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Determinants of the remittances sent to Mexico 1980-2022: was there a structural change?

Determinantes de las remesas enviadas a México 1980-2022: ¿Hubo un cambio estructural?

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Abstract

Objective: We identify a new long-term relationship between remittances, Mexico's GDP, the United States Industrial Production Index, and the real exchange rate.
Methodology: For a quarterly sample from 1980 to 2022, we identified a structural break on the 3rd quarter of 2002. We divided the initial sample into two subsamples in order to estimate the corresponding cointegration vectors.
Results: The cointegration vector for the second subsample has two important changes as compared to that of the first subsample.
Limitations and implications: It is implied that remittances can actually generate a stabilizing effect on the foreign exchange market.
Originality and value: i) the sign of the estimated coefficient of the real exchange rate changes from negative to positive, ii) a time trend must be incorporated in the cointegration space.
Conclusions: We identify a long-term relationship among remittances and the variables that determine them after the structural break.
Keywords: Remittances, real exchange rate, cointegration, structural change, Gregory-Hansen test.
JEL Classification: F24, F41, C32.

Resumen

Objetivo: Identificar una nueva relación de largo plazo entre las remesas, el PIB de México, el Índice de Producción Industrial de Estados Unidos y el tipo de cambio real.
Metodología: Para una muestra trimestral de 1980 a 2022, identificamos un cambio estructural en el 3er trimestre de 2002. Dividimos la muestra inicial en dos submuestras para estimar los respectivos vectores de cointegración.
Resultados: El vector de cointegración para la segunda submuestra tiene dos cambios importantes respecto al correspondiente a la primera submuestra.
Limitaciones e implicaciones: Implica que las remesas pueden generar eventualmente un efecto estabilizador en el mercado cambiario.
Originalidad y valor: i) el signo del coeficiente estimado del tipo de cambio real cambia de negativo a positivo, ii) se debe incorporar una tendencia determinística en el espacio de cointegración.
Conclusiones: Identificamos una relación de largo plazo entre las remesas y las variables que las determinan después del cambio estructural.
Palabras clave: Remesas, tipo de cambio real, cointegración, cambio estructural, prueba Gregory-Hansen.
Clasificación JEL: F24, F41, C32.

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Introduction

Remittances received in Mexico have become the most important source of foreign currency since 2018 (see **Figure 1**). However, as remittances increase, the discussion about whether their measurement is the most accurate also increases. The discussion was started when its definition was changed in October 2002.

The current balance of payments includes the concept of unilateral transfers that are what an economy contributes to another without receiving anything in return. These transfers include family remittances, e.g., those that a resident abroad sends to a resident in Mexico. Up to the year 1988 the definition of remittance included only post and telegraph orders. From 1989 onwards, remittances also included money orders and checks that were paid by banks and offices of currency exchange. Since 1993, this definition also considered remittances in cash, in kind, and bank drafts (see Pérez-Akaki and Álvarez-Colín (2007)). However, Banco de México adopted a new definition, which was published in the Diario Oficial de la Federación on the October 29th of 2002:

> "Remittance: Singular or plural, the amount in national or foreign currency from abroad, transferred through companies, originated by a person called sender to be delivered in national territory to another person called beneficiary. In the terminology of the Balance of Payments, this is identified as a family remittance."

The Inter-American Development Bank defines remittances in the following way: "…it is a financial flow that they (migrants) send to their families in their countries of origin" (see Pérez-Akaki and Álvarez-Colín (2007: 228)). On the other hand, the International Monetary Fund (IMF) provides two definitions: "…remittances from workers such as current transfers from resident foreigners who have stayed in that place for at least one year", and "…the funds sent by non-resident immigrants who have been in the country for less than a year, regardless of their legal and immigration status; such funds are calculated as the workers' or employees´ compensation that form the income that non-residents have received from residents" (see Bravo-Benitez (2011)). After comparing the four definitions, we can say the one used by Banco de México is the least accurate. First, it restricts remittances to international personal flows that use a formal financial intermediary; second, it ignores the length of migrants´ stay and third, it also ignores if they are workers or not. From the last quarter of 2002 onwards, the flows of money identified as remittances recorded an extraordinary growth and they were sent mainly as electronic transfers. For 2021, the electronic transfers represented 99.0% of remittances, while remittances in cash and in kind represented only 0.6%, and money orders represented only 0.4%[1].

Pérez-Akaki and Álvarez-Colín (2007) list and discuss 5 inconsistencies between remittances data recorded by Banco de México and other sources of information. In this section we address what we consider the three most controversial topics pointed out by these authors and we incorporate other two topics. The first one is the spectacular growth of remittances after the last change in the definition. These authors emphasize that "… up to 2001, remittances had an average monthly growth of 4.13 million dollars. Since January 2001, remittances showed an average monthly growth of 7.26 million dollars, significantly higher than that in the previous term. This behavior was maintained until October 2002, when the average monthly growth rate increased to 24.49 million dollars". This remittances behavior was not fully explained by the macroeconomic variables that determine them (see discussion below).

[1] Banco de México (2022).

The second inconsistency is that the increase in remittances does not match the data revealed by the ENIGH - Encuesta Nacional de Ingresos y Gastos de los Hogares[2] (Household Income-Expenditure Survey) carried on every two years from 1994 to 2004 and in 2005 by INEGI - Instituto Nacional de Estadística y Geografía (ENIGH and INEGI by their acronyms in Spanish, respectively). Although the figures reported by Banco de México increased rapidly from 2002 onwards, the proportion of households that received remittances and the average amount received by each family remained relatively stable. The estimation for a specific year of total remittances based on the ENIGH does not match the estimation provided by Banco de México.

The third inconsistency refers to the lack of impact of the increase in remittances in the economy of the states where migrants send the money. The authors highlight the relative importance of remittances as compared with Foreign Direct Investment (FDI), social-oriented expenditure and investment in social-oriented construction using information at state level. For example, in 2004 remittances were 500% higher than FDI in states as Zacatecas, Michoacán, Durango and Guanajuato; while in 2003 remittances were again 500% higher than the social oriented construction in Colima, Guanajuato, Guerrero, Jalisco, Michoacán, Nayarit, San Luis Potosí, Sinaloa, Tabasco and Zacatecas, and their impact on the state economy was not perceived, despite the significant amount of money that remittances represented in those years.

Furthermore, Pérez-Akaki and Álvarez-Colín (2007) quote Zárate (2004), who used social accounting matrices and information for 1989, and estimated that 4,431 US dollars were required to create a job. According to this, remittances received in 2004 should have created 440,000 jobs. However, only 260,000 new jobs were registered at the Instituto Mexicano del Seguro Social, and Mexican GDP grew a little more than 4% in that year. According to Pérez-Akaki and Álvarez-Colín (2007), the definition of remittances used by Banco de México is the reason why there is no consistency in the estimates of remittances at the national level, recent migration data and ENIGH results.

Although migration increased in the 1990s, it began to gradually decrease during the first fifteen years of this century. This is why migration itself cannot explain either the accelerated growth of remittances, at least with the available data.

A more recent inconsistency could have emerged during the Covid-19 pandemic registered in 2020. Cuecuecha-Mendoza and Cruz-Vázquez (2022) point out that:

> "With the arrival of the Covid-19 pandemic, a collapse in remittances from Mexicans was predicted due to the suspension of economic activities in the United States and its impact on unemployment and income of Americans. However, reality was different, since remittances significantly increased during 2020, because Mexicans not only managed to keep their jobs, but also increased the amount of money they sent to their families".

Furthermore, Pérez-Akaki and Álvarez-Colín (2007) point out:" Before 2001, estimates of remittances to Mexico based on the US balance of payments showed a level higher than that reported by the Banco de México. After that year this behavior was reversed, and the difference has been growing with time".

Águila et al. (2012b) point out that:

> "Some (authors) attribute at least part of the difference to the fact that survey data are collected during the periods of the year when remittance flows are smaller, while others argue that official

[2] A nationally representative household survey based on a stratified random sample and conducted by INEGI.

> figures overestimate remittance flows because they do not correspond to remittances only and include other sources of transfers, perhaps even illegal activities, such as money laundering".

On the other hand, different authors discuss sources of the underestimation of remittances: Carriles et al. (1991), Águila et al. (2012b), and Muñoz-Jumilla (2004).

We can illustrate the growing importance on a macroeconomic level of remittances sent to Mexico. The dynamics of remittances was only affected by the 2009 Great Recession. From the third quarter of 2013 and to the date of elaboration of this paper, remittances have registered only positive annual growth rates. Remittances rose from 698.7 million of dollars (MOD) in 1980 to 51,569.8 MOD, in 2021, which represents an average annual growth rate of 11.1%.

To make a comparison among the main sources of foreign currency, we must consider balances instead of only exports. On one hand, Mexico exports crude oil, but on the other hand, it imports gasoline, and when the price of crude oil rises, the price of petrochemicals also increases, the latter offsetting the positive effect of the former. In many cases, manufacturing exports require imported intermediate goods, so importing becomes a step prior to exporting. These are examples of why balances, not just exports, should be accounted for. **Figure 1** shows how the balance of remittances have overcome other traditionally important sources of foreign exchange since 2018: FDI and the oil balances.

