Determinants of the exchange rate in Mexico: the portfolio balance approach

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Abstract

This paper aims to examine the determinants of the exchange rate based on the portfolio balance model. Using the Autoregressive Distributed Lag Model (ARDL), we empirically evaluate the effect of private net foreign assets and the traditional factors affecting the exchange rate dynamics in Mexico from 1990-2019. The main results suggest that: *i)* the portfolio approach constitutes a consistent system to explain the behavior of the exchange rate; *ii)* an increase in economic activity and interest rate differentials triggers an appreciation of the exchange rate; *iii)* an increase in the inflation gap and private net foreign assets causes a depreciation.

Keywords: exchange rate determinants; portfolio balance model; ARDL model.

1. INTRODUCTION

The end of the dollar-gold convertibility regime in 1973 signified the operational end of the Bretton Woods international monetary model and the transition point towards an economic order articulated around a free-floating exchange rate system. Indeed, monetary and price stability are the foundations of this paradigm, where the interest rate is the key instrument for achieving these goals and the autonomy of the Central Bank is the guarantor of the credibility and effectiveness of monetary policy, with the external value of the national currency being subject to variations in supply and demand in the foreign exchange market. This paradigm shift would aim to compress current account imbalances, to strengthen the development of the financial system and to limit the short-term effects associated with external shocks, such as those generated by credit bubbles or speculative attacks (López-Marmolejo and Ventosa-Santaulària, 2019; Perrotini, 2007).

Undoubtedly, the behavior of foreign exchange markets is a relevant topic in economic science due to the consequences that atypical and systematic exchange rate imbalances have on financial profitability, macroeconomic stability and the dynamics of international trade. At the theoretical level, according to the portfolio balance approach, the exchange rate maintains a comovement with interest rate differentials, inflation, economic activity, money supply and the stock of financial assets (Wang, 2009; Cushman, 2007; Branson and Henderson, 1985; Frankel, 1984). At the empirical level, the results are mixed and inconclusive due to conceptual and methodological difficulties, particularly in the direction of the robustness of the indicators used to characterize the asset market and financial wealth (Kharrat et al., 2020; Xie and Chen, 2019; Capistrán et al., 2019; Salim and Shi, 2019; Beckmann et al., 2018; Cuiabano, 2017; Cushman, 2007).

Given the above, the present study seeks to answer the following question: What impact does the relative supply of assets, financial wealth, and monetary fundamentals have on the dynamics of the exchange rate in Mexico? The purpose is to obtain consistent evidence that allows us to establish a line of reflection on the dynamic effects that variations in the asset market and financial wealth generate on the peso's value against the dollar. From this perspective, it is assumed that exchange rate variations offset the dynamics of the asset markets at the international level, in other words, imbalances in the financial account of the balance of payments.

The contribution of this study is based, first, on the simulated analysis of the impact of private external asset holdings and bond demand, in addition to the traditional monetary determinants, on the dynamics of the exchange rate in the case of emerging economies; Second, at the methodological level, the empirical operationalization is carried out using an Autoregressive Model with Distributed Lag (ARDL), which incorporates an error correction equation, through which the short-term dynamics of the variables, influenced by the deviations from the equilibrium path, are introduced to the long-term behavior of the system, thus ensuring consistent and efficient estimators. It also reduces bias due to endogeneity problems or restrictions in the sample size (Pesaran et al., 2001).

The article is organized as follows: the first part presents the theoretical discussion on the determinants of the exchange rate from the perspective of the portfolio balance model. In the second part, a brief review of the empirical literature is carried out in order to understand the main results and methodologies used regarding the explanatory factors of the exchange rate parity. The third section presents stylized facts about macroeconomic and financial dynamics in Mexico in order to outline a preliminary causal relationship between the exchange rate, the deepening of the capital market and the interest rate. The fourth section establishes the operationalization of the hypothesis. Finally, the conclusions are presented.

2. EXCHANGE RATE DETERMINANTS: THEORETICAL ELEMENTS

In the field of the theory of exchange rate determinants, two analytical routes can be identified: the nominal hypothesis, a construct in which the exchange rate is subject to changes in relative prices, the interest rate and the balance of payments (Frenkel and Rapetti, 2010; Wang, 2009; Frankel, 1984); and the competitiveness approach, in which the behavior of the exchange rate is determined by the dynamics of differentials in productivity, real wages and technology (Aghion et al., 2009; Begum, 2000). The debate between the two sides lies in the operation of the hypotheses of purchasing power parity and efficient markets in the context of industrial competition.

Consequently, the purpose of this paper is not to describe in detail the characteristics of the theoretical models or to be exhaustive in their enumeration but to identify the mechanisms and conditions that determine the dynamics of the exchange rate from the perspective of monetary and financial consolidation and integration.

Asset market, financial wealth and exchange rate

In the context of the Portfolio Equilibrium Model (PEM), the determination of the exchange rate is subject to the movements of the financial account of the balance of payments. Therefore, exchange rate variations would be geared to compensate for the dynamics of financial asset funds (Wang, 2009).

Analytically, this paper is based on Frankel's (1984) portfolio model, which, by construction, is based on a flexible exchange rate regime with rigid prices and the persistence of deviations between the profitability of domestic and foreign assets, which are assumed to be imperfect substitutes. Likewise, the system considers, on the one hand, that agents do not have complete information and are not perfectly rational and, on the other hand, the presence of restrictions and controls on capital, whose symbiosis generates risk aversion.

