increase in exchange rate variation of one standard deviation –which implies a raise of 0.63%– provokes an increase of 159.3% in the probability that BMX intervenes in moment  $t$ . Also, if  $\delta_t$  changes by a standard deviation, Banco de Mexico’s probability of intervening increases by 138.4%.

Table 4: Logit model of BMX’s reaction function

$I_{jt} = \frac{-6.8 *}{(0.387)} + \frac{1.52 *}{(0.183)} s_{t-1} + \frac{1.41 *}{(0.182)} \delta_{t-1} + \frac{1.89 *}{(0.603)} I_{t-1}$
Observations=4425; LR chi2(3)=259.4; McFadden's Adj. R2: 0.51

References: Standard Errors between ( ). \*\*\*, \*\*, \* indicates statistically significance at 10%, 5% y 1% respectively.

Table 5 shows that days with an intervention present a FX daily variation of 1.86%, this means that Banco de Mexico intervenes in days with high volatility since the average of the series is 0.013%. Hence without matching the first impression is that interventions are not effective to stop a depreciation of the exchange rate and it increases the volatility of the series. However, when we compare days with and without interventions but with similar probability that Banco de Mexico intervenes we obtain different results.

Table 5: Average Treatment Effect of Sell Intervention of 200 millions of dollars or more (SI) on Exchange Rate Daily Variation ( $s_t$ )

Variable	Method	I	WI	Difference	Standard Deviation	t-statistic
$s_t$	NA	1.86	-0.01	1.87	0.09	20.39
	ATET	1.86	1.97	-0.11	0.44	-0.25
$s_{t+1}$	NA	0.12	0.01	0.11	0.10	1.15
	ATET	0.12	0.33	-0.20	0.52	-0.40
$s_{t+2}$	NA	-0.50	0.02	-0.51	0.10	-5.37
	ATET	-0.50	1.14	-1.64	0.48	-3.42*
$s_{t+3}$	NA	0.01	0.01	0.00	0.10	0.00
	ATET	0.01	-0.52	0.54	0.46	1.15
$s_{t+4}$	NA	0.44	0.01	0.44	0.10	4.55
	ATET	0.44	0.61	-0.16	0.45	-0.36

References: I: Set of observations in which Banco de Mexico (BMX) intervened. WI: Set of observations in which BMX did not intervene. NA: Not arrange. ATET: Average Treatment Effect of the days with interventions. \*\*\*, \*\*, \* indicates statistically significance at 10%, 5% y 1% respectively.  $s_t$  is the daily variation of the exchange rate in moment t.

The days with a similar probability that Banco de Mexico intervene but it did not intervene have an average variation of 1.97%. Thus, the ATET is equal to -0.11% which means that an intervention does not avoid a depreciation of the exchange rate but it provokes that the depreciation be smaller than in a case

without it. Nevertheless, this difference is not statistically significant at regular levels. In moment t+1 we also obtain a negative ATET of -0.21%, because in average when Banco de Mexico intervenes exchange rate depreciates 0.12% and when it does not the exchange rate increases 0.33%, thus the raise is 2.75 time bigger when it does not intervene. Despite of these results, again, the ATET is not statistically significant different from zero.

In moment t+2 the exchange rate shows an appreciation of 0.5% on average when Banco de Mexico intervened, the days when Banco de Mexico did not intervene but has a similar PS shows a depreciation of 1.4%, which means that the ATE is equal to -1.63%, hence when Banco de Mexico intervene after two days it avoid a depreciation of the peso of 1.63%, this is the only case in which the ATET is significant at normal level of significance.

We interpret this result in the following way: when agents realize that Banco de Mexico is on the market depreciations are smaller than if agents would have known that Banco de Mexico is not. In moment t+2 they turn their position around because they know that interventions are effective and they can break the devaluation pace of the exchange rate; then as they expect that the exchange rate will appreciate in the future they start supplying dollars to the market with the consequence of appreciating the exchange rate. This is clearly the case of banks that participate in Banco de Mexico's auctions; for example, when Banco de Mexico does an auction of dollars with minimum price it supplies dollars to banks at an exchange rate of 1.02 times the exchange rate of the day before if and only if the day before the exchange rate depreciated 2%, with this instrument Banco de Mexico imposes a ceiling to the raise of exchange rate and diminishes the pressure in the exchange rate market. Finally, in moments t+3 and t+4 the ATET is not statistically significant.