Figure 1 clearly shows how the increase in remittances has become a fundamental variable in a macroeconomic level. There are studies that analyze the possibility that remittances could cause a distortion called the "Dutch disease", as will be discussed in the next section. However, as described above, the expected positive effect of remittances has not been clearly perceived in a similar proportion in a microeconomic level. For this reason, it is important to analyze from a statistical perspective whether the change in definition caused a structural change in the remittances time series and, even more importantly, if it caused a change in the cointegration vector between remittances and their explanatory macroeconomic variables.

The hypothesis of the present investigation is that the cointegration vector among remittances and their determinants has changed after a structural break, generated by the modification of the definition of remittances. To prove this hypothesis, first we use a quarterly sample from 1980 to 2022 to perform the Gregory-Hansen (1996) test to find out if there is a trend level shift and/or a regime shift.

The rest of the paper is organized as follows: in the next section we present a focused survey, emphasizing estimations made for Mexico and previous studies that detected structural changes in remittances. Afterwards, we describe the data for the whole sample from the 1st quarter of 1980 to the 1st quarter of 2022, we report the results of the Gregory-Hansen tests and the breakpoint unit root tests for each variable, and we split the initial sample into two subsamples to carry out the unit root tests. Subsequently, we estimate the cointegration vectors for each of the two subsamples, following the Johansen (1991) procedure[3]. For the second subsample, which starts on the date of the structural break and ends in the 1st quarter of 2022, we also estimate the error correction model, we perform both the coefficients significance and the weak exogeneity tests. In the following section, we discuss possible economic implications of our findings and finally we present some concluding remarks.

A survey on remittances based on the Mexican case

The aim of this section is to present a basic background and a review of the literature on remit-

[3] See also Johansen (1995).

tances as related to this research in order to explain its findings. A comprehensive review of the theoretical and empirical literature on remittances and all the economic, social, and demographic variables on which they impact is beyond the scope of this paper. However, we provide references of surveys and papers that study remittances and their relationship with macro- and microeconomic variables.

Factors that determine the migratory flows and how remittances are spent in Mexico

Because the number of Mexicans who migrate and work in the United States comprises one of the main explanatory factors for remittances, we begin this subsection by describing recent estimates of migration flows. Águila et al. (2012a) determined three major causes of migratory flows:

a) Significant job availability in the United States and wage differentials between these countries.
b) Poor performance of the Mexican economy.
c) Networks include family members and friends who already live in the United States.

There has been migration from Mexico to the US for more than a century, and there have been several experiences within this span. Pérez-Akaki and Álvarez-Colín (2007) point out some of them: i) migration of Mexicans that arose from the construction of the railway system in the southern United States in the late 19th century; ii) emigration caused by the Mexican Revolution; iii) deportation of Mexicans from the United States due to the Great Depression during the decade of the 1930s generated flows in the opposite direction, and iv) the Brasero program during World War II attracted a significant number of Mexican workers to the most important metropolitan centers of the neighbor country. More recently, unemployment provoked by the cumulative lag in job creation, which in turn stimulates migration from Mexico to the USA. Cárdenas (1996) points out that:

> "… while the Mexican economy needed to create 100,000 jobs in 1950 to maintain the same level of unemployment in the country, in 1970 -20 years later- that amount practically doubled to reach above 200,000 jobs. But in the following two decades the explosion occurred. For the mid-1990s the Mexican economy needed to create above one million new jobs every year to employ young people entering the labor force".

Far from meeting this need in terms of job creation, the Mexican economy registered a Gross Domestic Product (GDP) contraction of 6.3% in 1995 because of the financial and banking crises detonated by the abandonment of the currency band in December 1994. The currency depreciation fueled inflation that reached 52% in 1995. Inflation remained in a two-digit figure until 2000, when it decreased to 9%. The increase in the consumer price national index in the period 1995-1999 reduced the real wage. Thus, unemployment and low real wages stimulated migration.

After the 1994-1995 economic crisis, two factors identified by Águila et al. (2012a) stimulate migration because they became more important: poor performance of the Mexican economy and an increase in the wage differential. Gaspar-Olvera (2018) and Passel et al. (2012) estimate the number of migrants from Mexico to the United States since 1991 to 2014 in the first case, and to 2010 in the second one. According to these sources of information, the number of migrants had been growing since the beginning of the 1990s, but after the 1994-1995 economic crisis, the estimated number increased rapidly until it reached a maximum in year 2000. From that year onwards, the number of migrants tends to decrease.

The United States registered two economic recessions in the first decade of the twenty first century. The first one in 2001 (the "dot com" economic crisis) and the second one in 2009 (the subprime mortgage crisis). These crises encouraged the United States government to enforce immigration policy, so it was more difficult for migrants to cross the border and stay in that country. For this reason, migration cannot explain the remittances dynamics after 2001.

It is relevant to identify how Mexican families spend the remittances received. One of the main sources of information is the "Poll for migration on the northern border of Mexico" (EMIF by its acronym in Spanish) carried out by El Colegio de la Frontera for Mexican migrants entering the country by land. For the period 2016-2019 the available statistical information is comparable[4]. However, as migrants can choose up to two answers for the same question, the original data do not sum 100%. For this reason, we work with standardized data, so that the percentages sum 100%. We must emphasize that the percentages are obtained from the number of answers in each possible topic, and they do not reflect the amount of dollars sent to Mexico for each concept. The corresponding percentage that represents the number of answers in favor of "Food and clothing" is the most important and it has been stable (around 47%). The percentages that represent the answers in favor of "Health care" and "Education" has decreased around two points between those years: from 26.8 to 24.3%, and from 7.7 to 5.8%, respectively. In addition, the number of answers in favor of "Buy, construction and improvement of housing" has increased its relative weight between 2016 (6.5%) and 2019 (14.3%). The concept "Pay debts" has decreased its percentage from 9.3% in 2016 to 3.5% in 2019.

On the other hand, Airola (2007) carried out a cross-section analysis using data from the ENIGH for 2000. Using weighted least squares, the author estimates a model of the share of spending that goes to the consumption of a specific kind of good based on the number of people in the household within defined age, gender categories, education, and marital status of the head of household, urban or rural, and of a dummy variable to represent whether the household receives remittances. Airola (2007) finds that households that received remittances spend bigger shares of their income in durable goods, healthcare, and housing and spend a lower share of their budget on food, in comparison to those households that do not receive remittances. This shows how households spend the remittances they receive.

A focalized survey

Why migrants send remittances?

Elbadawi and Rocha (1992) have classified the empirical studies on the determinants of remittances in two groups. The first one is called the Endogenous Migration perspective, which considers the sending of remittances as an endogenous variable in the migration decision process, in which altruism plays a fundamental role in explaining remittances. Within this first group, there are models in which the migrant maximizes an intertemporal utility function to determine an optimal consumption-savings trajectory. Usually, the family´s utility level is an argument of the migrant's utility function. In this context, migrants care about the consumer basket of goods and services of their families. If the level of economic activity decreases and negatively impacts the family income in the country of origin, then the migrant will tend to compensate for by sending more remittances. This explains why remittances are negatively related to the GDP or other income variables in the country of origin. On the other hand, when there is a real depreciation in the domestic currency, migrants might send less foreign currency to afford the same consumer basket. This is a possible justification

[4] The information for the 2020 is not comparable because of Covid-19.

of why remittances can be negatively related to the real exchange rate (see Castillo (2001)). The last two cases can be interpreted as a risk sharing arrangement that compensates the lack of insurance markets in developing countries (see Cuecuecha-Mendoza and Cruz-Vázquez (2022)).

The second group of empirical studies is called the portfolio investment approach and considers remittances only as a transfer of savings from the host country to the country of origin. Under this approach, migrants seek to maximize their utility by determining their consumption and the allocation of savings among assets in both countries. In this case, the optimization exercise does not consider the conditions of the migrants' families at all. Under this approach, remittances are strongly influenced by the interest rates differential and the real exchange rate. Regarding the first variable, if the interest rate in the country of origin increases with respect to that prevailing in the receiving country, then remittances will also increase, and vice versa. Regarding the second variable, if the real exchange rate depreciates, then the purchasing power of foreign currency will increase. For his reason, migrants can send more remittances to increase the purchase of assets in Mexico or reduce the debts they contracted to reach the host country. This is a possible justification of why remittances can be positively related to the real exchange rate (see the estimation for the second subsample of the present study). An example is provided by López, Molina and Bussolo (2007): migrants send remittances to build a house in their respective places of origin to inhabit it in their retirement and when there is a domestic currency real depreciation, migrants could send more foreign currency to accelerate investment and take advantage of the real depreciation of the domestic currency. Notice that the endogenous migration and portfolio investment approaches provide two alternative explanations for the relation between remittances and the real exchange rate.