Therefore, first of all, it is considered that financial wealth (R^j) is distributed by agents between money (D), domestic bonds (B^d) and the holding of foreign assets (B^f) so that agents' demand for assets[1] is determined by:

$$B^j = \left[a^j + b(i - i^* - \Delta e^E)\right]R^j \qquad (1)$$

Where B^j and R^j are, respectively, the demand for bonds and non-monetary financial wealth of the agents, the coefficients a^j and b capture the sensitivity of asset demand and risk aversion, respectively, while Δe^E, i and i^* are, in that order, the expected depreciation rates of the exchange rate and domestic and foreign interest rates; the superscript j represents portfolio investors (domestic, US and rest of the world). Extending equation (1), we have:

$$B = a^d R^d + a^f R^f + a^{wr} R^{wr} + b(i - i^* - \Delta e^E)R \qquad (2)$$

In this formulation a^d, a^f, a^{wr}, R^d, R^f and R^{wr} constitute, in that order, the sensitivity of asset demand and financial wealth of domestic, foreign and rest of the world agents (portfolio investors) (in the aggregate form, we $R \equiv R_d + R_{USA} + R_r$). In terms of the risk premium (preference between domestic and foreign assets), we have:

$$i - i^* - \Delta e^E = \sigma\tilde{B} - \gamma\tilde{R}^d + \delta\tilde{R}^f - \eta \qquad (3)$$

Where $\tilde{B}$ represents the proportion of total non-monetary financial wealth allocated to bond holdings (total demand); while $\tilde{R}^d$ and $\tilde{R}^f$ are the relative wealth of domestic and foreign residents; while γ, δ and η capture the ratio between agents' consumption sensitivity and risk aversion.[2] Generically, this function measures the impact on the risk premium due to variations in portfolio composition between domestic and foreign assets.

Second, in the short term, it is argued that exchange rate depreciation expectations are determined by the exchange rate imbalance with respect to its equilibrium value $\tilde{e}$ and by the domestic inflation rate differential with respect to the foreign one $\tilde{\pi}$, i.e.:

$$\Delta e^E = \tilde{\pi} - \theta\tilde{e} \qquad (4)$$

Combining (3) and (4), the long-term function of the exchange rate will be:

$$\overline{e} = e + \frac{1}{\theta}\left[(i - i^*) - \sigma\tilde{B} + \gamma\tilde{R}^d - \delta\tilde{R}^f + \eta - \left(\overline{\pi} - \overline{\pi}^*\right)\right] \qquad (5)$$

Agreeing that the money market is in equilibrium and the persistence of deviations in the hypothesis of the uncovered parity of interest, then the reaction function of the exchange rate with portfolio equilibrium is determined[3] as follows:

$$e_t = \tilde{m} - \phi\tilde{y} + \left(\lambda + \frac{1}{\theta}\right)\tilde{\pi} - \frac{1}{\theta}\tilde{\imath} + \frac{\sigma}{\theta}\tilde{B} - \frac{\gamma}{\theta}\tilde{R}^d + \frac{\delta}{\theta}\tilde{R}^f - \frac{\eta}{\theta} \qquad (6)$$

As described in equation (6), the exchange rate with rigid prices (e) is determined by movements in the relative supply of assets $\tilde{B}$ and the restriction of wealth $\tilde{R}$. According to this function, an increase in the stock of domestic bonds will generate an increase in domestic financial wealth and the preference for foreign bonds. Thus, if the wealth effect is greater than the substitution effect, then the net effect will be a depreciation of the local currency; the same impact will increase the domestic interest rate or the expected exchange value. In contrast, an expansion of the stock of foreign bonds held by residents and of foreign wealth and a reduction in the foreign interest rate would result in an appreciation of the local currency.

3. DETERMINANTS OF THE NOMINAL EXCHANGE RATE: A REVIEW OF THE EMPIRICAL LITERATURE

In the literature, the results are mixed regarding the empirical consistency of the monetary approach to exchange rate determination, particularly in the case of emerging economies, due, among other factors, to the difficulties in measuring the conceptual structure (robustness of the indicators), the study aggregation and methodological limitations. In the context of the new macroeconomic consensus, this condition requires the incorporation of the effect linked to the dynamics of the asset market and financial wealth in order to address the biases in the process of rationalization of hypotheses (overestimation/underestimation) due to the omission of relevant variables and, thus, an adequate interpretation of the empirical contrast (Catalán, 2022; Kharrat et al. , 2020; Xie and Chen, 2019; Capistrán et al., 2019; Salim and Shi, 2019; Beckmann et al., 2018; Cuiabano, 2017; Warshaw, 2016; Danga and Kiptui, 2016; Afat et al., 2015; Dabrowski et al., 2014; Yuan, 2011; Loria et al., 2010).

Using quarterly data for Mexico from 1994-2018, Catalán (2022) studies the consistency of the monetary aspect to explain exchange rate variations. In his estimations, based on an autoregressive model with error correction (ARC), he finds evidence supporting the conjecture of Bilson's 1978 flexible price model, in which the differentials of the money supply, the Gross Domestic Product (GDP) and the interest rate maintain a comovement with the exchange rate in the long run. However, his results are inconclusive with respect to the validity of Frenkel's 1976 monetarist inflationary expectations hypothesis, Dornbusch's 1976 rigid price hypothesis, Frankel's 1979 interest rate differential and Mussa's 1982 rational expectations hypothesis.

Using a dynamic panel model, Kharrat et al. (2020) examine the consistency of the portfolio approach on exchange rate determination (multilateral scheme) in a sample of 64 countries from 1971 to 2015. Transversely, empirical support is found for the portfolio balance model: on the one hand, they systematically find that the effect associated with money supply and inflation is consistent with the theoretical foundation; on the other hand, their results are more limited in terms of the impact of production, the interest rate and the stock of assets, as their statistical sign and significance depend on the sample size, the periodicity of the data, the measurement of the dependent variable and the subperiod of study.