In conclusion both methodologies -GARCH and ATE- show that sell interventions of 200 millions of dollars or more are effective to move the exchange rate in the Banco de Mexico's desired direction. Thus, from these results and Banco de Mexico operations it is possible to conclude that the *modus operandi* of the central bank is the following: *i)* Banco de Mexico accumulates NFA as much as it can when exchange rate market is stable, principally through purchase of dollars from PEMEX and dollars purchases through put options (Banco de Mexico Annual Report, 1999)<sup>10</sup>; *ii)* Banco de Mexico intervenes in the exchange market when an exchange rate devaluation jeopardizes the achievement of the inflation target. The intervention brakes the devaluation pace of Mexican peso and it generates a tendency to stabilize it in a level

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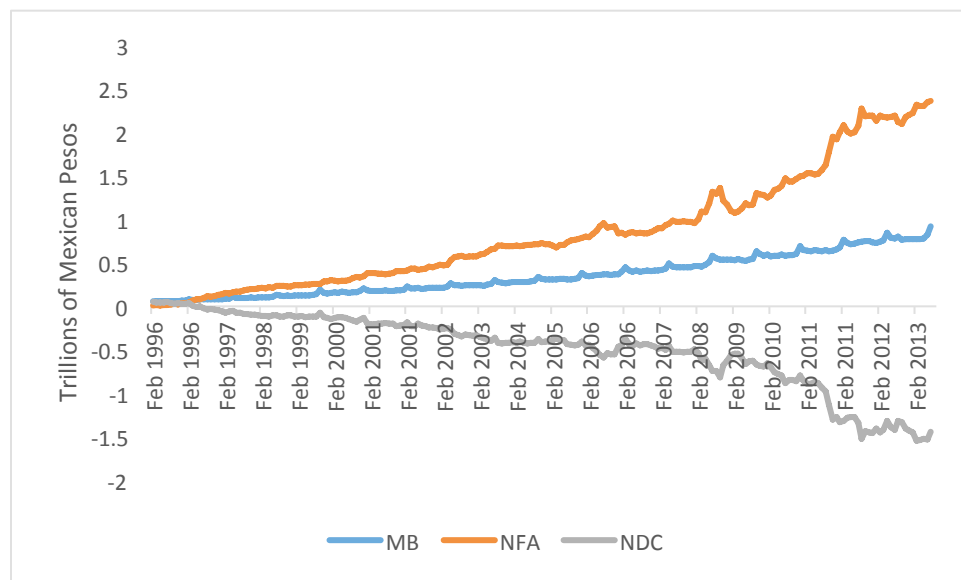
<sup>10</sup> The Exchange Commission explains in the February-22-2010 press communication that "...the most important source of reserves accumulation comes from Banco de Mexico's directly purchases of dollars from PEMEX...".

consistent with the inflation target. The following section investigates the degree of sterilization of the Banco de Mexico interventions.

### 3.5.- Sterilized interventions: the long-run relationships between Net Foreign Assets (NFA) , Net Domestic Credit (NDC) and Monetary Base (MB)

We study the relationship between NFA, NDC and MB during 1996-2013 to establish the magnitude of sterilization of Banco de Mexico’s monetary policy. We mentioned above that exchange rate interventions are a second instrument of monetary policy, independently of the interest rate, if and only if they are sterilized; thus they neither shift the liquidity condition in the money market nor the interest rate. As in equation (1) Banco de Mexico defines the MB as the sum of NFA and NDC. Thus, if Banco de Mexico’s objective is to keep the MB constant it has to increase or decrease the NDC in the same amount but in the opposite direction when NFA changes, which means a complete sterilization as was explained in equation (1). Graph (4) shows that in the studied period it seems that Banco de Mexico had sterilized almost the whole NFA variations. It also shows a smooth increase in the MB. Banco de Mexico sustains that the increase is due to a remonetization of the Mexican economy (see Banco de Mexico Annual Report, 2007, p. 42).

Graphic 4.- Evolution of the Monetary Base (MB), Net Financial Asset (NFA), and Net Domestic Credit (NDC), Mexico 1996-2013



Source: Banco de Mexico.

Reference: NDC: see Table 6. NFA: see Table 1. MB: Monetary Base.

Bofinguer and Wollmershäuser (2001) uses OLS to analyze the degree of sterilization of the monetary policy because variables in the equation are integrated of degree one  $I(1)$ , thus they are  $I(0)$  in first-difference. Also Hüfner (2004) uses the same methodology. Bofinguer and Wollmershäuser (2001) estimates the following model:

$$(20)\Delta NDC_t = \beta_0 + \beta_1\Delta NFA_t + \beta_2\Delta NDC_{t-1} + \epsilon_t.$$

Where  $\Delta$  indicates the first difference of the variable and  $\epsilon_t$  are the model's errors. In the case of total sterilization we expect that  $\beta_0 = 0$  and  $\beta_1 = -1$ .

Nevertheless, if the variables have a long-run relationship the estimation of equation (20) will produce a model with a misspecification problem and non-efficient estimators (Phillips, 1991). Thus instead of equation (20) we must study if this variables are cointegrated or not. It is important to stress that the model does not analyze the sterilization policy related to exchange market intervention, but instead it analyses the global Banco de Mexico's sterilization policy. The model coefficients indicate the expected Banco de Mexico actions when NFA varies independently of the origin of the variation.

