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An Exploration of the Relative Influence of the Determinants of the Mexican Peso - U.S. Dollar Exchange Rate

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Abstract

This article examines the impact over time of the government's primary balance, remittances, foreign direct investment expectations, and real interest rates on the Mexican peso to US dollar exchange rate between 2003 and 2023, using monthly and quarterly data. An autoregressive distributed lag model with bounds testing and a Granger non-causality test are employed. The results indicate that, although the significance of all variables changes over time, foreign direct investment expectations and the government's primary balance influence the exchange rate throughout the entire period. Foreign direct investment expectations and remittances exert the most persistent long- and short-run influence, respectively. The evolving significance across time of these determinants implies the need of a dynamic and adaptable policy framework to currency stability in Mexico.

JEL Classification: F31, O24, C50.

Keywords: Mexican peso, exchange rate determinants, cointegration, Granger non-causality.

Una Exploración de la Influencia Relativa de los Determinantes del Tipo de Cambio Peso Mexicano - Dólar Estadounidense

Resumen

Este artículo analiza el efecto a lo largo del tiempo del balance primario gubernamental, las remesas, las expectativas de inversión extranjera y las tasas de interés reales sobre el tipo de cambio peso mexicano-dólar estadounidense entre 2003 y 2023, utilizando datos mensuales y trimestrales. Se emplea el modelo auto-regresivo de retardos distribuidos con prueba de límites y la prueba de no-causalidad de Granger. Los resultados indican que, aunque la importancia de todas las variables cambia en el tiempo, las expectativas de inversión extranjera y el balance primario gubernamental influyen en el tipo de cambio a lo largo de todo el período. Las expectativas de inversión extranjera y las remesas ejercen la influencia más persistente a largo y corto plazo, respectivamente. La evolución de la importancia a lo largo del tiempo de estos determinantes implica la necesidad de un marco de políticas dinámico y adaptable para la estabilidad del tipo de cambio en México.

Clasificación JEL: F31, O24, C50.

Palabras clave: Peso mexicano, determinantes del tipo de cambio, cointegración, no-causalidad de Granger.

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1. Introduction

There is a complex relationship between the exchange rate and macroeconomic fundamentals that continues to be a challenging issue yet to be fully understood, making it a subject of great research interest. For a country like Mexico, an emerging economy with a heavily traded currency, investigating the dynamics of the Mexican peso exchange rate and its determinants against major currencies, especially the U.S. dollar, is crucial due to the exchange rate's direct impact on economic growth, competitiveness in global markets, and other key indicators.

The literature recognizes an extensive array of variables that determine the exchange rate between two currencies. Some of the most frequently cited include foreign direct investment (Qamruzzaman, Karim, & Wei, 2019), fiscal discipline (Jalles, Mulas-Granados, Tavares, & Correa Caro, 2018), remittances (Fisera & Workie Tiruneh, 2023), and real interest rates differentials (Long, Zhang, & Hao, 2022), among many other.

From the highest Mexican peso to U.S. dollar exchange rate, recorded in March 2020, the Mexican currency appreciated by approximately 28% by the end of March, 2023. This exchange rate movement occurred despite a slow growth of Mexico's GDP in real terms, averaging around 0.63% per year, from the first quarter of 2020 to the first quarter of 2023. For the most part, the Mexican currency appreciation occurred between November, 2021 and March, 2023, when the peso gained more than 17% in value relative to the U.S. dollar[2]. In this context, analysts present several reasons for the appreciation of the Mexican peso generally aligned with the theoretical perspectives on the topic. One of them is the government's strict fiscal policy and commitment to maintaining a tight primary balance (Priego, 2023). Observers also mention increased real interest rate differentials between Mexico and the U.S. (Quintana, 2023). Additionally, foreign exchange market participants point out to the anticipation of a significant shift in global trade in the coming years, which could potentially lead to increased foreign direct investment, related to what is known as "nearshoring" (Lei & O'Boyle, 2022), and empirical tests detect a non-linear multivariate dependence between the Mexican stock market index and that country's currency exchange rate with respect to the U.S. dollar (Coronado et al. 2017). Finally, analysts highlight remittances as a key factor of the appreciation of the Mexican peso (Barría, 2023).

Thus, the motivation of this paper is to thoroughly investigate the aforementioned factors and determine whether they actually have a significant influence on the MXN/USD exchange rate during the last 20 years (from January, 2003 to March, 2023). Likewise, the study aims to examine how the impact of these factors evolved over time. By analyzing their influence on the exchange rate, we seek to gain a better understanding of the long-run relationship and the short-run dynamics, and to provide insights into the exchange rate fluctuations and trends.

The study applied the autoregressive distributed lag (ARDL) model and the bounds testing framework proposed by Pesaran, Shin, & Smith (2001). While other cointegration testing procedures are suitable for I(1) variables only, a feature of ARDL modeling is its ability to handle both I(0) and I(1) series within the same ordinary least squares regression (Menegaki, 2019). Also, to determine

[2] On March 24, 2020, the exchange rate was 25.1185 Mexican pesos for one U.S. dollar, on November 26, 2021 it was 21.8185 Mexican pesos for one U.S. dollar, and on March 31, 2023, the exchange rate was 18.0415 Mexican pesos for one U.S. dollar.

the presence of Granger non-causality among the variables, the research applied the Toda-Yamamoto procedure to the Granger non-causality test (Toda & Yamamoto, 1995). By taking this comprehensive point of view, the study was able to examine the long-run and short-run relationships and the causality dynamics among the variables of interest.

This study contributes to the literature in two relevant ways. First, while previous research has examined the relationship between expected and realized exchange rates (Beckmann & Czudaj, 2017), there is a gap in the literature on the relationship between FDI expectations and the exchange rate. This research appears to be the first to incorporate specialists' FDI expectations as a determinant of the MXN/USD exchange rate. Second, the study makes temporal partitions to examine the evolution of the determinants under investigation, providing a more comprehensive understanding of their time-varying impact on the exchange rate.

The subsequent structure of the research paper is as follows: Section 2 presents a concise review of the relevant literature, Section 3 describes the data and explains the research methodology employed, Section 4 presents the empirical findings, and Section 5 covers the discussion of the results and serves as the concluding section of the paper.