Xie and Chen (2019) analyze the dynamics of the exchange rate reaction function (e_t), according to the monetary approach, in six countries during the period 1974:01-2001:03. In general, in their estimations, they find evidence of cointegration between the exchange rate and its determinants. Specifically, first of all, they find bidirectional causality between the money supply (m_t) and e_t in France, Italy, Japan and the United Kingdom, while the relationship is unidirectional in Germany (from m_t to e_t) and Canada (from e_t to m_t); second, they observe unidirectionality from production to e_t; third, they find bidirectionality between the interest rate (i_t) and e_t, except in Canada where the direction runs from i_t to e_t; fourth, causality is unidirectional from inflation to e_t, except in Italy where it is bidirectional.

In a paper for Mexico, Capistrán et al. (2019) empirically contrast the Dornbusch exchange rate overreaction mechanism during the period 1990:01-2015:04. In their regressions, they find that shocks to domestic interest rates and GDP tend to appreciate the exchange rate. In contrast, they find that a shock to money demand triggers an exchange rate depreciation; they also find that an increase in prices triggers an appreciation of the currency. Moreover, their results confirm bidirectional causality between the interest and exchange rates, implying that the Central Bank reacts endogenously to exchange rate shocks to avoid an inflationary pass-through.

Salim and Shi (2019) review the robustness of the flexible-priced monetary model (*MMPF*) in Indonesia over the period 1999:04-2017:01 using an *ARDL* model (linear and nonlinear). While the regressions revealed that macroeconomic fundamentals, including the trade balance, consistently drive (comovement) the exchange rate, the results are also inconclusive regarding the conjectures of the *MMPF*; partially, the estimates suggest that an increase in the differentials of the money supply, interest rate, inflation, and trade balance lead to a depreciation of the rupee. In contrast, a widening of the output gap leads to an appreciation.

Using a *VEC* model, Beckmann et al. (2018) analyze the long-term relationship between the exchange rate and its macro fundamentals based on the monetary approach in the eurozone over the period 1999:01-2015:07. Although they find evidence of a comovement between the euro/dollar exchange rate and the monetary components in their results, the empirical evidence is somewhat mixed around the monetarist hypothesis; although the estimates confirm that an increase in the local interest rate leads to depreciation. In contrast, the effects of an increase in the money supply and output are appreciation and depreciation, respectively.

In an analysis of Latin America and Asia, Cuiabano (2017) evaluates, using a dynamic panel, the long-term determinants of the exchange rate in 14 countries[4] for the period 1999:01-2015:04. Although their estimates confirm a comovement between the exchange rate parity and its macro fundamentals, the results are inconsistent with the conjectures of the flexible-price monetary model. The empirical evidence for the sample as a whole indicates that variations in the money supply and the interest rate result in an appreciation of the local currency, while the expansion of prices causes a depreciation; at the regional level, the coefficients lacked statistical significance.

Supported by a *VEC* model, Warshaw (2016) analyzes, through an extension of the monetary model, the role of the parallel exchange rate in Turkey from 1987-1998. Overall, his estimates show mixed evidence. While his regressions confirm that the deepening of the differential in the money supply leads to a depreciation of the Turkish lira, the sign of the parameters associated with the output and interest rate gaps is inverse to the theoretical rationale. He also finds that the extension of parallel exchange rate operations generates losses in the nominal value of the local currency. Based on this result, he argues that including the factors that distort the exchange market improves the system's predictive (adjustment) ability.

Danga and Kiptui (2016) analyze the short and long-term determinants of exchange rate fluctuations in Kenya over the period 1993:03- 2014:04. In their regressions, supported by an *ARDL* model, they find that an increase in international reserves and the interest rate gap leads to an appreciation of the Kenyan currency, while an increase in the money supply results in a depreciation. As for the coefficient of the current account balance, their results lacked statistical significance.

Based on country-level estimates, Afat et al. (2015) study the consistency of the monetary model (flexible prices *MMPF*, rational expectations *MMER* and real interest rate gaps *MMTIR*) in 34 OECD economies over the period 1970:07-2014:05. Empirically, they find no support in their results to validate the MMPF; in contrast, they find that the MMER fundamentals are verified only in Sweden (krona/dollar) and the United Kingdom (pound/euro), while the MMTIR basis is solid only for Mexico (peso/dollar) and partial in the Eurozone (euro/dollar). They argue that the fragility of the monetary approach is due to deviations in the purchasing power parity (*PPP*) condition and the lassitude of the money demand function.

With support from a dynamic panel model, Dabrowski et al. (2014) examine whether the *MMPF* is an efficient construct in exchange rate determination in Hungary, Moldova, Poland, Czech Republic, Romania, Serbia, Turkey and Ukraine during the period 2001:04 2012:04. In their regressions, they first find evidence of comovement between the exchange rate and its determinants; second, the signs of the coefficients are consistent with the expected values of the monetary approach, i.e., deepening money supply differentials generate depreciation while widening output and price gaps lead to appreciation; third, unidirectional causality from the money supply to the exchange rate and from the exchange rate to price variations.

Using *VEC* and *ARCH* regression techniques, Yuan (2011) analyzes the long-term relationship between the exchange rate and its macro fundamentals, based on four variants of the monetary model, for the cases of Australia, Canada, the United States, Japan and the United Kingdom during the period 1973:01- 2007:02. Overall, the estimates find mixed evidence regarding the fundamentals of the monetarist approach. He concludes that this reinforces that the exact nature of exchange rate dynamics is complex and that monetarist variables only partially explain its behavior.

In another study of Mexico, during the period 1994:01-2007:04, Loria et al. (2010) find that the monetarist approach represents a significant approximation to explain exchange rate fluctuations in the long term.