Papers that study how macroeconomic variables determine remittances

There are two approaches to study remittances at the macroeconomic level. The first one is the identification of the macroeconomic variables that determine remittances, and the second approach refers to the impact that remittances have on macroeconomic variables. For the group of studies that focus on the determinants of remittances, Elbadawi and De Resende-Rocha (1992) suggest that:

> "...empirical models for the determination of remittances should include the number of migrants, the level of income in the host country, an approximate variable for the duration of the stay, inflation in the sending country, exchange rate premium in parallel markets (or the interest rate differential between the host and origin countries), as well as indicators of incentive schemes designed to attract remittances".

Several studies have been based on the recommendations of Elbadawi and de Resende-Rocha (1992). The Vargas-Silva and Huang theoretical model (2006) determines a positive and a negative relation between remittances and the income variables for the foreign and the domestic countries, respectively. The importance of this theoretical model is to establish that remittances will increase if macroeconomic conditions in the host country improve and if conditions in the country of origin worsen. For the first case, the income variable of the host country is expected to have a positive influence on remittances, while for the second one the income variable of the country of origin is expected to have a negative impact on remittances. The production variable or wage income can be used to represent the macroeconomic conditions in host and origin countries.

Castillo (2001) estimates a cointegration vector for the period between the 1st quarter of

1980 and the 3rd quarter of 2000; he defines remittances as the variable of interest as a function of Mexico's GDP, United States GDP, and the real exchange rate. The author finds a positive elasticity of remittances with respect to United States GDP (2.7%) and negative elasticities with respect to Mexico's GDP (-0.96%) and the real exchange rate (-0.20%). One explanation for the negative elasticity of remittances with respect to Mexico's GDP is that families residing in Mexico must compensate for the decrease in their domestic income with an increase in the income they receive via remittances.

Islas-Camargo and Moreno-Santoyo (2011) estimate three different cointegration vectors between the 1st quarter of 1980 and the 4th quarter of 2008; they include proxy income variables for Mexico and the US, as well as the number of migrants and the differential of interest rates. In the first model, the authors use Mexico and United States GDPs as proxy income variables for those countries, the real exchange rate as a proxy for socioeconomic stability, and the number of migrants. In the second model, the authors add the interest rate differential to the variables of the first one. The third model substitutes the GDP of Mexico and of United States for the prevailing wages in each country as proxy income variables, maintaining the rest of the variables of model 1. In relation to the GDP of the United States, the authors detect a relationship positive: low economic activity in the host country reduce remittances. However, the authors find opposite signs of the relationship between remittances and Mexico's GDP in models 1 and 2, so they point out that the sign of the estimated coefficients for Mexico's GDP is not robust. Regarding the real exchange rate, the authors point out: "The real exchange rate is negatively and significantly related to remittances in all the estimated models" (Islas-Camargo and Moreno-Santoyo (2011)).

Vargas-Silva and Huang (2006) use a time series for Mexico only, and on the other hand, they construct a panel data for 5 countries: Mexico, Brazil, Colombia, the Dominican Republic, and El Salvador. The authors point out that there is no evidence that Mexican variables cause -in Granger's sense- remittances. The authors conclude that remittances respond to a greater extent to changes in the macroeconomic variables of the host country than of the country of origin, which was clearer in the case of Mexico.

Salas-Alfaro and Pérez-Morales (2006) also study which macroeconomic variables influence remittances sent from the United States to Mexico. These authors estimate an econometric model where they find that remittances depend positively on United States GDP and negatively on Mexico's GDP, with estimated coefficients of 2.069 and -0.002, respectively.

There are two papers that estimate a structural change in the equation that determines remittances. Pérez-Akaki and Álvarez-Colín (2007) re-estimate the Castillo (2001) model expanding the sample until 2006. Using the Chow test, these authors identify a structural break for 2001, a year before when the remittances definition was changed. Cuecuecha-Mendoza and Cruz-Vázquez (2022) study the impact of covid-19 on remittances sent to Mexico from the US testing a structural break in the long- and short-run equations that explain them, using monthly data from January 2014 to May 2021. The variables they use are remittances, Economic Activity General Index (IGAE, for its acronym in Spanish), a production index provided by the Federal Reserve Economic Data, the monthly index for real minimum wages from Banco de México, the average hourly wage earnings provided by the Bureau of Labor Statistics, the nominal exchange rate and interest rates differential. Authors report that the Johansen cointegration test confirms two cointegration equations. When the authors perform the Wagner-Wied test, they identify that a structural change took place in 2020m4 because of the Covid-19 pandemic.

Impact of remittances on some macroeconomic variables

Let's focus on the Dutch disease. Rabbi et al. (2013) point out that: "The term 'Dutch Disease' was first used in the 26 November 1977 issue of The Economist to refer to unfavourable effects on the manufacturing sector of the Netherlands following the discovery of natural gas during the 1960s". The growing availability of foreign currency made the Dutch guilder stronger, which reduced the competitiveness of the traditional exporting sector.

Although the symptoms of the Dutch disease were associated with the discovery of natural resources, any significant increase in the availability of foreign exchange can cause the same results, as an increase in the price of commodities, in FDI and in remittances, for example. The World Bank (2006) and the International Monetary Fund (2005) have accepted that remittances have the potential to create a Dutch-Disease-type of phenomenon. Ratha (2013) studies the possibility of remittances appreciating the real effective exchange rate in some countries. The author works with a panel data for China, India, Mexico, the Philippines, and Lesotho. This author finds evidence of the effects of "Dutch disease" for the Philippines in the short term, and for China and Lesotho in the long term. However, the author concludes that there is no evidence that this effect is present for Mexico at the time of the study, neither in the short- nor in the long-run.

Lartey, Mandelman and Acosta (2012) work with disaggregated sectorial data for developing and transition countries, and they show that rising levels of remittances have spending effects that can lead to an appreciation of the real exchange rate and a reallocation of resources from the trade to the non-trade sector. On the other hand, Rabbi et al. (2013) find that remittances appreciate the real exchange rate (RER), and this undermines the competitiveness of the export sector of Bangladesh. These authors use the Johansen cointegration and they find that the estimated coefficient of remittances as a determinant of the RER is 0.70, Rabbi et al. (2013). Acosta et al. (2009) estimate a two-sector dynamic stochastic general equilibrium model to analyze the effects of remittances for El Salvador, using Bayesian techniques. The authors find that an increase in remittances flow leads to a decline in labor supply and an increase in consumption demand that is biased toward non-tradable goods. López, Molina and Bussolo (2007) find that remittances appear to lead to a significant real exchange rate appreciation in some Central America and the Caribbean countries, when flows are too large relative to the size of the recipient economies. Amuedo-Dorantes, et al. (2010) find that remittances appreciate the real exchange rate for a broader sample of economies and depreciate it for small-island developing economies.

There are other variables that can be influenced by remittances. For example, remittances can possibly impact on economic growth. Ramírez and Sharma (2008) build a panel data for 23 Latin American and Caribbean countries, which they classify into two groups: high and low income. Then, they carry out a cointegration analysis for the 1990-2005 period. Their results suggest that remittances have a positive and significant impact on GDP per capita growth for both groups. In contrast, Barajas et al. (2009) use a cross-section model to estimate the impact of remittances on economic growth too. These authors emphasize the problem of endogeneity between remittances and growth, so they use instrumental variables in their econometric analysis. The authors note that remittances have a statistically significant impact in less than half of the estimates, and when they do, it is generally negative. They conclude that, in the best scenario, remittances do not have a positive impact on economic growth.

Remittances and microeconomic variables

Ruiz and Vargas-Silva (2009) refer to microeconomic contributions pointing out that: "this kind of studies are usually interested in the relationship between remittances and specific individual factors such as income (both of the household and of the migrant), gender, age, time in the foreign country, marital status, family composition, among others". For example, Salas-Alfaro and Pérez-Morales (2006) analyze the effect that remittances have on income distribution in Mexico. For this purpose, these authors use information from the ENIGH for the years 1994, 1996, 1998, 2000 and 2002, and their analysis focuses on the distribution of total current income by household deciles and the current income without remittances. Based on the Gini coefficients calculated for each of these 5 years, the authors conclude that "…remittances contribute to improve the income distribution among household deciles, but in some cases, they reduce inequality in income distribution within deciles" (Salas-Alfaro and Pérez-Morales, 2006).

Hassan et al. (2017) survey includes Mexico, Guatemala, El Salvador and Philippines, where the authors confirm that remittances reduce poverty at the household level and improves educational and health outcomes for the family with one migrant member. For their own study, Hassan et al. (2017) emphasize that remittances and poverty are endogenous and are jointly determined in a system. Therefore, they estimate the effect of remittances on poverty using a system of simultaneous equations with panel data from 37 economies. Their results show that remittances significantly reduce poverty in the sample of remittance-dependent countries.

Migration and remittances are also influenced by climate change. Guatemala, Honduras y El Salvador integrate the Northern Triangle of Central America, where rural residents are vulnerable to environmental change. Sigelmann (2019) points out:

> "Guatemala and El Salvador are among the top 15 countries world-wide that are most exposed to natural disasters, especially earthquakes and droughts. Agriculture is the main source of economic activity for approximately one third of all Northern Triangle residents, most of whom grow maize, beans, rice, and coffee. Repeated or sudden drought, particularly in the dry corridor, has led to chronic malnutrition in children under 5".