2. Literature Review

The complex relationship between exchange rates and Foreign Direct Investment (FDI) has been studied under various theoretical approaches, including portfolio balance theory, market imperfections, internalization theory, and exchange rate expectations, among others. Within this context, some studies argue for causality running from FDI to the exchange rate. In a research from 1988 to 2008, Ibarra (2011) finds that that all types of capital inflows contributed to the appreciation of the Mexican peso. However, other authors have reported a two-way relationship between exchange rates and FDI. Tsaurai (2015) identifies a causal relationship from FDI to the value of the South African rand in the short-run, and from the value of the rand to FDI in the long-run. Alshubiri (2022) found a negative relationship between the exchange rate and FDI in the long-run, although significant only for developed countries belonging to the G7, but not statistically relevant for the Gulf Cooperation Council countries.

The theoretical framework on the association between the exchange rate and fiscal discipline suggests that the latter is crucial when a country adopts a fixed exchange rate regime. It is necessary to ensure that the government avoids overspending, which can lead to budget deficits. Such deficits, in turn, may deplete the essential foreign reserves that are required to support the fixed exchange rate. While countries with floating exchange rate regimes may not attribute the same level of importance to fiscal discipline, the soundness of the government's budget remains relevant. Fiscal discipline can influence investor confidence, government credibility, and economic stability, which impact the exchange rate. Jalles et al. (2018) estimate the budgetary position that would have been in place for each Eurozone country if they had operated under flexible exchange rates instead of fixed exchange rates. Their findings strongly indicate that maintaining fixed exchange rates had an adverse impact on fiscal discipline. Also, Tunaer Vural (2019) concludes that fiscal expenditures are among the main fundamental determinants of the Turkish real effective exchange rate. In their analysis of the real exchange rate behavior in Mexico, López Villavicencio & Rymond Bara (2008) found evidence of higher inflows to the Mexican economy as a consequence of higher real interest rates, as well as a negative effect on the real exchange rate of the primary deficit and the net accumulation of external liabilities.

Remittances[3] represent a significant and increasing source of income for many countries and, for that reason, research in this area has experienced a significant growth, remarkably in economies that heavily rely on such flows for foreign income. Remittances exert influence on the exchange rates in recipient countries and their volume has both positive and negative effects. On the positive side, remittances can contribute to economic growth in recipient countries. In contrast, they can also result in the depreciation or appreciation of their national currencies. When the receiving country's currency appreciates against others, it dampens exports and boosts imports, leading to a broader current-account deficit and a potential decline in global competitiveness-particularly in the tradable goods sector (Amuedo-Dorantes, 2014). In a study of a sample of 134 developing and emerging economies, Fisera & Workie Tiruneh (2023) find that remittances contribute to long-term appreciation in real terms of the domestic currency. Akçay (2023) examines the asymmetric causality relationships between real effective exchange rates and remittances in Mexico and reports that positive shocks to remittances lead to the appreciation of the Mexican peso in the medium- and long-run cycles. On the other hand, negative shocks to remittances do not result in depreciation of the Mexican peso. In contrast, Ito (2019) concludes that the inflow of remittances leads to the depreciation of the real effective exchange rate in the 18 developing countries examined in his study. A similar finding is reported by Adejumo & Ikhide (2019) for the exchange rate in Nigeria.

The relationship between interest rates and exchange rates has been a subject of analysis in various theoretical and empirical models. The prevailing theory emphasizes that interest rate differentials have a particularly significant impact on the exchange rate in the short run. Specifically, when the domestic interest rate exceeds the rate in international markets, a country undergoes positive financial capital inflows that result in the appreciation of the local currency. Moreover, in his seminal paper Dornbusch (1982) suggests that the concept of purchasing power parity theory ensures that the structure of domestic prices is ultimately determined by international factors. This implies that fluctuations in exchange rates have an impact on the inflation rate, and consequently, Central Banks may adjust the real interest rate to protect the exchange rate or stabilize the inflation rate. In their analysis of the relationship between the Mexican peso and the U.S. dollar using non-linear ARDL modeling, Capasso, Napolitano, & Viveros Jiménez (2019) find an asymmetric causality of the real exchange rate on the real interest rate. However, they also conclude that in the long-run, the interest rate does not exert a statistically significant influence on the exchange rate. In contrast, Frömmel, Vukovic, & Wu (2022) found evidence of a significant influence of economic fundamentals on the real exchange rate under the PPP context; however, they point out that such effects were not linear in the case of the Deutsche mark/USD exchange rate between 1973 and 2004.

[3] Funds transferred from migrant workers to their country of origin.

3. Data and Methodology

3.1 Data

The study conducted quarterly and monthly analyses of the series for the full sample period, spanning from January 2003 to March 2023. For monthly data, the research also examined four subsamples, each covering 48 months: 2003-2006, 2007-2010, 2011-2014, and 2015-2018, along with one sample of 51 months from January 2019 to March 2023. This last subsample includes the first three months of 2023, during which the Mexican peso appreciated by more than 7% against the U.S. dollar, an event considered relevant for the study. The data were gathered from several sources, as described in Table 1.

Table 1. Variables definitions and sources

Indicator / Variable	Definition and Sources
Mexican peso to U.S. dollar exchange rage	The exchange rate (FIX) is determined by Mexico's central bank as an average of quotes in the wholesale foreign exchange market for operations payable in 48 hours. Source: Banco de México (Banxico).
Nominal GDP	Mexican peso millions. Converted from quarterly to montlhly data using Denton-Cholette's interpolation. Quarterly data source: Instituto Nacional de Estadística y Geografía (INEGI).
Remittances	USD millions. Source: Banco de México.
Mexican government's primary budget balance	Mexican peso millions. Source: Secretaría de Hacienda y Crédito Público (SHCP).
Average of the surveys on the expectations of private sector specialists on foreign direct investment for the current year (year t).	USD millions. Source: Banxico.
CETES annualized yield (28 days maturity)	Source: Banco de México.
T-bills annualized yield (4 weeks to maturity)	Computed from the discount rate. Source: Federal Reserve Economic Data (FRED).
Annualized inflation rate in Mexico	Source: Banxico.
Annualized inflation rate in the U.S.	Source: Bureau of Labor Statistics (BLS).