3. THE ROLE OF FINANCIAL ASSETS IN MEXICO'S EXCHANGE RATE DYNAMICS

Economic performance and exchange rate parity: stylized facts

The 1982 balance of payments crisis was a turning point for the Mexican economy that would require the design and implementation of a new economic growth and development strategy aimed, on the one hand, at resolving the economic and financial imbalances accumulated during the substitutive industrialization phase (persistent inflationary pressure, debt expansion and exchange rate volatility) and, on the other hand, at boosting competitiveness and productive efficiency. In addition to a wide range of financial and trade reforms, this structural change would require implementing an exchange rate policy that cushions the impact of external shocks, adjusts the balance of payments, and strengthens the financial position.

Between 1983 and 1994 (December 21), the monetary authority operated at least three fixed or semi-fixed (predetermined) exchange rate regimes, a period during which the exchange rate policy functioned as a nominal anchor for inflation: *i)* exchange control, *ii)* regulated floating and *iii)* exchange rate bands with controlled slippage (determined by the Exchange Commission). In effect, these modifications would aim to compensate for the imbalances linked to the excessive liquidity (credit) of the economy, the widening of the inflationary gap (internal and external), the process of export reorientation and variations in energy and raw material prices, as well as improving the efficiency of the foreign exchange market (transaction costs). However, by the mid-nineties, the volatility of international financial markets, the increase in the size of the debt, the normalization of the Federal Reserve's (FED) monetary policy and the contraction of dollar reserves, combined with a strong speculative attack on the peso, led to an abrupt adjustment of the exchange rate and, with it, the economic collapse and an exponential increase in inflation. In this context, a change in economic policy was carried out in order to contain the inflationary process, specifically, monetary policy would be used as a nominal anchor and the interest rate as an instrument. This new guideline of the Banco de México would be accompanied by the adoption of a free-floating exchange rate system, which was expected to reduce the sensitivity of the Central Bank's assets to exchange rate variations and grant greater flexibility to monetary policy, in line with the fundamentals of the New Macroeconomic Concession (Banco de México [BANXICO], 2009).

In a little more than three decades of operation of the Open Economy Model (MEA), the Mexican economy experienced a marked stagnation of the GDP and capital investment, marked by the systematic contraction of productivity and a persistent trade deficit (given the high share of foreign value added in export production), which has had as a counterpart the sliding of the exchange rate and relative prices, to ensure the competitiveness of the tradable sectors (see Table 1).

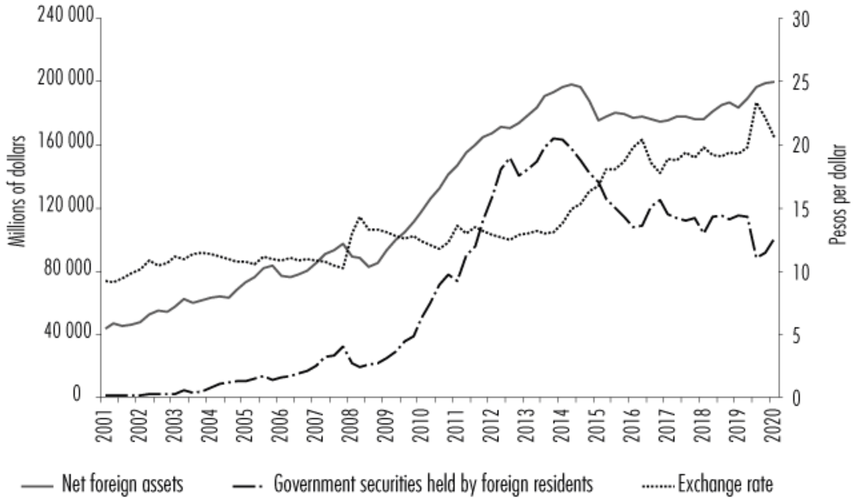
Table 1. Mexico: selected economic indicators

Indicator	*1980-1990*	*1990-2000*	*2000-2010*	*2010-2021*
GDP /1	1.9	3.4	1.5	1.6
Total factor productivity /1	-2.2	-0.3	-1.1	-0.5
Capital formation /1	-1.1	3.9	1.7	-0.8
Trade balance /2	2.9	-1.6	-1.7	-1.2
Fiscal deficit/2	-7.7	-0.2	-1.6	-2.5
Total net public sector debt/2	69.4	24.9	19.3	38.4
91-day cetes interest rate/3	53.4	24.4	8.3	5.0
Inflation /1	65.1	18.3	4.7	3.9
Stock market capitalization/2	4.9	26.8	26.4	36.6
Foreign direct investment/3 /4	5.6	9.7	13.4	12.5
Exchange rate /1	61.9	12.9	2.9	4.4

Notes: 1/ Average annual growth rate; 2/ Indicator as a proportion of the GDP; 3/ Average of the indicator; 4/ as a proportion of gross fixed capital formation. Total factor productivity and market capitalization data available until 2020.

Source: Prepared by the author with data from the World Bank (2022), BANXICO (2022), FRED (2022) and IMF (2022).