For this reason, after a drought, some family members are forced to try to migrate to the United States, because if they succeed, they will be able to send remittances. That all family members stay in their hometowns is not really an option due to food insecurity, which is likely to worsen in the face of climate change.

We are interested in estimating a cointegration vector for remittances, proxy income variables for Mexico and the United States as theoretically justified by Vargas-Silva and Huang (2006) and the real exchange rate, given that Castillo (2001) and Islas-Camargo and Moreno-Santoyo (2011) showed its importance explaining the former variable.

Data and Preliminary Analysis

The whole data sample

We consider four not seasonally-adjusted variables expressed in natural logarithms: i) Remittances sent to Mexico (R) expressed in constant dollars (we divide remittances in U. S. dollars by the U. S. consumer price index); ii) Mexico´s GDP in millions of chained 2013 pesos (YMX); United States Industrial Production Index (IPI) 2017=100, and the bilateral Real Exchange Rate (RER)[5]. To construct the latter variable, we multiply the nominal exchange rate peso-dollar by the United States consumer price index, and we divide the product by the Mexican consumer

[5] The graph for RER is **Figure 4**.

price national index. We consider only the United States consumer price index because around 95% of remittances were sent from the US in 2020 (see Nuñez and Osorio-Caballero (2021)).

Initially, we use a sample from the first quarter of 1980 to the first quarter of 2022. Its size is determined by the availability of quarterly information, and it encompasses the samples of Castillo (2001); and Islas-Camargo and Moreno-Santoyo (2011). The statistical information was obtained from the INEGI, Banco de México and the Federal Reserve Bank of Saint Louis. Their respective official websites are: www.inegi.org.mx, www.banxico.org.mx and www.stlouisfed.org. We use E-views 12 as statistical software.

The Gregory-Hansen and the breakpoint unit root tests

In an early stage of this research, we attempt to estimate a cointegration vector using the sample from the 1st quarter of 1980 to the 1st quarter of 2022. However, no cointegration vector was not found, and for this reason we decide to perform the Gregory-Hansen (1996) test to identify a possible structural break. This test considers a null hypothesis of no cointegration which is evaluated against the alternative hypothesis of cointegration in the presence of shifts.

Using this test, we can identify if there is either a change in the intercept, a change in the intercept and the trend coefficient or a change in the intercept and the slope coefficients. One of the main advantages of the Gregory-Hansen test is that it provides the date of the regime shift, which is determined endogenously. The results of this test are reported in **Table 1.**

Table 1 shows that, in absolute values, the ADF statistic is lower than its critical value, which implies that the null hypothesis is not rejected in the three considered cases. However, both $Z\alpha$ and Zt statistics are higher than their corresponding critical values for three models. According to these statistics, the null hypothesis of no cointegration is rejected in favor of cointegration for all the cases considered by the Gregory-Hansen (1996) test. The 3rd quarter of 2002 appears as possible brake date determined by the last two test statistics. For this reason, we consider the 3rd quarter of 2002 as the break date.

In addition, we perform breakpoint unit root tests for each time series for the whole sample to find out if at least one time series has a breakpoint on or if it is close to the brake date identified by the Gregory-Hansen test. The results of such tests are reported in **Table 2**. We considered the innovational outlier model, which assumes that the break occurs gradually[6]. We considered 4 different models: numbered from 0 to 3. In model 0, we test the null hypothesis of a random walk against the alternative of a stationary model with an intercept break. In model 1, we test the null hypothesis of a random walk with drift against the alternative of a trend stationary model with intercept break. In model 2, we test the null hypothesis of a random walk with drift against the alternative of a trend stationary model with intercept and trend breaks. In model 3, we test the null hypothesis of a random walk with drift against the alternative of a trend stationary model with trend break. The breakpoint unit root tests reveal that remittances experienced an intercept and trend breaks, based on the results for model 2. The break date is the 4th quarter of 2002, just on the quarter the remittances definition changed and one quarter after the break date identified by the Gregory-Hansen test.

This evidence suggests that there is the possibility of a change in the cointegration vector in the 3rd quarter of 2002, which would explain why a cointegration vector was not found based on the whole sample without considering the structural

[6] We also tested the additive outlier model, which assumes the breaks occur immediately. However, in this case the null hypothesis was not rejected.

break. In addition, the breakpoint unit root tests reveal that the real exchange rate experienced a trend break, based on the results for model 3. The break date is the 1st quarter of 2007, which is a close date to 2002, in a span of more than 40 years. The cointegration vector after the break date (2002q3) should reflect the trend breaks that registered both remittances as the real exchange rate.

Finally, the breakpoint unit root tests reveal that Mexican GDP registered an intercept, an intercept and a trend, and a trend break according to models 1, 2 and 3, respectively. The break date for the first two tests is the 4th quarter of 1982 while the break date for the last one is the 4th quarter of 1983. Since they occurred early in the whole sample, they do not affect the estimate of the new cointegration vector after the structural break.

As a result of the Gregory-Hansen and the breakpoint unit root for remittances tests, we decide to split the initial sample in two subsamples. The first one starts in the first quarter of 1980 and ends in the second quarter of 2002[7] (90 observations), while the second one starts in the 3rd quarter of 2002 and ends in the 1st quarter of 2022 (79 observations). Thus, we estimate a cointegration vector for each subsample to identify the possible changes in the slope coefficients and evaluate the need to include a time trend in the second subsample.

7 As we want to keep the findings of Castillo (2001) and Islas-Camargo and Moreno-Santoyo (2011) comparable with our estimate for the first subsample (see below), we decided to maintain the start of the first subsample at 1980q1 instead of moving 1984q1, for example. In addition, the main findings of this paper refer to the second subsample that does not include the quarters in which the Mexican GDP time series structural change took place.

Unit root tests for each subsample

We perform the Augmented Dickey-Fuller (ADF) test[8] for the time series of each variable to detect unit roots within the two subsamples to find out if it is possible to perform the Johansen cointegration test for each of the two subsamples. The results are reported in **Table 3**. In the case of the ADF test, the lag length is selected to minimize the Schwarz information criterion. The ADF tests postulates as a null hypothesis that the time series has a unit root against the alternative that the series is stationary. When we consider the ADF test for a time series which is integrated of order one [I(1)], the null hypothesis should not be rejected when the variable is expressed in levels, meanwhile the null should be rejected when the same variable is expressed in first differences.

According to the ADF test and within each subsample, the four variables can be considered as I(1). Based on the results of **Table 3**, we carry on with the estimation of the cointegration vectors for each subsample.

The estimation of the cointegration vector for each subsample

The VAR model and the cointegration vector for the first subsample: 1st quarter of 1980 – 2nd quarter of 2002

We decided to follow the Johansen (1991, 1995) procedure to test cointegration. According to this approach, Juselius (2006) points out that: "…the magnitude of the eigenvalues λ_i is an indication of how strongly the linear relation $\beta_i' \; R_1, t-1$ is correlated with the stationary part of the pro-

8 See Dickey and Fuller (1979) and (1981). The decision about the specification of the model was based on the visual inspection of the respective graph and on the procedure proposed by Dolado et al. (1990), which is summarized in Enders (2010). The specification of the model is compared with that was determined by other authors for the same variables in similar periods, when available.

cess $R_{0,t}$". In this way, the Johansen (1991, 1995) procedure derives a test to "... discriminate between those λ_i, i=1, ..., r which correspond to stationary relations and those λ_i, i=r+1, ..., p which correspond to non-stationary relations", (Juselius (2006)). Since the time series have a quarterly frequency, we decided to incorporate 5 lags for both subsamples[9]. We included permanent dummy variables[10] for the 1st and 4th quarters of 1982, for the 3rd quarter of 1985, for the 1st, 3rd and 4th quarter of 1990, and for the 1st and 2nd quarters of 1995. The first two dummy variables reflect the first devaluation of the Mexican peso in February and the beginning of the external debt crisis in 1982. The third dummy variable reflects the economic effects of the earthquake that mainly affected Mexico City in September 1985. The fourth, fifth and sixth dummy variable reflects the return of Mexico to the international capital markets (see Calvo et al. (1993)). The last two dummy variables are associated with the Mexican economic crisis that was triggered when Banco de México abandoned the currency band in December 1994, but the effects on the real economy happened until 1995. The results are reported in **Table 4**.

In the first section of **Table 4**, the null hypothesis that there is not a cointegration vector is rejected because the trace statistic is higher than the corresponding critical value. The subsequent null hypothesis to test is that there is one cointegration vector, which is not rejected because the trace statistic is smaller than the corresponding critical value. Therefore, we can conclude that there is one cointegration vector. In the second section of **Table 4**, the estimated coefficients of the cointegration vector are reported. As we can see, we reproduce the same qualitative results obtained previously by Castillo (2001) and Islas-Camargo and Moreno-Santoyo (2011): remittances depend positively on the US income variable and negatively on the Mexico´s income variable and on the real exchange rate.

Although we do not use the same proxy income variables for Mexico and the United States as the other authors, the ones we use are closely related to theirs. In addition, their samples are not so different from the first subsample in the current exercise (see **Table 8**).