Source: Authors' own

Quarterly nominal GDP observations were interpolated into monthly data using the Denton-Cholette benchmarking procedure (Cholette, 1984) with the condition that each three-month observation matches the sum of the quarterly data between the corresponding dates. The conversion of monthly to quarterly data for cash flow series, such as remittances, involved aggregating monthly observations to match each quarter. Additionally, for series representing an account balance, such as the government's primary budget balance, the corresponding end-of-month observation during the data conversion process was used. The same approach was followed for the Mexican peso to U.S. dollar exchange rate, as well as the annualized yield and inflation rates. Finally, since the expectations of private sector specialists on foreign direct investment are observed monthly but reported as yearly data, they were divided by 4 and 12 for the quarterly and monthly analyses, respectively.

Some of the indicators, regarded as determinants of the MXN/USD exchange rate were transformed into ratios relative to nominal GDP. Specifically, the study examined the ratio of remittances to GDP (Essayyad, Palamuleni, & Satyal, 2018) and the ratio of the government's primary budget balance to GDP, which served as a representation of fiscal discipline (Foremny, Sacchi, & Salotti, 2017). Furthermore, the study accounted for the real interest rate differential between both countries as another driver of the MXN/USD exchange rate (Capasso et al., 2019). The study also considered the specialists' expectations on foreign direct investment to GDP ratio as a determinant of the MXN/USD exchange rate.

4. Autoregressive Distributed Lag and Bounds Testing Framework

To test for the long-term equilibrium relationship between the MXN/USD exchange rate and the determinants described above, the study applied the autoregressive distributed lag (ARDL) model and the bounds testing framework (Pesaran & Shin, 1999; Pesaran et al., 2001). An ARDL is a comprehensive dynamic model that incorporates lagged values of the response variable, as well as the contemporaneous and lagged observations of the independent variables. Pesaran & Shin (1999) assert that this method has the advantage of providing reliable estimates for the long-run coefficients, which exhibit asymptotic normality regardless of whether the underlying predictors are I(0) or I(1). Furthermore, the bounds testing procedure proposed by Pesaran et al. (2001) assesses whether the ARDL model involves a long-term relationship between the dependent variable and the regressors. Besides the indirect estimation of the long-run equilibrium relationship, the ARDL procedure enables the direct estimation of short-run effects. The short-run relationship is captured by the lagged values of the variables and their coefficients in an error correction model (ECM) that considers how the variables respond to changes in each other. Meanwhile, the long-run relationship is captured by the coefficients of the cointegrating terms, identified through the bounds testing procedure (Pesaran et al., 2001).

The ARDL approach has several advantages when compared to other cointegration testing techniques (Hoque, Yakob, & Kruse, 2017; Nkoro & Uko, 2016). Firstly, this technique simplifies the analysis of the relationship between the response and input variables by utilizing ordinary least squares (OLS) regressions. Secondly, in comparison to other cointegration methods, the ARDL approach is more reliable for small sample sizes (Haug, 2002). This characteristic is particularly relevant for the subsample analyses used in this research. Finally, unlike other cointegration methods, the ARDL allows for the inclusion of both I(0) and I(1) series in the same OLS regression, whereas it is also appropriate for accommodating I(1) variables only. It is worth mentioning,

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however, that the F-statistic of the test is not valid if the series' integration order is higher than I(1) (Menegaki, 2019).

As the test's F-statistic has a non-standard distribution, Pesaran et al. (2001) developed the corresponding critical values for large samples, which this study applies to the 2003-2023 quarterly and monthly observations. However, for the subperiod analyses, the study applied the bounds test's critical values put forward by Narayan (2005), which are suitable for samples between 30 and 80 observations.

The primary model used in the ARDL and bounds testing framework is the following unrestricted Error Correction Model (ECM):

$$\Delta MXN_t = \beta_0 + \sum_{i=1}^{p} \beta_{1,i} \Delta MXN_{t-i} + \sum_{i=0}^{q_1} \gamma_{1,i} \Delta XFDIGDP_{t-i} + \sum_{i=0}^{q_2} \gamma_{2,i} \Delta PBALGDP_{t-i} + \sum_{i=0}^{q_3} \gamma_{3,i} \Delta REMGDP_{t-i} + \sum_{i=0}^{q_4} \gamma_{4,i} \Delta RIRD_{t-i} + \theta_0 MXN_{t-1} + \theta_1 XFDIGDP_{t-1} + \theta_2 PBALGDP_{t-1} + \theta_3 REMGDP_{t-1} + \theta_4 RIRD_{t-1} + \varepsilon_t \quad (1)$$

In equation (1), *MXN* represents the exchange rate of the Mexican peso to the U.S. dollar in European terms (i.e., Mexican pesos per U.S. dollar). *XFDIGDP* denotes the specialists' expectations on foreign direct investment in Mexico, expressed as a percentage of GDP, as reported by Banco de México's monthly survey results. *PBALGDP* stands for the ratio of the Mexican government's primary budget balance as a percentage of GDP. *REMGDP* represents the remittances to GDP ratio, also as a percentage. *RIRD* stands for the real interest rate differential between the 28-day-to-maturity Mexican government debt (CETES) and the 4-week-to-maturity U.S. debt (T-bills)[4]. The first difference operator is denoted as Δ. The constant term is represented by β_0, while β_1 and γ_1 to γ_4 are the short-run coefficients for *MXN* and each of the independent variables (*XFDIGDP*, *PBALGDP*, *REMGDP*, and *RIRD*), respectively. The long-run coefficient for the Mexican peso exchange rate is denoted by θ_0, while those for the independent variables are represented by θ_1 to θ_4, respectively.

In the bounds approach, when the test fails to reject the null hypothesis of no long-run relationship, the appropriate specification is a short-term ARDL model. In this study, the short-term ARDL model is represented by:

$$\Delta MXN_t = \beta_0 + \sum_{i=1}^{p} \beta_{1,i} \Delta MXN_{t-i} + \sum_{i=0}^{q_1} \gamma_{1,i} \Delta XFDIGDP_{t-i} + \sum_{i=0}^{q_2} \gamma_{2,i} \Delta PBALGDP_{t-i} + \sum_{i=0}^{q_3} \gamma_{3,i} \Delta REMGDP_{t-i} + \sum_{i=0}^{q_4} \gamma_{4,i} \Delta RIRD_{t-i} + \varepsilon_t \quad (2)$$

The study utilized the Akaike information criterion (AIC) to determine the optimal number of lags for the ARDL estimations. Additionally, the analyses incorporated the Ljung-Box Q-statistics to verify the presence of high-order serial correlation in the residuals and White's test, without cross terms, to establish the presence of heteroskedasticity in the residuals.

