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INCOME ELASTICITIES OF THE MAIN TAXES IN MEXICO & THE REVENUE LOSS DUE TO THE COVID-19 PANDEMIC

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QUE PARA OBTENER EL TÍTULO DE

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PRESENTA

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A mi familia, por apoyarme en todas mis decisiones y proyectos.
A mis profesores, especialmente a Daniel y Juan, de quienes he aprendido valiosas cosas más allá del ámbito académico.
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Abstract

This work focuses on estimating the income elasticity of the main form of taxes in Mexico and quantifying revenue loss during the COVID-19 pandemic. The study employs both Vector Error Correction (VEC) and Autoregressive Distributed Lag with Error Correction Mechanism (ARDL ECM) models. Both model specifications yield robust estimates of income elasticities that confirms that Mexico has an elastic tax revenue. That is, the tax revenue grows more than proportional to GDP growth. Furthermore, the study conducts a counterfactual analysis to estimate revenue loss attributable to the pandemic. The work finds substantial revenue losses across tax categories, around 1% of 2020 GDP.

List of abbreviations

Abbreviation	Meaning
VAT	Value Added Tax
IT	Income Tax
TTR	Total Tax Revenue
GDP	Gross Domestic Product

Contents

1	**Introduction**	**1**
2	**Literature review**	**2**
3	**The tax system in Mexico**	**6**
4	**Data**	**8**
5	**Methodology**	**12**
6	**Results**	**14**
7	**Conclusions**	**28**
8	**Bibliography**	**30**

List of Tables

2.1 Elasticities from other studies for Mexico and other countries 5

6.1 Unit root tests (p-values) 15
6.2 Johansen test results (p-values) 16
6.3 VEC model results for the three tax categories 18
6.4 ARDL long-run estimates of elasticities for the three tax categories 20
6.5 Revenue Loss from Taxes 27

List of Figures

3.1 Proportion of the federal taxes due to VAT and IT 7

4.1 GDP and TTR 9
4.2 GDP and VAT 10
4.3 GDP and IT 11

6.1 IRFs for Total Tax Revenue 22
6.2 IRFs for VAT 22
6.3 IRFs for IT 23
6.4 Counterfactuals for TTR 24
6.5 Counterfactuals for IT 25
6.6 Counterfactuals for VAT 25

1. Introduction

An adequate control of fiscal policy is crucial for any government. One tool used to assess whether a country's fiscal activity is favorable is the measurement of the income elasticity of tax revenue. Income elasticity of tax revenue and buoyancy are two important concepts in the analysis of tax systems. Income elasticity of tax revenue measures the responsiveness of tax revenue to changes in national income (GDP), capturing how tax revenues grow with economic growth. An elasticity greater than one indicates that tax revenues grow more than proportionately with GDP, while an elasticity less than one indicates that tax revenues grow less than proportionately. In contrast, buoyancy includes both the natural growth of tax revenues due to economic expansion and the effects of discretionary tax changes, such as rate adjustments and policy reforms. This study uniquely focuses on income elasticity, aiming to isolate the responsiveness of Mexico's main taxes— IT and VAT—to economic growth, without considering the impact of discretionary tax changes.

Results obtained by other authors suggest that a healthy fiscal system should have an elasticity greater than one. That is, budgetary collection should grow more than proportionally to income. For the case of Mexico, this topic is crucial because of the way the federal budget is distribuited across the states.

In this regard, the present work contributes to estimating the income elasticities of the main taxes in Mexico using two models that allow for a more precise evaluation of the collection along with the other variables used. More specifically, the cointegration relation between the variables is used. Additionally, the two cointegration models are compared to check how robust the estimated results are.

An additional element included in this research is that, based on the estimated elasticities, an approximate value of the loss of budgetary collection during the COVID-19 pandemic is obtained. This exercise is useful to demonstrate the utility of applying cointegration methods to this type of exercises. That is, since these methods yield short-term estimators, it is possible to calculate variations of the series during periods that exhibit abnormal behaviors and deviate from their long-term trend.

2. Literature review

Mansfield (1972) examines the elasticity and buoyancy of Paraguay's tax system from 1962 to 1970, finding that the elasticity of total tax revenue with respect to GDP is 1.14, while the buoyancy is 1.69. This indicates that discretionary changes significantly contributed to revenue growth. The analysis decomposes the elasticity into tax-to-base and base-to-income elasticities, showing that import duties and wealth taxes have high elasticities, whereas export taxes have low elasticity.