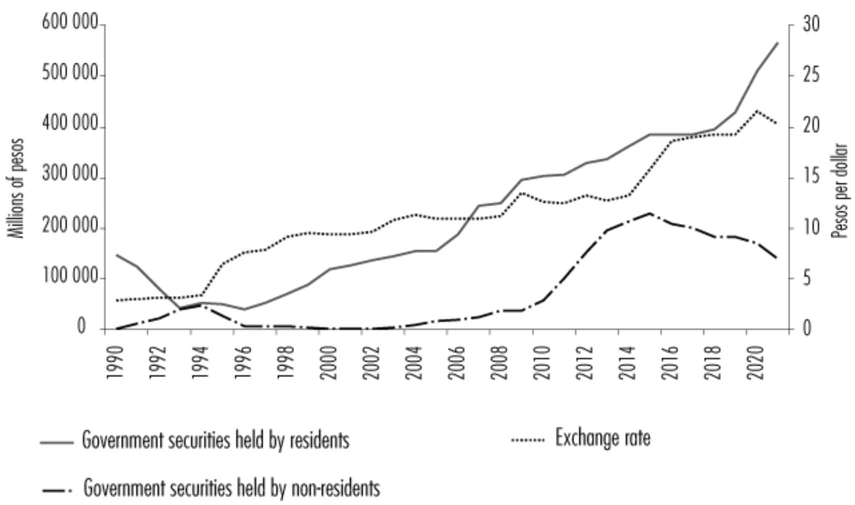
Figure 1. External assets, bonds and exchange rates



Source: Compiled by the author with data from BANXICO (2022) and IMF (2022)

As for the money and capital markets, within the framework of the MEA, some contrasts also emerge. Indeed, Mexico has achieved a significant expansion of stock market capitalization and, with it, of foreign assets, a condition that has improved its financial position and liquidity capacity. However, it has also become a risk factor for the exchange rate due to the potential implications that the growing influx of short-term foreign capital has on the margin of response (adjustment) to external shocks and the stability of the financial system, in addition to the restricted results in terms of savings and the high bias of credit towards short-term financing.

Figure 2. Government securities and exchange rate

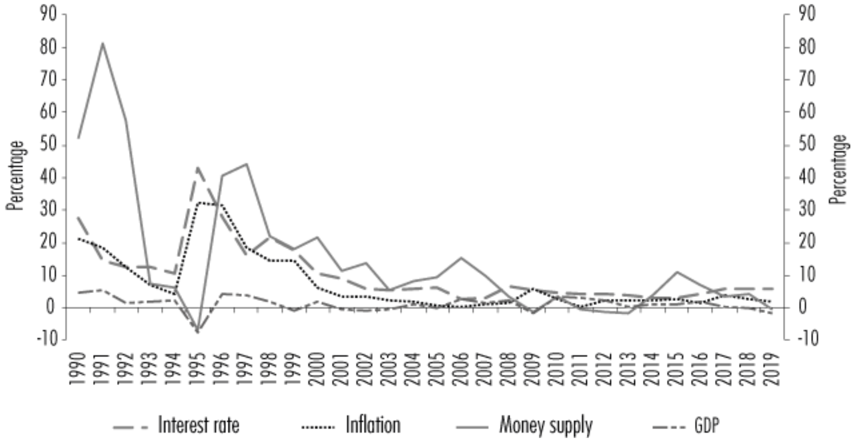


Source: Compiled by the author with data from BANXICO (2022) and IMF (2022).

It is worth noting that since 2013, the Mexican economy has experienced significant variations in foreign portfolio investment flows and the market capitalization rate. This condition has generated pressures on the exchange rate value of the peso despite the deepening of exchange rate coverage[5] (see table 1, figures 1 and 2). Some of the factors that have influenced these capital market imbalances are linked to: *i)* the normalization of the US Federal Reserve Bank's monetary policy; *ii)* the increase in the fiscal deficit; *iii)* the increase in short-term debt; *iv)* significant variations in oil prices; *v)* the inflationary differential.

In effect, the single objective monetary scheme places the interest rate as the instrument of the monetary authority, which means that in the long term, it has become the mechanism for adjusting inflationary expectations. However, since the 2008 subprime crisis, the monetary rule in Mexico has operated, in practice, as an instrument to contain the uncontrolled volatility of the exchange rate in the short term, especially in the face of monetary policy movements in the United States, in order to moderate the pass-through effects on domestic prices.

Figure 3. Dynamics of the monetary determinants of the exchange rate



Note: The variables represent the interest rate, money supply (M1), inflation and GDP growth rate gaps between Mexico and the United States.

Source: Compiled by the author with data from BANXICO (2022) and FRED (2022).

Regarding monetary expansion, particularly since 2008, BANXICO has maintained a cycle synchronized with the direction of the FED's monetary policy, based on the perspective that changes in the quantity of money are aimed at providing liquidity to the financial market, thus becoming a countercyclical adjustment instrument to ensure the dynamics of financial asset prices. However, this expansion pressures exchange rate parity and marginal effects on output.

Empirical estimation and methodological aspects

For the empirical analysis of the relationship between the exchange rate, relative asset supply and financial wealth in Mexico, an *ARDL* model is assumed. An advantage of *ARDL* models is that this methodology allows regressions of systems with variables of different order of integration, *I(d),* which helps to solve the requirements on the stationarity properties of the standard cointegration analysis. Likewise, it produces efficient and consistent estimators, even when the system series are endogenous or in small samples (Pesaran et al., 2001).[6]

Thus, the stochastic specification of equation (6) is defined as follows:

$$e_t = \sum_{j=1}^{p} \lambda_j e_{t-j} + \sum_{j=0}^{q-1} \theta_j' H_{t-j} + u_t \qquad (7)$$

Where e_t is the peso/dollar exchange rate[7] and H_t represents a column vector of explanatory variables (net private foreign assets of Mexico, af_{MX}, and the United States, af_{USA}; demand for domestic bonds, vg_{MX}; interest rate, $\tilde{r}$; inflation, $\tilde{\pi}$; output, $\tilde{y}$; money supply, $\tilde{m}$; [8] λ_j and θ_j' are vectors of coefficients; while u_t is a column vector of random variables with zero mean and constant variance.