[4] *RIRD* is computed as follows, considering annualized rates: (CETES – Mexico's inflation) – (T-bills – U.S. inflation)

5. Toda-Yamamoto Procedure for Granger Non-Causality

The Granger non-causality test is a valuable method for identifying causal relationships between a set of variables. It evaluates whether one independent variable (*X*) Granger-causes a response variable (*Y*) by examining whether the prediction error of the current *Y* decreases when incorporating not only its past observations but also past values of *X*. The study used the procedure outlined by Toda & Yamamoto (1995) to assess Granger non-causality. This approach has the advantage of being valid regardless of whether the time series are cointegrated of any order, or even not cointegrated (Jain & Ghosh, 2013). The Toda-Yamamoto method uses a modified Wald test to impose parameter restrictions on the vector autoregression (VAR) with lag length *k*. The correct order of the system is established by adding the maximum order of integration,[5] d_{max}, to *k*. The estimated VAR($k + d_{max}$) model ignores the coefficients of the last lagged d_{max} vector. The Wald statistic asymptotically follows a chi-square distribution where its degrees of freedom are the same as the number of excluded lagged variables. This holds true regardless of whether the process is stationary or cointegrated. A VAR model of order *p* can be represented as:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \Psi_i y_{t-i} + \Omega z_t + \upsilon_t \tag{3}$$

In equation (3), y_t represents a *n* x 1 vector of endogenous variables, *t* is the linear trend (*t* = 1, 2, …, *T*), α_0 and α_1 are *n* x 1 vectors, z_t is a *q* x 1 vector of exogenous variables, and υ_t represents a *n* x 1 vector of random errors, which are independently and identically distributed (i.i.d.). The Toda-Yamamoto procedure treats the additional lags of the variables as exogenous and, consequently, includes such lags in the z_t vector.

6. Results

6.1 Descriptive Statistics and Stationarity Tests

Table 2 shows the descriptive statistics of the monthly observations. *PBALGDP* exhibits the highest volatility as measured by the coefficient of variation (CV). This is the result of the Mexican government's considerable primary budget deficits between 2003 and 2008. The largest deficit (5.7% of GDP) was a result of the Federal Government assuming the cost of a law reform related to its employees' retirement plans for an amount of 270.5 billion pesos in December 2008. On the other hand, the primary budget exhibited substantial surpluses in 2016 and 2017, resulting from an effort of the Mexican government to adhere to the consolidation path and ensure debt sustainability. All the variables were leptokurtic and skewed, except for the *RIRD* which, according to the Jarque-Bera test, is normally distributed.

[5] If one of the variables is I(1), d_{max} = 1, and so on.

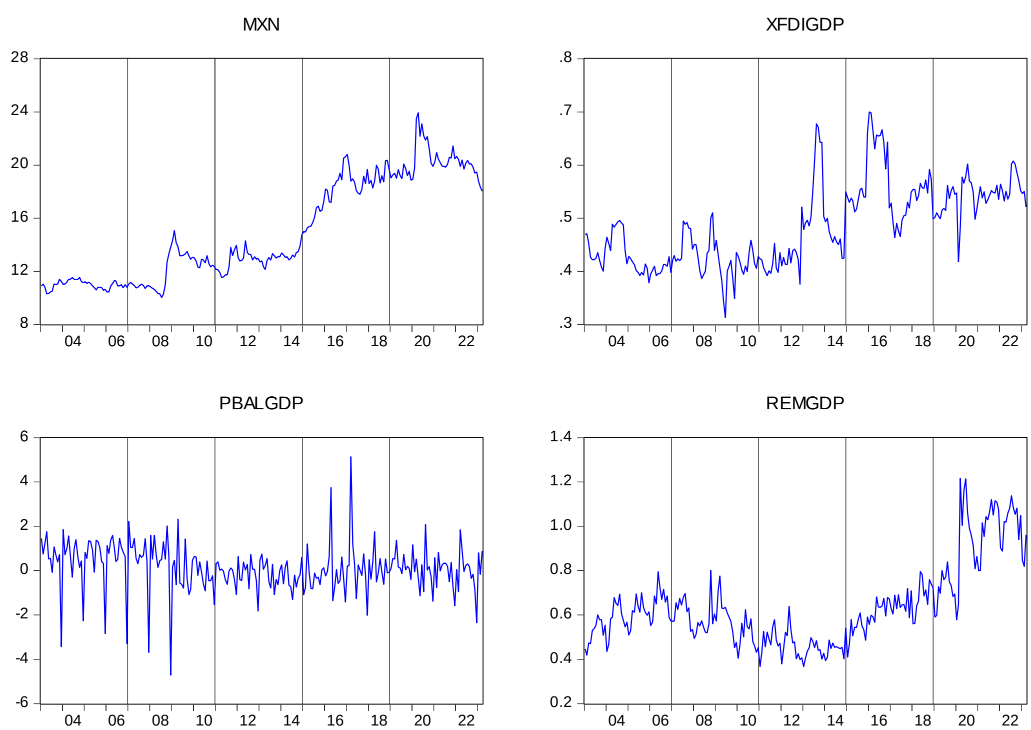
Table 2. Descriptive statistics: Monthly observations

Monthly Observations

	MXN	XFDIGDP	PBALGDP	REMGDP	RIRD
Mean	14.9563	0.4861	0.1402	0.6392	2.7519
Median	13.2269	0.4820	0.1811	0.5954	2.6000
Maximum	23.9283	0.7000	5.1361	1.2160	7.4000
Minimum	10.0353	0.3130	-4.7084	0.3679	-3.1700
Std. Dev.	3.8351	0.0766	1.0479	0.1882	2.0011
Skewness	0.4420	0.5479	-0.3882	1.1775	-0.0104
Kurtosis	1.6785	2.7130	7.8394	3.8238	2.8187
Jarque-Bera (*p*-value)	0.0000	0.0015	0.0000	0.0000	0.8449
Observations	243	243	243	243	243

Source: Authors' own

Figure 1 presents the graphical progression of the Mexican peso – U.S. dollar exchange rate and the four independent variables between January, 2003 and March, 2023. The vertical lines in the graphs illustrate the divisions for the five subsample periods. Considering the full sample period, the *MXN* exhibits an upward trend, indicating a depreciation of the Mexican currency against the U.S. dollar. Nevertheless, from March 2020 onwards, there is a downward trend (i.e., the Mexican currency appreciates), which becomes more pronounced from November 2021 to March 2023. Between 2003 and 2023 *XFDIGDP* and *REMGDP* show an upward trend, while *PBALGDP* and *RIRD* do not show any obvious trend during this period.