In the third section of **Table 4**, we present some diagnostic tests. In the VAR model we can estimate a measure of the goodness of fit, named Trace Correlation[11], which is like the R^2 in the linear regression model. In this case, the trace correlation is 0.73. The VAR model fulfills the assumptions of normality, homoscedasticity, and no autocorrelation of errors, as it is reported in the last part of **Table 4**.

It is important to carry out a stability test of the cointegration coefficients estimated in each subsample using the logarithm of the likelihood calculated recursively through the following test statistic corrected for the bias $Q^{Corr}_{T(t_1)}(t_1)$ (Juselius (2006)). The test statistic is constructed according to the following formula:

$$Q_T^{Corr}(t_1) = \frac{t_1}{T}\sqrt{\frac{T}{2p}}\Big[\{\log \mid \widehat{\Omega}_{t1} \mid - \log \mid \widehat{\Omega}_T \mid\} + \frac{1}{T}\Big\{\Big(\frac{1}{2}p(1-p)\Big) + r + p(k-1) + 1\Big(1-\frac{t_1}{T}\Big)\Big\}\Big]$$

Where:

$\widehat{\Omega}_T$ is the covariance matrix of the errors obtained by the estimation using the complete subsample, in this case from 1980q1 to 2002q2.

$\widehat{\Omega}_{t1}$ is the covariance matrix of the errors obtained by the estimation using a part of the subsample, which changes as t_1 runs.

9 The Hannan-Quinn information criterion indicates that 5 lags should be considered when using the whole sample and the second subsample, while for the first subsample, it indicates 4 lags.

10 Juselius (2006) defines as a permanent intervention dummy variable (... 0, 0, 1, 0, 0, ...).

11 $Trace\ Correlation = 1 - \left\{ trace\left[\overline{\Omega\{COV(\Delta X_t)\}^{-1}}\right] \big/ \rho \right\}$. See Juselius (2006).

t_1 is the time index that runs to enlarge the part of the subsample.

T is the full subsample size.

p is the number of variables.

r is the number of cointegration vectors.

k is the number of lags in the variables in levels.

This statistic is calculated by subtracting the (natural logarithm of) determinant of the covariance matrix of the residuals from the (natural logarithm of the) determinant of the covariance matrix of the residuals of a portion of the subsample, including bias-correcting terms. As the size of the part of the subsample is increased, either forward or backward, a plot is obtained for the statistic $Q_T^{Corr}(t_1)$. There are two alternative ways to obtain the covariance matrix of the errors. The first is to estimate the original model and only change the size of the part of the subsample to obtain the covariance matrix of the errors (Model X). The statistic $Q_T^{Corr}(t_1)$ of the X model is useful to assess the stability of short-term coefficients. The second way is through the estimation of auxiliary regressions. The first is to estimate the first differences of the variables in the period "t" (ΔX_t) based on first lagged differences (ΔX_{t-1}), the constant and the dummy variables to obtain the residuals $R_{0,t}$. The second auxiliary regression consists of estimating the levels of the variables lagged one period (X_{t-1}) based on first lagged differences (ΔX_{t-i}), the constant and the dummy variables to obtain the residuals $R_{1,t}$. Finally, we estimate the model $R_{0,t} = \alpha\beta' R_{1,t} + error$ (R model). Once again, by changing the size of the part of the subsample, the covariance matrices of the errors are obtained to calculate the test statistic. The $Q_T^{Corr}(t_1)$ of the R model is useful for evaluating the stability of the coefficients of the cointegration vector within each subsample, so it is crucial that this statistic does not fall into the rejection region in any case. Under the constant parameter assumption, the critical value is 1.36 at 95 percent confidence. If the bias-corrected test statistic is divided by 1.36, the new reference value for rejecting the null hypothesis is 1.0. The results of this test calculated recursively forward and backward are reported in **Figure 2**.

The $Q_T^{Corr}(t_1)$ tests corresponding to the R model do not fall in the rejection region in any of the parts of the first subsample, regardless of whether the tests are forward- or backward-recursive. This implies that the coefficients of the cointegration vector or long-term coefficients can be considered stable throughout the first subsample.

The VAR model and the cointegration vector for the second subsample: 3rd quarter of 2002 – 1st quarter of 2022

We include permanent dummy variables for the 3rd and 4th quarters of 2008, and the 1st and 2nd quarters of 2009. All these dummy variables are justified by the Great Recession caused by the subprime mortgage's crisis. We also include dummy variables for the 2nd quarter of 2017 which is related to an increase in the gasoline price, which was implemented in Mexico a quarter before, and for the 2nd quarter of 2020 which is justified for the SARS-COV-2 recession. We must include a time trend in the cointegration space, otherwise we would not have obtained a cointegration vector.

In the first section of **Table 5**, the null hypothesis that there is not a cointegration vector is rejected, while the subsequent null hypothesis that there is one cointegration vector is not rejected. We can conclude that there is one cointegration vector. In the second section of the same table, we present the estimated coefficients of the cointegration vector.

After the structural change detected in the 3rd quarter of 2002, we find two important differences between these results and those obtained using the first subsample which are qualitatively like those obtained by Castillo (2001) and Islas-Camargo and Moreno-Santoyo (2011) (see

Table 8). The first one is that the cointegration vector in the second subsample includes a deterministic trend with a positive estimated coefficient. The trend breaks identified for remittances in 2002q4 help explain this result. Before the break identified by the Gregory-Hansen test in 2002q3, it was not necessary to include this time trend in the exercise based on first subsample (which ends in 2002q2), and neither Castillo (2001) nor Islas-Camargo and Moreno-Santoyo (2011) included it in their respective analyses. The emergence of the time trend implies that remittances will keep on growing even if the values of the explanatory variables remain constant. The second difference is that a depreciation of the RER stimulates positively the remittances sent to México, i.e., there is a positive relation between those variables, instead of the negative relation estimated both in the first subsample and in previous studies by the authors mentioned before. Again, the trend breaks for remittances and for the real exchange rate help to explain this result.

On the other hand, the estimated coefficient for IPI remains almost equal (5.42 and 5.35) in both subsamples, while the estimated coefficient for YMX changes from the first subsample (-4.97) to the second one (-2.65). In the next section, we discuss potential consequences of the new sign of the estimated coefficient for the RER. In the third section of Table 5, we present some diagnostic tests. The Trace Correlation is 0.71 and the VAR model fulfills the assumptions of normality, homoscedasticity, and no autocorrelation of errors, as it is reported in the last part of Table 5. We perform the $Q_T^{Corr}(t_1)$ of the R model to evaluate the stability of the coefficients of the cointegration vector for the second subsample. The test statistic is depicted in Figure 3. The coefficients of the cointegration vector or long-term coefficients can be considered stable throughout the second subsample because the $Q_T^{Corr}(t_1)$ tests corresponding to the R model do not fall in the rejection region in any of the parts of the second subsample, regardless of whether the tests are forward- or backward-recursive. According to the results of this test, we can consider long-term coefficients stability within each subsample.

We proceed to estimate of the error correction model (ECM) corresponding to the second subsample. The results are in Table 6. As we can see in section 2 of such table, the null hypothesis that each coefficient is statistically equal to cero is rejected, according to the $x^2_{(1)}$ statistic, which implies that the estimated coefficients for the four variables and the time trend are statistically significant in the cointegration space. On one hand, the weak exogeneity tests reveals that YMX, IPI and RER can be considered as weakly exogeneous variables, given that the estimated adjustment coefficients are not statistically significant according to the $x^2_{(1)}$ statistic.

The estimated adjustment coefficient in the equation for ΔR is statistically significant and negative. Johansen (1995) points out: "... agents react to the disequilibrium error through the adjustment coefficient α, to bring back the variables on the right track, that is, such that they satisfy the economic relations". In the case of the equation for ΔR_t, the estimated adjustment coefficient is -0.20. This means that when remittances are higher than they should be, according to the long-run relation, remittances tend to decrease towards the value determined by such relation. This implies that around 20% of the disequilibrium error tends to be eliminated in each period. That is the importance of the negative sign in the adjustment coefficient.

From the first section of Table 6 we can obtain the cointegration equation:

$$R_t = -6.26YMX_t + 4.75IPI_t + 2.95RER_t + 0.02\,trend + 76.81 + \varepsilon_t \quad (1)$$

From equation (1), we can obtain the disequilibrium error or error correction term:

$$ECT_t = R_t - (-6.26\,YMX_t + 4.75\,IPI + 2.95\,RER + 0.02\,trend + 76.81) \quad (2)$$

The ECM model fulfills the assumptions of normality, homoscedasticity, and no autocorrelation of errors, as it is reported in the last part of **Table 6**. The ECM specific for ΔR_t is reported in **Table 7**. We follow the "from general to particular" approach when we estimate ΔR_t using Ordinary Least Squares as a function of i) the error correction term; ii) differences of R, YMX, IPI and RER including 1 to 4 lags, and iii) all the dummy variables in differences. Then we test the restrictions that some estimated coefficients are simultaneously equal to cero. The null hypothesis is that a group of coefficients are not statistically significant. If the null hypothesis is not rejected, the group of variables can be removed from the model, otherwise the variables cannot be excluded from the model.