If the error term follows a process *I(0)* and there is evidence of comovement between the series of the system, then the long-term relationship must incorporate an error correction equation whose dynamics capture the deviations of the variables with respect to the equilibrium path. Thus, equation (7) shall be defined as follows:

$$\Delta e_t = \beta_0 + \beta' \tau_t + \psi e_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta e_{t-j} + \sum_{j=0}^{q-1} \theta_j' \Delta \tau_{t-j} + u_t \qquad (8)$$

In this expression, e_t is the peso/dollar exchange rate; Ψ the error correction parameter; τ_i a vector with the determinants of the exchange rate (net private foreign assets of Mexico, af_{MX}, and the United States, af_{USA}; demand for domestic bonds, vg_{MX}; interest rate, $\tilde{r}$; inflation, $\tilde{\pi}$; output, $\tilde{y}$; money supply, $\tilde{m}$); β' and θ'_j the long-term and short-term parameters, respectively; while u_t and Δ represent the error term and the first difference operator, respectively (Pesaran et al., 2001).

According to the fundamentals of the portfolio balance model (Wang, 2009; Frankel, 1984), the coefficients associated with the money supply and inflation rate gaps, as well as with Mexico's stock of private net foreign assets, are expected to be positive, i.e., the compensatory mechanism for an increase in *m*, π and/or af_{MX} will be an exchange rate depreciation. In contrast, the deepening of output and interest rate margins, the demand for domestic bonds and the accumulation of US net foreign assets are expected to result in an appreciation of the local currency.

Analysis and interpretation of results

The data comprise quarterly series from 2001:04 to 2019:04 on nominal exchange rate (peso/dollar), interest rate of 91-day treasury certificates, global index of economic activity, monetary aggregate *M1*, national consumer price index, net foreign assets, special drawdown rights and international reserves of Mexico and the United States. The information can be found in the statistical repositories of BANXICO, the International Monetary Fund (IMF) (International Financial Statistics) and the Federal Reserve Bank (Federal Reserve Economic Data).

Empirically, first, the stochastic properties of the series included in the system were analyzed based on the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, whose results suggest that the variables are stationary stochastic processes in first differences. Second, we determined the persistence of comovement between the variables of each estimated model based on the algorithm of Pesaran et al. (2001), whose statistics confirmed the presence of cointegration (see Annex). Third, the consistency and efficiency of the estimated parameters were determined using the Breusch-Godfrey, White and Royston tests, which showed no problems of autocorrelation or heteroscedasticity, although the hypothesis of normal distribution of the residuals was mixed (see Annexes). It is important to note that in each model, the speed of adjustment coefficient has the expected sign, suggesting convergence to equilibrium.

The estimations generally show significant results around the portfolio balance model (see table 2). First, the evidence confirms a negative relationship between exchange rate variations and the interest rate differential, which suggests that, with the deepening of the gap in financial yields (i > i*), an exchange rate appreciation is generated by the higher turnover of domestic debt certificates and, therefore, of capital flows. However, these movements have disruptive effects on both the cost of domestic credit and the prices of medium and long-term fixed-income instruments. It should be noted that, despite the stability of interest rate differentials, after the 2008 financial crisis, the Mexican currency entered a trajectory of systematic exchange rate correction (depreciation) against the dollar, with inflection in 2013, explained among other factors by *i)* the volatility of commodity prices; *ii)* the normalization of US monetary policy; *iii)* the instability of stock markets, particularly in emerging economies, and, with it, country risk aversion; *iv)* an increase in the size of Mexican debt (domestic and external); *v)* the progressive imbalance in the balance of payments, associated with lower FDI inflows, lower oil prices[9] and the volume of portfolio investment; *vi)* the contraction of international reserves; and *vii)* the reduction in remittance flows following the 2008 financial crisis.[10]

Table 2. Mexico: Determinants of the nominal exchange rate

Dependent variable /1 Δe	*Model 1*	*Model 2*	*Model 3*	*Model 4*
constant	0.1068	-3.6095	-6.3348	-3.7087
	[0.919]	[0.077]**	[0.048]*	[0.085]**
$\tilde{m}$	0.3435	0.1898	0.2374	0.0478
	[0.003]*	[0.007]*	[0.016]*	[0.602]
$\tilde{y}$	-0.6559	-4.0461	-5.0369	-3.7638
	[0.126]	[0.001]*	[0.004]*	[0.001]*
$\tilde{\imath}$	-0.0071	-0.0109	-0.0194	-0.0190
	[0.132]	[0.127]	[0.075]**	[0.052]**
$\tilde{\pi}$	0.6468	-0.2992	-0.1461	0.2893
	[0.000]*	[0.444]	[0.722]	[0.444]
$afnp_{MX}$	-	0.0011	0.0011	0.0014
		[0.002]*	[0.009]*	[0.002]*
$afnp_{USA}$	-	-	0.00003	-0.00003
			[0.441]	[0.341]
vg_{MX}	-	-	-	-0.1878
				[0.042]*
α	-0.1528	-0.1092	-0.0930	-0.1024
	[0.008]*	[0.002]*	[0.008]*	[0.003]*

Note: 1/ Estimates using an Autoregressive Model with Distributed Lag (ARDL). p-value in square brackets, significant parameters * at 5% ** at 10%.

Source: Compiled by the author with data from International Financial Statistics and BANXICO.

In the same way, the evidence confirms a negative correlation between the product differential and the exchange rate. This result validates the rationale that a greater dynamism of economic activity (y > y*) generates an exchange rate appreciation by the increase in demand for domestic currency and foreign exchange inflows.