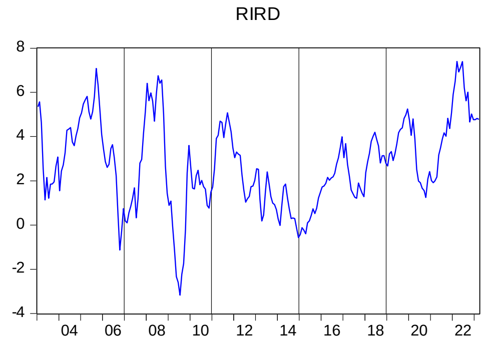


Figure 1. Graphical representations of the monthly observations
Source: Authors' own

Table 3 presents the correlation coefficients between the variables. The highest correlation coefficient is between *MXN* and *XFDIGDP* (0.70), while the lowest is between *MXN* and *PBALGDP* (-0.12). As the correlation coefficients are all below the 0.80 threshold, which is deemed as an indicator of a high correlation (Bouraoui & Phisuthtiwatcharavong, 2015), there is no evidence of potential issues regarding multicollinearity problems for subsequent analyses[6].

Table 3. Pairwise correlation analysis: Monthly observations

	MXN	**XFDIGDP**	**PBALGDP**	**REMGDP**	**RIRD**
MXN	1.00000				
XFDIGDP	0.70097	1.00000			
PBALGDP	-0.12440	-0.09094	1.00000		
REMGDP	0.69286	0.39340	0.01741	1.00000	
RIRD	0.11538	0.06113	0.12832	0.34595	1.00000

Source: Authors' own

As described earlier, the ARDL method and the bounds testing framework are applicable to the underlying variables as long as their integration level does not exceed I(1). It is also essential to establish the order of integration of the variables to determine the correct lag length of the VAR system for the Toda-Yamamoto procedure. To deal with this issue, the study performed the KPSS (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) and the Breakpoint Modified Augmented Dickey-Fuller (BM-ADF) test (Perron, 1989). Table 4 presents the results of these tests, which are consistent and concur on the order of integration of the variables. The analyses also considered the KPSS and BM-ADF tests for the subperiod analyses. While *PBALGDP* consistently remained stationary at levels, the remaining variables changed their order of integration for different subperiods[7]. For instance, *MXN* alternated between being I(1) and I(0) across the five subperiods. On the other hand, *REMGDP* remained I(0) for each subperiod except the last one, during which it was I(1) according to the BM-ADF tests, evidencing a possible regime change during this period. So, the shifts of the variables

[6] In the case of quarterly data, the highest correlation coefficient is between *MXN* and *XFDIGDP* (0.73) and the lowest is between *MXN* and *PBALGDP* (-0.20).
[7] These results are not presented here for brevity's sake but are available upon request.

between stationarity at levels and at first difference indicate that the data-generating process undergoes variations over time. The properties of the time series are not constant throughout the entire analysis period, strongly suggesting the presence of structural breaks.

Table 4. Full sample period unit root tests: Quarterly and monthly observations

Panel A: Quarterly Observations

		KPSS				Breakpoint Modified ADF						
Sample	**Variable**	**I(0)**		**I(1)**		**I(0)**		**Time of Break**	**I(1)**		**Time of Break**	**Order of Integration**
2003Q01 2023Q01	MXN	0.1640	*	0.1314	***	-4.1486		2015Q2	-11.1521	***	2020Q1	I(1)
	XFDIGDP	0.1156	***	----		-6.2238	***	2013Q1	----		----	I(0)
	PBALGDP	0.3259		0.1715	***	-4.0547		2016Q1	-20.6435	***	2017Q1	I(1)
	REMGDP	0.1193	**	----		-6.1461	***	2012Q2	----		----	I(0)
	RIRD	0.2074	***	----		-5.0142	**	2008Q3	----		----	I(0)

Panel B: Monthly Observations

		KPSS				Breakpoint Modified ADF						
Sample	**Variable**	**I(0)**		**I(1)**		**I(0)**		**Time of Break**	**I(1)**		**Time of Break**	**Order of Integration**
2003M01 2023M03	MXN	0.2556		0.0959	***	-4.1240		2015M06	-17.9556	***	2020M03	I(1)
	XFDIGDP	0.1375	**	----		-6.0526	***	2012M11	----		----	I(0)
	PBALGDP	0.2550		0.1157	***	-4.8544		2008M11	-16.1490	***	2016M04	I(1)
	REMGDP	0.4530		0.1450	***	-4.3480		2012M05	-6.6090	***	2020M03	I(1)
	RIRD	0.2286	***	----		-4.6134	**	2021M04	----		----	I(0)

KPSS test H0: the series is stationary; Breakpoint Modified ADF test H0: the series has a unit root.
***, **, and * denote significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' own

7. ARDL Results

Table 5 registers the bounds test *t*-statistic as well as the results pertaining to the long-run relationship between the variables for the full sample period and the five subsamples. It also shows the error correction term (ECT_{t-1}) for each model. The full sample models corresponding to quarterly and monthly observations, as well as those related to the 2007-2010, 2015-2018, and 2019-2023 subperiods included structural break dummy variables with positive and statistically significant coefficients[8]. According to the results of the bounds test, the variables exhibited a stable equilibrium in their movements, except for the 2015-2018 subsample period, during which the null hypothesis of no-cointegrating relationship could not be rejected. Accordingly, the study applied equation (2) to account for lack of cointegration in that subperiod.

[8] In most cases, the constant term was also positive and statistically significant. The exception were the 2007-2010 and 2015-2018 subsamples.