### 3.5.1.- Data and results

We use nominal monthly data of NFA, NDC and MB for the period 1996-2013. Table 6 shows unit root test results for variables involved; we can consider that the variables are  $I(1)$  at 1%. Table 7 shows the trace cointegration test which says that there is at least one cointegration relationship between the NFA and NDC. We assume the existence of an intercept in the equilibrium vector when we run the cointegration test.

Table 6.- Adjusted Dickey-Fuller test for Net Foreign Assets (NFA) and Net Domestic Credit (NDC)

NFA

Lags	DF-GLS Statistic	Integration Degree at 1% Critical Value	1% Critical Value	5% Critical Value	10% Critical Value
4	-0.37	1	-3.48	-2.91	-2.62
12	-0.51	1	-3.48	-2.83	-2.55

NDC

Lags	DF-GLS Statistic	Integration Degree at 1% Critical Value	1% Critical Value	5% Critical Value	10% Critical Value
1	-1.24	1	-3.48	-2.93	-2.64
12	-1.04	1	-3.48	-2.83	-2.55

Reference: To choose the number of lags we use Ng–Perron sequential t, minimum Schwarz information criterion, and the Ng–Perron modified Akaike information criterion. NDC: Net Domestic Credit and it is equal to the difference between Net Foreign Assets and the Monetary Base. NFA: see Table 1.

Table 7.- Cointegration trace test between Net Foreign Assets (NFA) and Net Domestic Credit (NDC)

Maximun Rank	Eigenvalue	Trace Statistic	5% Critical Value
0	--	118.85	25.32
1	0.43	5.01*	12.25
2	0.02	--	--

References: \* indicates the number of cointegration vector for the variables. NDC: see Table 6. NFA: see Table 1.

Table 8 shows the results of the estimation of the cointegration vector normalized for NDC. The coefficient of the NFA presents the expected sign –negative- and it is statistically significant at 1%. The point estimate is -0.75, which means that a reduction of 100 million Mexican pesos (mp) in NFA will lead to an increase of 75 mp in NDC. This result indicates that Banco de Mexico almost totally sterilizes its interventions in the exchange rate market and allows us to conclude that interventions are an independent instrument of Banco de Mexico.

Table 8: Cointegration Model of Net Foreign Assets (NFA) and Net Domestic Credit (NDC)

$NDC_{t-1} = \frac{0.05 *}{(0.02)} - \frac{0.75 *}{(0.02)} NFA_{t-1}$
Cointegration coefficient: $D(NDC) = \frac{-0.15 *}{(0.04)}$ ; $D(NDC) = \frac{0.18 *}{(0.04)}$ .

References: Standard Errors in ( ). \*\*\*, \*\*, \* indicates statistically significance at 10%, 5% y 1% respectively. AF: Asymmetric factor. NDC: see Table 6. NFA: see Table 1. The variables were expressed in trillions of dollars.

#### 4.- Final Remarks: another instrument for what?

Banco de Mexico maintains that it does not use the exchange rate as an intermediate objective to control inflation and controls it through sterilized intervention. The present paper challenges that position and shows that the monetary authority uses multiple instruments to manage the exchange rate. Specifically, we show that interventions were effective in the studied period and, also, that there exists several mechanisms to accumulate international reserves when markets are quiet. The problem is to communicate the goals of the exchange rate policy puts at risk the more important principles of the inflation targeting regime, because Banco de Mexico cannot be as transparent and accountable about the exchange rate policy as it is with the interest rate policy. We establish that Banco de Mexico interventions has a clear anti-inflationary bias because it aggressively tries to avoid depreciations of the Mexican peso, but it does not energetically combat appreciation of the Mexican currency. Hence, the additional instrument is only used for the same objective, the consecution of an inflation rate equal to the inflation target. Thus, in the long-run this policy is consistent with a low and stable inflation but it tends to appreciate the exchange rate in real terms which affects negatively the economic activity because it deteriorates the competitiveness of national goods in international commerce.

The paper establishes a strong position about the effectiveness of Banco de Mexico interventions and the utilization of the exchange rate as an intermediate objective to control inflation, though it leaves open a series of normative and positive issues. The paper mentions that when the uncovered interest parity is put aside the determinants of the exchange rate are not clear at all, especially with respect to what explains the daily variation of the exchange rate. Heterodox economists must develop models of the exchange rate that include how the agents form their expectations about the future to try to explain the daily movements of the exchange rate. These models might be useful to explain the specific mechanisms that transmit the effect of interventions to the exchange rate.

Last but not least, the paper establishes that interventions are effective in a scheme where the only objective is to meet the inflation target. An open question is whether this instrument could be used in a framework where the exchange rate policy is oriented toward generating a competitive and stable real exchange rate. (see Epstein and Yeldan (2008)).



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