The redundant variable test consists in comparing the sums of squared residuals (SSR) of the unrestricted and the restricted models. In this way, we carry on performing the redundant variable test until we cannot remove more variables[12]. As we can see in **Table 7**, the number of explanatory variables is halved. Specifically, of six dummy variables among the differences that were initially included, only one maintains its statistically significant coefficient, i.e., that for the first quarter of 2009. As we can see in the lower part of **Table 7**, the errors fulfil the assumptions of normality, with no autocorrelation and homoscedasticity. In addition, the CUSUM test and the CUSUM of squares test supports the assumption of stability of this model.

[12] In order to remove a group of variables, the t-statistic, the F-statistic, and the likelihood ratio must not be in the null hypothesis rejection area.

Implications for the Mexican economy

In **Table 8**, we contrast the results estimated in both subsamples of the present study with those obtained by Castillo (2001), and Islas-Camargo and Moreno-Santoyo (2011). The three studies match with the theory developed by Vargas-Silva and Huang (2006), given that remittances respond negative and positively to the proxy income variables for the origin and host countries, respectively, although those are based on different samples[13].

The comparison of the relative magnitude of the estimated coefficients by Castillo (2001), Islas-Camargo and Moreno-Santoyo (2011) and in the first subsample is not appropriated given that the proxy income variables for both countries are not strictly the same[14]. According to the estimation for second subsample, a time trend must be incorporated in the cointegration space.

From the statistical point of view, its inclusion is supported by the Gregory-Hansen test that revealed a level shift with trend in the 3rd quarter of 2002 and by the breakpoint unit root test that reveals that remittances experienced an intercept and trend breaks in the 4th quarter of the same year.

The main argument that explains the emergence of the time trend in the cointegration vector is the change in the definition of remittances that was implemented in the 4th quarter of 2002 by Banco de México. In the introduction we discussed the implications that the quoted authors have attributed to the new remittances´ definition. The time trend reflects the growth in remittances that is not explained by Mexico´s GDP, Industrial Production Index of the United States, and the real exchange rate.

[13] The sample used by Islas-Camargo and Moreno-Santoyo (2011) encompasses the sample used by Castillo (2001).

[14] A clear example is Mexico´s GDP because the series used by Castillo (2001) was measured in chained pesos of 1993, while the "same" series used in the present study is measured in chained pesos of 2013.

The Gregory-Hansen tests also reveal a regime shift which implies changes in at least one of the estimated slope coefficients. In the case of the RER, the change in the slope coefficient is evident because the sign of the estimated coefficient changed from negative to positive, as we can see in the third row of **Table 8**. The breakpoint unit root test revealed that the RER experienced a trend break, based on the results for model 3 (see **Table 2**), which helps explain the change in the sign of the estimated coefficient.

In the first subsample, the RER registered periods of accumulated appreciation followed by a sudden depreciation; but when we run a regression of the RER against a constant and a time trend the coefficient of the latter is negative. By contrast, when we run the same regression for the second subsample the estimated coefficient of the time trend becomes positive (see **Figure 4**).

There were three external shocks along the second subsample that depreciated the RER significantly from which it did not fully recover: i) subprime mortgages crisis in 2008-2009, ii) the SARS-COV-2 pandemic in 2020, and above all iii) the US presidential campaign won by Trump in 2016. The positive sign of the estimated coefficient of the RER turns out to be very important in the context of a high growth rate of remittances because they may eventually have a stabilizing effect both on nominal and real exchange rates. For example, a sudden depreciation of the nominal and real exchange rates could increase the remittances sent to Mexico, and the initial currency depreciation could be partially offset eventually, as they have become the most important source of foreign exchange as it was described in the Introduction.

Mexico faces economic and financial instability because of the globalization of trade and financial markets. There are a lot of examples, the most recent ones are the Great Recession in 2009 and the recession in 2020 due to the pandemic of SARS-COV-2. As a result of this, international capital movements have produced high exchange rate volatility in the emerging economies. In this scenario, the potential stabilizing effect described above would be good news, especially if remittances keep on growing as in recent years. A further investigation is needed to test if this stabilizing effect is relevant[15].

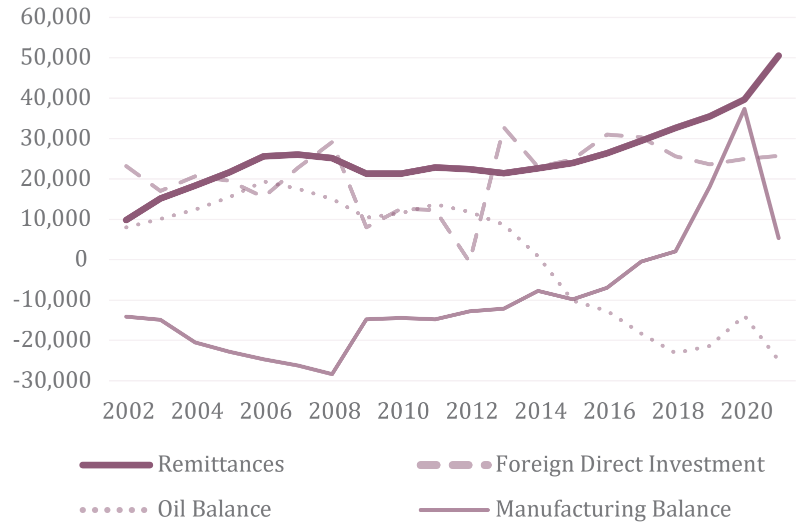
In addition, if remittances increase significantly, then there could be a RER appreciation causing the effects of the "Dutch disease" previously discussed. The higher the ratio of remittances to Mexico's GDP, the more likely it is to face the problem of the Dutch disease. In 2021, this ratio reached 4.0%. The inclusion of a time trend implies that there is an element that drives the growth of remittances, regardless of the behavior of the other explanatory variables. Additionally, with a scenario of low economic growth in the next 2 years, the time for the Mexican economy facing the Dutch disease might be closer than we imagine.

Concluding remarks

The Gregory-Hansen tests reveal that there was a regime shift and a level shift with trend on the same break date: 3rd quarter of 2002. After having identified the sign change in the estimated coefficient of the real exchange rate and the need to include a time trend in the cointegration space for the second subsample, a new long-run relationship between remittances and the variables that determine them has been identified. This study reveals that the change in the remittances´ definition can explain the emergence of the time trend in the cointegration vector. In addition, the emergence of a time trend in the real exchange rate time series explains the change in its sign in the cointegration space. These findings should lead us to study the remittances´ potential stabilizing effect on the real exchange rate and the possibility that the Mexican economy might face the Dutch disease problem in a near future.

[15] This implies to estimate a cointegration vector where the real exchange rate is explained by remittances, among other variables.

Figure 1
Main sources of foreign currency for Mexico in millions of dollars
Annual data 2002 –2021.



Source: Own elaboration with information of Banco de México.

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Table 1
Gregory-Hansen Cointegration Test Remittances, Mexico´s GDP,
US Industrial Production Index and Real Exchange Rate
1st Quarter of 1980 – 1st Quarter of 2022

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Level shift				
ADF procedure	Lag	Break	Statistic	Critical Value
t-stat	4	2002 Q1	-3.14	-5.28
Phillips procedure		Break	Statistic	Critical Value
Zα-stat		2002 Q2	**-62.23**	-53.58
Zt-stat		2002 Q3	**-6.07**	-5.28
Level shift with trend				
ADF procedure	Lag	Break	Statistic	Critical Value
t-stat	4	2002 Q1	-3.68	-5.57
Phillips procedure		Break	Statistic	Critical Value
Zα-stat		2002 Q3	**-81.16**	-59.76
Zt-stat		2002 Q3	**-7.43**	-5.57
Regime shift				
ADF procedure	Lag	Break	Statistic	Critical Value
t-stat	4	2004 Q1	-4.04	-6.00
Phillips procedure		Break	Statistic	Critical Value
Zα-stat		2002 Q3	**-72.84**	-68.94
Zt-stat		2002 Q3	**-6.83**	-6.00

Bold statistics values imply that the null hypothesis is rejected (95% confidence level).

Source: calculations by the authors.