Table 5. Bounds tests, long-run relationships, and error correction terms
Response Variable: MXNt

	Quarterly Data		**Monthly Data**											
	Full Sample (2003Q1 - 2023Q1)		**Full Sample (2003M01 - 2023M3)**		**Subsample 1 (2003M01 - 2006M12)**		**Subsample 2 (2007M01 - 2010M12)**		**Subsample 3 (2011M01 - 2014M12)**		**Subsample 4 (2015M01 - 2018M12)**		**Subsample 5 (2019M01 - 2023M03)**	
Bounds test (*t*-statistic)	5.7702	***	4.6217	**	7.3889	***	6.4051	***	5.1882	**	2.1767		7.6870	***
Long-run equation coefficients														
XFDIGDP	11.0957		13.4855	**	5.0859	***	2.4761		-0.3691		----		-58.1702	**
PBALGDP	-3.0719	**	-1.7815	***	-0.2337	***	0.5550		-0.3573		----		0.5939	
REMGDP	-4.2209		1.6176		2.0892	***	11.0383	***	7.6944	*	----		2.4579	
RIRD	-0.0306		-0.0517		-0.0943	***	0.1882	*	-0.7041	***	----		0.0339	
$BREAK_j$	4.7984	***	5.2031	***			3.6870	***	1.6707	**	----		1.7832	***
ECT_{t-1}	-0.1853	***	-0.0862	***	-0.7266	***	-0.5430	***	-0.4250	***	----		-0.5914	***

Source: Authors' own

The ECT_{t-1} coefficient across all the models is consistently negative and exhibits high significance. This suggests that the series are non-explosive (Jain & Ghosh, 2013) and provides a robustness check for the bounds test outcome of cointegration among the variables (Kremers, Ericsson, & Dolado, 1992). The coefficients of the error-correction term for both to the full-sample quarterly and monthly models suggest a slow speed of adjustment for the Mexican peso to U.S. dollar exchange rate in response to changes in the independent variables before reaching its equilibrium level. However, the ECT_{t-1} coefficients for the subsample models suggest that such adjustments occurred relatively quickly, taking approximately 1.4 to 1.7 months (equivalent to about 6 to 7 weeks) during the different subperiods.

The results exhibited in Table 5 also support the notion of changing significance of the input variables in the long-run. The outcomes for the full sample period shows mixed evidence regarding the statistical relevance of *XFDIGDP*. According to the quarterly data model, this variable coefficient was not significant, whereas in the monthly data specification, it showed significance at the 5% level. The coefficients of this regressor were also significant during the first and last subperiods, but interestingly, their signs are opposite. The sign was negative for all the statistically significant coefficients of *PBALGDP*. However, it seems that the significance of this regressor in the full sample period was mainly driven by the results observed in the 2003-2006 subsample.

Even though the long-run coefficients of *REMGDP* were not statistically significant in both full period analyses, they consistently showed positive and significant effects, at the 10% level or lower, throughout the subperiods from 2003 to 2014. These results also hold true for *RIRD*, where the coefficients were significant during the same subperiods, although with changing signs. This suggests a fluctuating impact of this variable on the Mexican peso to U.S. dollar exchange rate over that specific time range. In brief, the study found that the long-run relationship between *MXN* and *XFDIGDP*, as well as between *MXN* and *PBALGDP* was significant for the full sample period, and remained significant during the first and last subperiods. However, the long-term relationship between *MXN*,

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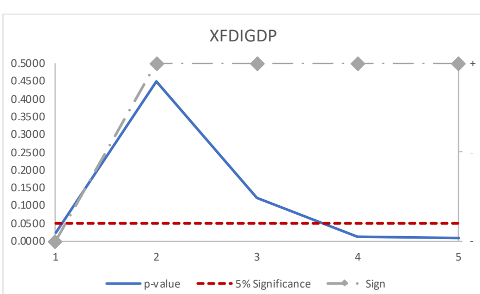
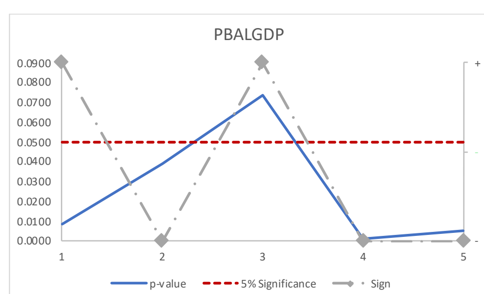
REMGDP, and *RIRD* was statistically relevant only during the first three subsamples. Therefore, these results stress the time-varying relationship of the independent variables and the Mexican peso to U.S. dollar exchange rate.

To evaluate the statistical relevance of the short-run coefficients of the ARDL models, the study assessed the significance of each independent variable by considering the lowest *p*-values among the contemporaneous or lagged coefficients and whether the sign of such coefficients was positive or negative[9]. Figure 2 illustrates these findings. The graphs present two vertical axis: the left-side axis are the *p*-values of the coefficients and the right-side axis denote whether the lowest *p*-value coefficients had a positive or negative sign. The horizontal dotted line without markers represents the 5% significance level. The solid line in the graphs corresponds to the *p*-value results of the short-run coefficients for each subsample. Finally, the dashed line with markers denotes whether the coefficient contributed to the depreciation of the MXN (i.e., a positive coefficient) or had an impact on the appreciation of the MXN (i.e., a negative coefficient) during the specific subsample under examination.

In the first subperiod, the changes in *XFDIGDP* had a negative impact on the current change in *MXN*, indicating a relationship with the appreciation of the Mexican currency, and this effect was statistically significant. However, in the last two subsamples, this effect became positive (related to a *MXN* depreciation) but still significant. Out of the four significant coefficients of *PBALGDP*, only one was positive, specifically during the first subsample. This indicates a consistent negative relationship between the Mexican government's balance and the peso exchange rate to the U.S. dollar. Throughout all the subperiods, the short-run coefficients for *REMGDP* were consistently significant and positive, except for the coefficient in the last subperiod, which had a negative sign. The findings for *RIRD* are similar to those of *REMGDP*, except that the lowest *p*-value coefficient was not significant in the 2015-2018 subperiod. However, the short-run coefficient with the lowest *p*-value was significant and positive during the subperiods from 2003 to 2014. In the last subperiod, 2019-2023, the coefficient remained statistically significant, but became negative. Remarkably, *XFDIGDP*'s short-run coefficients presented the opposite pattern of the coefficients of both *REMGDP* and *RIRD* throughout the subsamples. Moreover, in the short-term, *XFDIGDP* had a significant effect on the appreciation of *MXN* during the initial subperiod, but impacted on the depreciation of the Mexican currency during the last subperiod. However, the results evidence the reverse behavior for *REMGDP* and *RIRD*.





[9] The complete numerical results are available upon request.