Meanwhile, the estimates suggest, in the sense of the portfolio equity model, that a deepening of the inflationary margin (π > π*) reduces the nominal value of the peso against the dollar since the increase in domestic prices, *ceteris paribus*, would lead to a loss of competitiveness (increase in unit labor costs) and, thus, a deterioration in the balance of payments; a condition that will require a compensatory adjustment through a depreciation of the local currency.

As for the effect of the money gap, empirical estimates show that an increase in this indicator ($\tilde{m}$ > 0) produces a depreciation of the exchange rate, consistent with the hypothesis of the asset model. In other words, assuming the consistency of the purchasing power parity (PPP) principle, an increase in the money supply will accelerate aggregate demand, resulting in a change in relative prices and, thus, a potential deterioration in the terms of trade. Consequently, the market would expect the adjustment of the value of the local currency to reestablish the long-term equilibrium.

The regressions, conversely, confirm that an increase in Mexico's net private external assets ($afnp_{MX}$) generates a depreciation of the exchange rate. This result validates the idea that a net creditor position of bonds or stocks in the rest of the world (a relative decrease in the preference for domestic securities and, thus, in net wealth) reduces the value of the peso against the dollar. Notably, no significant statistical evidence was found in the estimations regarding the effect of changes in US net foreign assets ($afnp_{USA}$) on exchange rate dynamics.

As expected, the estimates corroborate that an increase in the demand for domestic securities results in an appreciation of the exchange rate since, in the short term, it generates a net inflow of capital and, thus, an increase in liquidity in the foreign exchange market.

4. CONCLUSIONS

This paper evaluated the long-term equilibrium relationship between the exchange rate, monetary variables (money supply differentials, interest rate, inflation, income), financial assets and the foreign exchange market in Mexico over the period 2001-2019, especially the effect (share and weight) of the stock of private net foreign assets.

After discussing the theoretical principles and the variety of empirical results in the literature, an extension of the monetarist model was operationalized with rigid prices. In general, the main empirical findings proved to be consistent with the portfolio equilibrium model: first, increases in the interest rate and income gaps generate an appreciation of the exchange rate; second, price instability, as well as growth in money supply, reduces the nominal value of the peso against the dollar; third, the relative decrease in the preference for domestic securities (contraction of net wealth) results in an exchange rate depreciation.

Some vicissitudes emerge with these results, including the role of the exchange rate in the operation of the New Macroeconomic Consensus (dual character). Opening up the Mexican economy required profound structural transformations to ensure macroeconomic stability and reduce the consequences of external shocks and financial volatility. Along this path, the implementation of a free-floating exchange rate regime is necessary (symbiosis) for the optimal operation of the monetary policy targeting inflation since it allows for the effective unbundling of the Central Bank's actions and confers autonomy to monetary policy, thus limiting the role of monetary aggregates. Indeed, the interest rate constitutes the only instrument of the monetary authority and the nominal anchor of the economy for achieving inflation targets in the long term and, in the short term, as the primary determinant of exchange rate variations. The integration of robust indicators on profitability, performance and financial structure needs to be discussed in future research, as well as the differentiation of the dynamic impact between developed and emerging economies, with the analysis turning to comparative studies between economic blocs.

APPENDIX

Table B1. Order of integration. Unit root test

Variable	*Dickey-Fuller Augmented*			*Phillips-Perron/1*			*# Lag*	*I(d)*
	Sin I and T	*I*	*I and T*	*Sin I and T*	*I*	*I and T*		
lne	1.595	-1.026	-2.507	1.615	-0.960	–	2	I(1)
		[0.7436]	[0.3246]		[0.7675]			
$\tilde{m}$	-0.054	-1.737	-1.748	-0.164	-2.006	-2.005	3	I(1)
		[0.4119]	[0.7291]		[0.2837]	[0.5988]		
$\tilde{y}$	-1.51	-0.938	-2.460	-2.033	-2.187	-8.447	8	I(1)
		[0.7752]	[0.3481]		[0.2109]	[0.0000]		
$\tilde{\imath}$	-0.514	-2.726	-2.725	-0.208	-2.171	-2.120	4	I(1)
		[0.0696]	[0.2260]		[0.2169]	[0.5348]		
$\tilde{\pi}$	4.93	0.545	-1.956	4.494	0.141	-2.599	7	I(1)
		[0.9862]	[0.6251]		[0.9687]	[0.2802]		
$afnp_{MX}$	2.538	0.127	-1.965	2.572	-0.096	-2.248	6	I(1)
		[0.9678]	[0.6202]		[0.9498]	[0.4628]		
$afnp_{USA}$	-0.574	-1.246	-2.223	-1.542	-2.417	-4.543	3	I(1)
		[0.6534]	[0.4767]		[0.1369]	[0.0013]		
vg_{MX}	0.674	-1.834	-2.825	0.728	-1.752	-2.694	2	I(1)
		[0.3638]	[0.1881]		[0.4043]	[0.2387]		
Δlne	-8.137	-8.349	-8.329	-10.93	-11.054	-11.027	2	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta\ \tilde{m}$	-9.852	-9.828	-9.829	-15.704	-15.665	-15.645	2	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta\ \tilde{y}$	-5.508	-5.682	-5.669	-26.579	-26.903	-26.824	7	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta\ \tilde{\imath}$	-5.609	-5.597	-5.560	-12.385	-12.358	-12.357	3	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta\ \tilde{\pi}$	-5.605	-7.689	-7.727	-7.366	-7.701	-7.695	6	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta afnp_{MX}$	-4.783	-5.788	-5.799	-15.159	-15.822	-15.803	7	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
$\Delta afnp_{USA}$	-11.502	-11.505	-11.480	-26.471	-26.443	-26.373	2	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		
Δvg_{MX}	-7.263	-7.404	-7.427	-10.196	-10.313	-10.314	1	I(0)
		[0.0000]	[0.0000]		[0.0000]	[0.0000]		

Note: 1/ The table reports the value of the Z(t) statistic for the Phillips-Perron test. The value in square brackets represents the p-value associated with the statistic. I: Intercept, I and T: intercept and trend.