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Table 2
Breakpoint Unit Root Tests for the whole sample Remittances, Mexico´s GDP, US Industrial Production Index and Real Exchange Rate
Sample: 1st Quarter 1980 -1st Quarter 2022

Innovational Outliers						
Model 0	H_0: random walk H_1: stationary model with intercept break					
Variables in levels	Lags[1] Schwarz I. C.	Specification[2] Trend	Break	Statistic	Probability[3]	Break date[4]
R	4	I	I	-1.94	0.985	-
YMX	4	I	I	-2.54	0.891	-
IPI	0	I	I	-2.78	0.796	-
RER	3	I	I	-3.63	0.317	-
Model 1	H_0: random walk with drift H_1: trend stationary model with intercept break					
Variables in levels	Lags[1]	Specification[2] Trend	Break	Statistic	Probability[3]	Break date[4]
R	12	I and T	I	-4.31	0.203	-
YMX	0	I and T	I	-5.26	0.014	1982q2
IPI	0	I and T	I	-3.21	0.843	-
RER	3	I and T	I	-4.01	0.363	-
Model 2	H_0: random walk with drift H_1: trend stationary model with intercept and trend breaks					
Variables in levels	Lags[1]	Specification[2] Trend	Break	Statistic	Probability[3]	Break date[4]
R	13	I and T	I and T	-5.25	0.041	**2002q4**
YMX	0	I and T	I and T	-5.29	0.037	1982q2
IPI	0	I and T	I and T	-4.36	0.308	-
RER	3	I and T	I and T	-4.90	0.099	-
Model 3	H_0: random walk with drift H_1: trend stationary model with trend break					
Variables in levels	Lags[1]	Specification[2] Trend	Break	Statistic	Probability[3]	Break date[4]
R	0	I and T	T	-3.21	0.584	-
YMX	0	I and T	T	-5.19	< 0.01	1983q4
IPI	0	I and T	T	-4.10	0.142	-
RER	3	I and T	T	-4.86	0.019	**2007q1**

[1] Maximum number of lags: 13.
[2] I means intercept and T linear trend.
[3] 95% confidence level.
[4] In case H_0 is rejected. It is the first observation after the break.
Source: Calculations by the authors using Eviews 12.

*MacKinnon (1996) one-sided p-values.

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Table 3
Unit Root Tests (ADF) Remittances, Mexico´s GDP,
US Industrial Production Index and Real Exchange Rate.

		Augemented Dickey-Fuller		
		Subsample 1st Quarter 1980 -2nd Quarter 2002		
Variables in Levels	H_0: the time series has a unit root.			
	Lags	Specification[1]	Statistic	Probability[2]
R	3	I & T	-1.68	0.75
YMX	4	I & T	-2.87	0.18
IPI	1	I & T	-2.37	0.39
RER	0	I	-1.68	0.44
Variables in Differences	H_0: the time series has a unit root.			
	Lags	Specification[1]	Statistic	Probability[2]
D (R)	2	I	-13.16	0.00
D (YMX)	3	I	-3.94	0.00
D (IPI)	0	I	-6.37	0.00
D (RER)	0	N	-7.81	0.00
		Subsample 3rd Quarter 2002 -1st Quarter 2022		
Variables in Levels	H_0: the time series has a unit root.			
	Lags	Specification[1]	Statistic	Probability[2]
R	5	I & T	-0.73	0.97
YMX	3	I & T	-1.58	0.79
IPI	0	I & T	-2.75	0.22
RER	0	I & T	-2.62	0.27
Variables in Differences	H_0: the time series has a unit root.			
	Lags	Specification[1]	Statistic	Probability[2]
D (R)	4	I	-3.80	0.00
D (YMX)	2	I	-8.87	0.00
D (IPI)	0	I	-9.46	0.00
D (RER)	0	I	-8.41	0.00

[1] I means intercept, T linear trend and N none.
[2] 95% confidence level.
Source: Calculations by the authors using Eviews 12.

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Table 4

Cointegration analysis following the Johansen procedure and diagnostic tests.
Remittances, Mexico´s GDP, US Industrial Production Index and Real Exchange Rate
1st Quarter of 1980 – 2nd Quarter of 2022. Includes an intercept
Includes a deterministic trend

i) Cointegration analysis								
	Eigenvalues				0.38	0.16	0.07	0.02
	Null hipothesis				rank = 0	rank ≤ 1	rank ≤ 2	rank ≤ 3
	λ trace statistic*				63.3*	22.58	7.83	1.60
	Critical values (95%)				47.86	29.80	15.49	3.84
	Probability				0.00	0.27	0.48	0.21
ii) Estimated cointegration vector								
Variables					R	Y	IPI	RER
	Normalized cointegration coefficients				1.00	4.97	-5.42	2.38
	Standard error					1.45	1.06	0.43
iii) Diagnostic test								
Trace correlation			Test statistic					
			0.73					
Normality			Test statistic		df		Probability	
Jarque-Bera			14.25	8			0.08	
	Skewness		6.12	4			0.19	
	Kurtosis		8.13	4			0.09	
Heteroscedasticity			Test statistic		df		Probability	
White (no cross terms)			461.70	480			0.72	
Autocorrelation								
Null hypothesis: No serial correlation at lag h								
Lags	1	2	3	4	5	6	7	8
Rao F-stat	0.90	1.34	1.57	0.75	0.77	0.64	1.49	0.57
df	(16, 150)	(16, 150)	(16, 150)	(16, 150)	(16, 150)	(16, 150)	(16, 150)	(16, 150)
Probability	0.57	0.18	0.08	0.74	0.72	0.85	0.11	0.90
Null hypothesis: No serial correlation at lags 1 to h								
Lags	1	2	3	4	5	6	7	8
Rao F-stat	0.90	1.13	1.16	1.12	0.99	0.99	1.12	1.06
df	(16, 150)	(32, 168)	(48, 160)	(64, 147)	(80, 133)	(96, 117)	(112, 102)	(128, 86)
Probability	0.57	0.31	0.25	0.28	0.51	0.51	0.27	0.38

* The trace statistic indicates one cointegrating equation at the 0.05 level.
Source: calculations by the authors.

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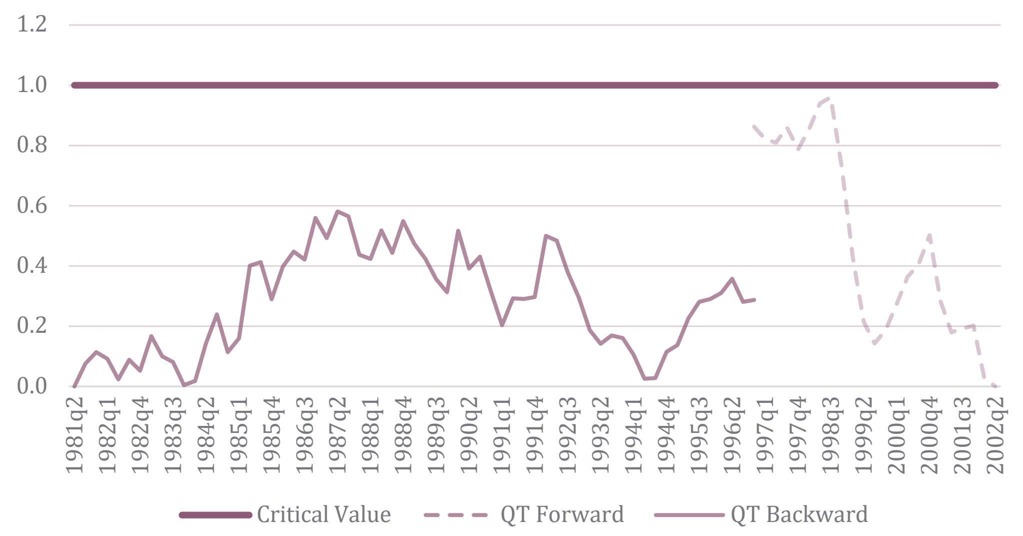
Figure 2

Recursive Tests of Constancy of the estimated cointegration vector coefficients Q_T^{Corr} (t_1) (forward and backward) Subsample 1980q1-2002-q2.



Source: estimations by the authors.

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Table 5

Cointegration analysis following the Johansen procedure and diagnostic tests.
Remittances, Mexico´s GDP, US Industrial Production Index and Real Exchange Rate
3rd Quarter of 2002 – 1st Quarter of 2022. Includes an intercept and a trend.

i) Cointegration analysis

Eigenvalues	0.50*	0.29	0.17	0.02
Null hipothesis	rank = 0	rank ≤ 1	rank ≤ 2	rank ≤ 3
λ trace statistic*	97.69	42.39	15.67	1.39
Critical values (95%)	63.88	42.92	25.87	12.52
Probability	0.00	0.06	0.52	0.99

ii) Estimated cointegration vector

Variables	R	Y	IPI	RER	Trend
Normalized cointegration coefficients	1.000	2.648	-5.353	-1.295	-0.008
Standard error		1.009	0.845	0.385	0.004
Adjutment Coeffcients	-0.149	0.027	0.035	0.086	
Standard error	0.058	0.011	0.008	-0.031	

iii) Diagnostic test

Trace correlation	Test statistic		
	0.71		
Normality	**Test statistic**	**df**	**Probability**
Jarque-Bera	3.19	8	0.92
Skewness	0.93	4	0.92
Kurtosis	2.26	4	0.69
Heteroscedasticity	**Test statistic**	**df**	**Probability**
White (no cross terms)	463.60	460	0.44

Autocorrelation

Null hypothesis: No serial correlation at lag h

Lags	1	2	3	4	5	6	7	8
Rao F-stat	1.74	0.41	0.95	1.14	0.29	1.37	0.60	0.95
df	(16, 138.1)	(16, 138.1)	(16, 138.1)	(16, 138.1)	(16, 138.1)	(16, 138.1)	(16, 138.1)	(16, 138.1)
Probability	0.05	0.98	0.51	0.33	1.00	0.17	0.88	0.51

Null hypothesis: No serial correlation at lags 1 to h

Lags	1	2	3	4	5	6	7	8
Rao F-stat	1.74	0.90	0.92	0.95	0.82	0.94	0.86	0.82
df	(16, 138.1)	(32, 152.8)	(48, 144.6)	(64, 131.5)	(80, 116.8)	(96, 101.6)	(112, 86.0)	(128, 70.3)
Probability	0.05	0.62	0.63	0.58	0.83	0.61	0.77	0.83

* The trace statistic indicates one cointegrating equation at the 0.05 level.
Source: calculations by the authors.