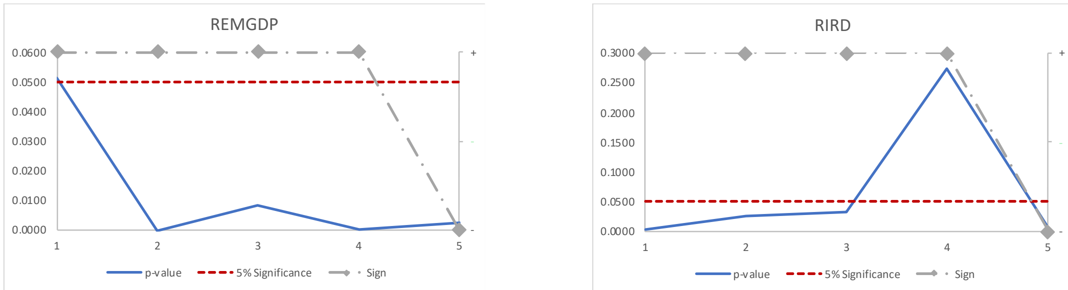


Figure 2. Graphical representation of the regressors' short-run coefficients
Source: Authors' own

8. Granger Non-Causality Findings

As described earlier, the study applied the Toda-Yamamoto procedure to test for Granger non-causality. Table 6 provides the results of the chi-square statistics from these tests for both quarterly and monthly observations in the full sample period and the five monthly subsamples. Throughout the entire period, the cumulative chi-squared statistic for the Granger-causal relationships between the independent variables (Y_i) and *MXN* is statistically significant. This implies that this group of regressors serves as a predictor of the Mexican peso's exchange rate to the U.S. dollar. This finding holds true in the first and the last two subsamples. *XFDIGDP*, *PBALGDP*, and *REMGDP* Granger-cause *MXN* in at least one subperiod. Surprisingly, though, the results of the test failed to reject the null hypothesis of no-causal relationship between *MXN* and *RIRD*, both for the complete sample and for any of the subperiods.

During the 2007-2010 subsample, *MXN* Granger-caused *XFDIGDP*, *PBALGDP*, and *REMGDP*, while a similar relationship was observed with the latter also during the 2011-2014 period. Additionally, the results show significant evidence of bidirectional causal relationship between *MXN* and *PBALGDP* throughout the full sample period as well as the 2015-2018 subperiod.

Table 6. Granger non-causality test results
From Y_i to MXN

Sample Period	XFDIGDP		PBALGDP		REMGDP		RIRD		All	
2003M01 - 2023M03	9.6579	**	8.3432	**	5.9105		3.5780		25.67197	**
2003M01 - 2006M12	35.3738	***	20.7478	***	12.0963	*	9.9207		81.76574	***
2007M01 - 2010M12	1.3934		3.3989		1.3060		2.0605		6.401252	
2011M01 - 2014M12	1.9872		0.3970		1.1507		0.7777		4.572001	
2015M01 - 2018M12	0.0887		7.1115	**	7.3086	**	3.8022		19.89024	***
2019M01 - 2023M03	28.4955	***	3.9956		5.0555		2.7402		49.60675	***

	From MXN to Y_i						
Sample Period	XFDIGDP		PBALGDP		REMGDP		RIRD
2003M01 - 2023M03	0.2939		26.1329	***	7.2700	*	1.6784
2003M01 - 2006M12	7.0041		11.9175	*	6.6599		4.2522
2007M01 - 2010M12	7.2972	**	11.2746	***	11.2643	***	1.8380
2011M01 - 2014M12	0.2465		2.0299		7.2795	**	0.2289
2015M01 - 2018M12	1.8080		18.3676	***	2.6456		0.3196
2019M01 - 2023M03	0.8007		8.2588	*	1.7801		6.6017

Source: Authors' own

9. Discussion and Conclusions

The analysis of the MXN/USD exchange rate is relevant for at least three reasons. Firstly, the undeniable importance of the U.S. currency in international trade and financial transactions worldwide. Over the past two decades, the U.S. dollar has been involved in approximately 88 percent of global foreign exchange transactions (Bertaut, von Beschwitz, & Curcuru, 2023). Secondly, a large bilateral trade between Mexico and the U.S. is evident, surpassing $263 billion from January to April 2023 alone. During this period, Mexico ascended as the leading trading partner of the U.S., displacing China from its previous position as the main trade partner. Finally, while several emerging economies' currencies have recently experienced a favorable cycle, the Mexican peso holds the added advantage of being the most liquid currency in Latin America (Barría, 2023) and ranks third most traded currency amongst those of emerging countries (Banco de México, 2022). So, this research aims to explore the long-run relationship and short-run dynamics over time between the Mexican peso to U.S. dollar exchange rate and the ratios of foreign direct investment expectations (as a proxy for nearshoring), the government's primary budget balance, and remittances to GDP, as well as the real interest rate differential between Mexico and the U.S.

The results of the unit root test for various subperiods provide evidence of regime changes in the variables, reflecting different economic events that fall outside the scope of this study. For example, during the 2007-2010 and 2015-2018 subperiods the Mexican peso to U.S. dollar exchange rate did not exhibit a trend and was stationary at levels. The opposite was true for the 2003-2006, 2011-2014, and 2019-2023 subperiods, although only in the latter the trend was negative, implying an appreciation of the currency in that subsample.

During the full sample period, and using monthly observations, the coefficient of the ratio of FDI expectations to GDP (*XFDIGDP*) was significant and positively related to the Mexican peso to U.S. dollar exchange rate (*MXN*) in the long-run. This pattern remains consistent in the initial subperiod, implying that overall, and particularly between 2003 and 2006, the weakening of the Mexican currency implied more foreign direct investment. These results align with the findings reported by Murshed & Rashid (2020) regarding FDI and currency depreciation, who attribute this relationship to FDI's focus on the tradable sector, leading to a lesser impact on non-tradable (domestic) prices. In contrast, throughout the 2019-2023 subsample, the situation is reversed, and the long-run coefficient of *XFDIGDP* implies a considerable and statistically significant appreciation of the *MXN*. Thus, the long-run ARDL results of the last subsample appear to reinforce the proposition concerning the anticipated significant shift in global trade and Mexico's valuable geographical advantage for nearshoring. Nevertheless, in view of the limited number of monthly observations in the subsample, prudent interpretation is warranted. The short-run coefficients in the last two subperiods imply that a positive change of *XFDIGDP* is related to a positive change (i.e., depreciation) of the Mexican currency to the U.S. dollar. These results tend to counter the nearshoring argument.