Source: Compiled by the author.

Table B2. Pesaran, Shin and Smith's cointegration test

Ho: There is no long-term relationship

		10%		*5%*		*1%*	
		I(0)	*I(1)*	*I(0)*	*I(1)*	*I(0)*	*I(1)*
Model 1	F =4.216	2.233	3.176	2.613	3.636	3.449	4.630
	t =-2.720	-2.536	-3.625	-2.850	-3.975	-3.465	-4.644
Model 2	F =14.540	2.183	3.209	2.562	3.688	3.420	4.757
	t =-3.116	-2.530	-3.839	-2.859	-4.219	-3.513	-4.961
Model 3	F =14.821	2.087	3.183	2.444	3.651	3.255	4.705
	t =-2.763	-2.507	-3.994	-2.842	-4.390	-3.510	-5.167
Model 4	F =13.873	2.031	3.133	2.366	3.577	3.127	4.574
	t =-3.086	-2.515	-4.171	-2.850	-4.570	-3.515	-5.353

Source: Compiled by the author.

Table B3. LM test for autocorrelation

Lag (p)	*Model 1 Prob > F*	*Model 2 Prob > F*	*Model 3 Prob > F*	*Model 4 Prob > F*
1	0.9496	0.1051	0.6089	0.6922
2	0.4043	0.2590	0.5797	0.4015
3	0.3365	0.3285	0.5980	0.1947
4	0.4927	0.4767	0.7427	0.1986
5	0.5983	0.0832	0.2888	0.1485

Ho: There is no autocorrelation.

Source: Compiled by the author.

Table B4. White's test for homoscedasticity

Statistic	*Model 1 Prob > Chi2*	*Model 2 Prob > Chi2*	*Model 3 Prob > Chi2*	*Model 4 Prob > Chi2*
White	107.69	66.00	65.00	66.00
	[0.0986]	[0.4421]	[0.4416]	[0.4421]

Ho: the residuals are homoscedastic.

Source: Compiled by the author.

Table B5. Normality test

Statistic	*Model 1 Prob > Chi2*	*Model 2 Prob > Chi2*	*Model 3 Prob > Chi2*	*Model 4 Prob > Chi2*
Royston	37.73	13.52	6.04	15.72
	[0.0000]	[0.0012]	[0.0488]	[0.0004]

Ho: Errors are normally distributed.
Source: Compiled by the author.

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[1] Foreign bonds (B^f) are considered to be the only ones that produce yields.

[2] Once the risk premium has been defined, we obtain $\sigma = \frac{1}{b}$; $\gamma = \frac{(a_d + a_r)}{b}$; $\delta = \frac{(a_r - a_{USA})}{b}$; $\eta = \frac{a_r}{b}$; $\tilde{B} = \frac{B}{R}$; $\tilde{R}^d = \frac{R_d}{R}$; $\tilde{R}^f = \frac{R_{USA}}{R}$.

[3] It is considered that, first, purchasing power parity is maintained only in the long run $(\bar{e} = \bar{p} - \bar{p}^*)$; second, the demand for domestic and foreign money is indicated by $\bar{p} = \bar{m} - \phi\bar{y} + \lambda\bar{i}$ and $\bar{p}^* = \bar{m}^* - \phi\bar{y}^* + \lambda\bar{i}^*$, respectively. Combining these formulations, considering the assumptions of uncovered parity of the interest rate and the law of a single price, in equilibrium the Frenkel-Mulsa-Bilson model is expressed as $\bar{e} = \tilde{m} - \phi\tilde{y} + \lambda\tilde{\pi}$, where $\tilde{y}$, $\tilde{m}$ and $\tilde{\pi}$ represent, respectively, the output gaps $(\bar{y} - \bar{y}^*)$, money supply $(\bar{m} - \bar{m}^*)$ and inflation gaps $(\bar{\pi} - \bar{\pi}^*)$ between the local and the foreign country.

[4] For Latin America, the sample includes information from Argentina, Bolivia, Brazil, Chile, Colombia, Mexico and Peru. For Asia, the panel adds data from China, Korea, Hong Kong, Indonesia, Japan, Malaysia and Thailand.

[5] The objective of this mechanism is to reduce the volatility of the value of financial assets, mitigating the abrupt response to external shocks around the restructuring of investment and debt portfolios.

[6] For example, VAR/VEC regressions lead to a significant loss in the degrees of freedom, since each lag included in the variables implies a high number of estimated parameters and, therefore, causes a potential weakening of the results of the econometric tests. Furthermore, it requires the series included in the system to have the same order of integration.

[7] The exchange rate is defined as the number of national currency units per dollar. Therefore, a decrease in the exchange rate represents an appreciation and an increase constitutes an exchange rate depreciation.

[8] The variables , , and are expressed as the gap between Mexico and the United States. The indicator of net private external assets is obtained as the total of net foreign assets minus international reserves plus special drawing rights.

[9] This coupled with the fall in oil production and exports, which, between 2013 and 2021, resulted in an average annual contraction equivalent to 5.1% and 8.6%, respectively.

[10] Between 2008 and 2013, remittance inflows to Mexico contracted at an average annual rate of 3.8%. Although they grew at an average annual rate of 9.7% between 2014 and 2021, this expansion was insufficient to offset the deterioration in the supply of foreign exchange during the same period.