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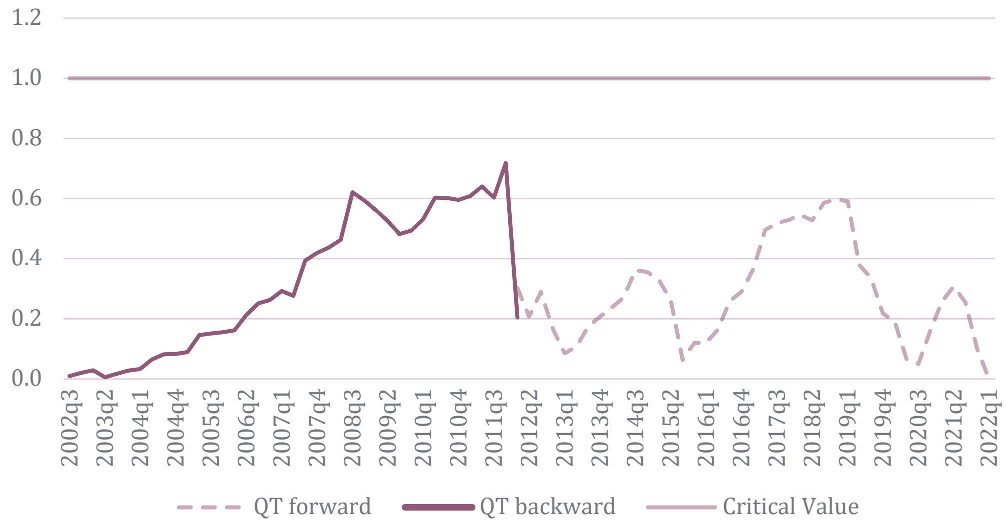
Figure 3

Recursive Tests of Constancy of the estimated cointegration vector coefficients $Q_T^{Corr}(t_1)$ (forward and backward) Subsample 2002q3-2022-q1.



Source: estimations by the authors.

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Table 6
Error Correction Model, Coefficients Significance, Weak Exogeneity and diagnostic tests: Remittances, Mexico´s GDP, US Industrial Production Index and Real Exchange Rate
3rd of Quarter 2002 – 1st Quarter of 2022.

i) Cointegration equation and adjustment coefficients

Variables	R	YMX	IPI	RER	Trend	C
Normalized cointegration coeffcients	1.00	6.26	-4.75	-2.95	-0.02	-76.81
Standar error		1.27	1.07	0.44	0.01	
T-Statistic		4.92	-4.45	-6.73	-3.30	
Adjustment coefficients	-0.20	0.01	-0.00	0.02		
Standar error	0.05	0.01	0.01	0.03		
T-Statistic	-4.31	1.27	-0.49	0.59		

ii) Significance tests of the coefficients of the cointegration vector

Variables	R	YMX	IPI	RER	Trend
$\chi2(1)$	11.71	10.62	6.03	19.68	5.54
Probability	0.00	0.00	0.01	0.00	0.02

iii) Weak exogeneity test

Variables	R	YMX	IPI	RER
$\chi2(1)$	12.45	1.76	0.31	0.31
Probability	0.00	0.18	0.58	0.58

iv) Diagnostic test

Normality	Test statistic	df	Probability
Jarque-Bera	7.40	8	0.49
Skewness	3.61	4	0.46
Kurtosis	3.80	4	0.43
Heteroscedasticity	Test statistic	df	Probability
White (no cross terms)	391.27	430	0.91

Autocorrelation

Null hypothesis: No serial correlation at lag h

Lags	1	2	3	4	5	6	7	8
Rao F-stat	1.65	1.11	1.25	1.15	0.57	1.02	1.05	0.61
df	(16, 147.3)	(16, 147.3)	(16, 147.3)	(16, 147.3)	(16, 147.3)	(16, 147.3)	(16, 147.3)	(16, 147.3)
Probability	0.06	0.35	0.23	0.31	0.90	0.44	0.41	0.87

Null hypothesis: No serial correlation at lags 1 to h

Lags	1	2	3	4	5	6	7	8
Rao F-stat	1.65	1.46	1.21	1.25	1.20	1.26	1.20	1.17
df	(16, 147.3)	(32, 163.9)	(48, 156.1)	(64, 143.2)	(80, 128.7)	(96, 113.4)	(112, 97.9)	(128, 82.2)
Probability	0.06	0.07	0.19	0.14	0.18	0.12	0.18	0.22

Source: estimations by the authors.

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Table 7
Specific Error Correction Model for Remittances

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECT(-1)	-0.19	0.03	-6.28	0.000
D(R(-1))	0.15	0.08	1.93	0.058
D(R(-2))	-0.42	0.09	-4.90	0.000
D(R(-4))	0.25	0.09	2.75	0.008
D(YMX(-2))	1.17	0.26	4.59	0.000
D(IPI(-1))	-0.57	0.31	-1.86	0.068
D(IPI(-2))	-0.80	0.35	-2.30	0.025
D(TCR(-1))	-1.12	0.18	-6.16	0.000
D(TCR(-3))	-0.63	0.15	-4.24	0.000
D(TCR(-4))	-0.36	0.14	-2.57	0.012
C	0.03	0.01	3.98	0.000
DD0901	0.10	0.04	2.50	0.015
R-squared	0.76	Mean dependent var		0.01
Adjusted R-squared	0.72	S.D. dependent var		0.10
S.E. of regression	0.05	Akaike info criterion		-2.87
Sum squared resid	0.19	Schwarz criterion		-2.51
Log likelihood	123.86	Hannan-Quinn criter.		-2.72
F-statistic	18.71	Durbin-Watson stat		2.08
Prob(F-statistic)	0.00			
Jarque-Bera			2.44	0.29
Skewness			0.36	
Kurtosis			3.48	
Breusch-Godfrey serial correlation LM F(9, 57)			0.90	0.54
White Heteroscedasticity F(11, 66)			0.89	0.55
CUSUM Test			Inside Bands	
CUSUM OF SQUARES Test			Inside Bands	

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Table 8
Results of three studies of the determinants of the remittances sent to Mexico.

	Castillo (2001)	Islas-Camargo & Moreno-Santoyo (2011)	Jiménez-Gómez and Flores-Márquez (2023)	
Samples	1980 Q1 - 2000 Q3	1980 Q1 - 2008 Q4	1980 Q1 - 2002 Q2	2002 Q3 - 2022 Q1
Variables	Estimated Coefficients			
Income of Mexico	-0.96	-2.90	-4.97	-2.65
Income of USA	2.70	0.17	5.42	5.35
Real Exchange Rate	-0.20	-5.86	-2.38	1.30
Immigration		-1.32		
Time trend				0.01

Source: Quoted references and authors' results.

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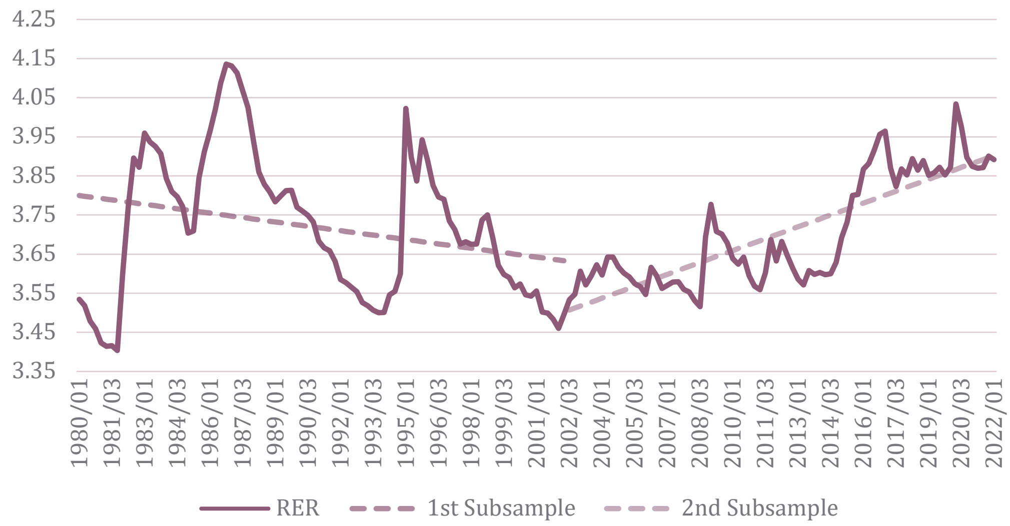
Figure 4
Natural logarithm of the Real Exchange Rate 1980q1-2022q1.



Source: Calculations by the authors based on information from Banco de México.

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