The research used the ratio of primary budget balance to GDP (*PBALGDP*) to represent the Mexican government's fiscal discipline, a variable deemed as a determinant of the exchange rate. Considering both quarterly and monthly results for the full period, fiscal discipline significantly contributed to the long-run appreciation of the MXN/USD exchange rate. This observation holds true for the initial subsample as well. However, the coefficients related to this variable were not significant in the remaining subsamples. Moreover, the results suggest that, in the short-run, *PBALGDP* contributed to the appreciation of the Mexican peso against the U.S. dollar in the 2007-2010 period, which generally coincides with the Global Financial Crisis, and from 2019 to 2023, which includes the COVID-19 pandemic episode. These results demonstrate robustness, as causality exists between *MXN* and *PBALGDP* throughout the full sample and several subperiods, with instances of two-way causality. Therefore, fiscal discipline proves to be a determinant of the Mexican peso to U.S. dollar exchange rate, exhibiting significance in both the long and short terms, and its relevance becomes more evident during crisis episodes.

The results within the ARDL framework imply that the long-run coefficient of the remittances to GDP ratio (*REMGDP*) was statistically significant only during the 2003-2006 subperiod, contributing to the depreciation of the Mexican peso relative to the U.S. dollar. This variable also played a significant role in the short-run depreciation of the Mexican currency, except during the 2019-2023 subperiod, when it contributed to the peso's appreciation. These findings indicate that, overall, the depreciation of the Mexican currency's exchange rate is related to a rise in remittances, as suggested by Rahman, Foshee, & Mustafa (2013) for the Mexican peso to U.S. dollar relationship, despite differing from the conclusions reached by Akçay (2023). Remarkably, the ARDL coefficients indicate that remittances may have had a significant impact on the short-term appreciation of the peso between 2019 and 2023. However, this relationship does not hold for the long-run in that specific subperiod and, primarily, the full sample. Arguably, this can be attributed to a large remittances flow stemming from the advantages that immigrants obtained from the economic stimulus package introduced by the U.S. government in 2020 in response to the COVID-19 pandemic[10]. Additionally, the study identifies Granger-causality running from *REMGDP* to *MXN*, and vice versa, in different subsamples. This finding also coincides with the outcomes documented by Rahman et al. (2013).

While in the ARDL framework the long-run coefficients of the real interest rate differential between Mexico and the U.S. (*RIRD*) were significant, indicating an appreciation of the *MXN* during the 2003-2006 and 2011-2014 subperiods, the long-run coefficient of *RIRD* was not significant for the full sample. These results agree with the findings reported by Capasso et al. (2019) who conclude that, in the long-run, the interest rate differential does not exert a statistically significant impact on the exchange rate. However, the short-term coefficients for this variable were significant and

[10] The Coronavirus Aid, Relief, and Economic Security Act (CARES) consisted in $2.2 trillion economic stimulus and included direct payments, unemployment benefits, small business assistance, and other forms of economic aid.

negative for all subperiods, except the second to last. The findings also imply that, at least in the short-term, *RIRD* appears to harm Mexico's global competitiveness by contributing to the appreciation of the peso against the U.S. dollar, particularly during the 2019-2023 subperiod. In this subperiod, the mean of the interest rate differential in real terms was 4.09%, while the overall mean for the entire period was 2.75%, which likely encouraged investors to pursue carry trade strategies that impacted on the peso's appreciation.

In short, the findings suggest that the ratios of foreign direct investment expectations to GDP and the government's primary budget balance to GDP have a significant influence on the exchange rate throughout the entire period under examination. However, it is important to note that the significance of these variables, as well as all the considered determinants, varies over time. Specifically, foreign direct investment expectations and remittances, respectively, seem to have the most persistent long- and short-term effects, as defined by the ARDL model, on the exchange rate across time. Moreover, the results suggest that the ratios of foreign direct investment expectations and the government's primary budget balance to GDP Granger-caused the Mexican peso to U.S. dollar exchange rate in the full sample period and several subperiods, while the ratio of remittances to GDP Granger-caused the exchange rate between the Mexican and U.S. currencies in the 2015-2018 subperiod.

From January, 2003 to March, 2023 the Mexican peso experienced an average annual depreciation of 3.2% against the U.S. dollar. However, a notable shift occurred between March, 2020 and March, 2023, during which the Mexican currency appreciated by approximately 9.3% per year to the U.S. dollar. This noteworthy shift in trend has drawn the attention of economic observers and foreign exchange market analysts who have put forward several explanations to understand this change.

Arguably against the general public's common view, an appreciation of a country's currency relative to those of other nations may prove damaging. On the other hand, a depreciation of a country's currency stimulates exports and discourages imports, leading to a reduction in current-account deficits and bolstering the global competitiveness of the country, particularly in tradable sectors. Cost-driven FDI is crucial in Mexico and other emerging countries (Hayakawa & Tanaka, 2011). This form of FDI primarily relies on the input resources of the host country for production, subsequently exporting to a third country or selling products back to the foreign companies' home country. The depreciation of the host country's currency will reduce the production costs for FDI firms, thus generating an export advantage and promoting foreign investment.

Preserving exchange rate stability is an essential goal for policymakers and economic authorities, particularly in emerging economies with highly traded currencies such as Mexico. Therefore, it is essential to examine and understand the factors that influence exchange rates and the causal connections among them. The findings of this research underline the importance of fiscal discipline in maintaining the stability of the Mexican peso to U.S. dollar exchange rate. Furthermore, the results indicate that recent real interest rate differentials have contributed to the Mexican peso's appreciation. Consequently, policymakers should carefully manage such differentials, as they can negatively impact the Mexico's competitiveness in international trade and its attractiveness as the destination of foreign direct investment, particularly in light of the prevailing nearshoring trend.

The study opens up several avenues for further research. Specifically, there is a need to investigate the role of fiscal discipline in determining the Mexican peso to U.S. dollar exchange rate during both crisis episodes and non-crisis periods. Additionally, more research is required to gain a comprehensive understanding of remittances' impact on the Mexican currency exchange rate and other economic indicators, especially from the year 2020 onwards. These gaps represent important areas for future investigations to enhance our knowledge in the field.

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