Similarly, Bilquees (2004) investigates the elasticity and buoyancy of Pakistan's tax system from 1974-75 to 2002-03. The study finds that the overall elasticity of tax revenue with respect to GDP is less than unity. Sales tax, particularly on imports and manufacturing, significantly contributes to revenue improvement. However, the inclusion of service sectors and utilities in the sales tax net has implications for the poor.

Creedy and Gemmell (2004) estimate the revenue elasticity of income and consumption taxes in the UK from 1989 to 2000. They find that income tax elasticities range from 1.2 to 1.4, while consumption tax revenue elasticities are around 0.7, declining from about 0.9 in the early 1990s. Their findings underscore the significant impact of tax policy changes on revenue elasticities, with consumption tax revenue growth driven by increased VAT rates and changes in consumption patterns.

Extending the analysis to the Netherlands, Wolswijk (2007) estimates the short-run and long-run elasticities of Dutch taxes from 1970 to 2005. The study finds that short-term elasticities are generally lower than long-term elasticities, especially for direct taxes like personal and corporate income taxes. This research highlights that short-term elasticities fluctuate more with economic cycles, while long-term elasticities reflect the stable growth of tax revenues. Additionally, the study notes asymmetry in tax-to-base elasticities, with higher elasticities in periods of above-equilibrium tax receipts, indicating shifts towards higher-taxed goods and services during economic expansions.

Furthermore, Yousuf and Huq (2013) analyze the elasticity and buoyancy of Bangladesh's tax system, finding that total tax revenue, income tax, and VAT are elastic, indicating a more than proportional response to changes in GDP, private consumption, and imports. However, customs duties are inelastic.

Machado and Zuloeta (2012) estimate the short-run and long-run elasticities of tax revenue with respect to GDP in eight Latin American countries using quarterly data. They find that long-run elasticities are generally greater than one, indicating that tax revenues increase more than proportionately with GDP in the long run. In contrast, short-run elasticities are not statistically different from zero in most cases. The study also notes that the corporate income tax (CIT) exhibits the largest long-run elasticity in most countries, while the short-run fluctuations of CIT and personal income tax (PIT) in some countries, like Brazil and Colombia, are significant over the business cycle.

In a more recent study, Casalecchi and Bacciottii (2021) examine the elasticity of tax revenues to GDP of Brasil, differentiating between short-term and long-term elasticities. They find that long-term elasticities of total tax revenues are less than unity, indicating that tax revenues grow at a slower rate than GDP over extended periods. In contrast, short-term elasticities are greater than unity, meaning tax revenues increase more than proportionately with GDP in the short run. The research also highlights that elasticity varies with the economic cycle, being higher during positive output gaps and lower during negative output gaps.

Moving to the Mexican case, Capistrán (2000) investigates the income elasticity of Income Tax (ISR) using a general-to-specific econometric approach. Covering the period from the first quarter of 1989 to the third quarter of 1998, the study finds that the long-term income elasticity of ISR is 1.466, indicating a strong responsiveness to changes in national income. The short-term income elasticity is significantly higher at 4.94, reflecting substantial immediate adjustments in tax revenue following income changes. The study emphasizes that an elastic tax system is essential for reducing economic uncertainty and ensuring stable revenue growth without frequent tax adjustments.

Cárdenas et al. (2008) also analyze the income elasticity of Mexico's main taxes. They find that the elasticities for VAT, IT, and total tax revenue are greater than one, indicating that these tax revenues are elastic. Specifically, the estimated elasticities are 1.12 for VAT, 1.15 for IT, and 1.20 for total tax revenue.

Fonseca and Ventosa-Santaulària (2011) also estimate the revenue elasticity of Mexico's main federal taxes, specifically the Income Tax (IT) and the Value-Added Tax (VAT). Using a cointegration model that accounts for strong exogeneity, the study finds that both taxes are highly elastic with respect to GDP. The estimated long-term elasticity is 2.16 for ISR and 2.03 for VAT, indicating that these tax revenues increase more than proportionately with GDP. The results suggest a strong relationship between economic growth and tax revenue, which provides a reliable basis for tax revenue projections.

Table 2.1 presents a comparative analysis of all the above income elasticity estimates for VAT, IT, and total taxes across various studies and countries. This comparison highlights the consistency in tax responsiveness to income changes, with most elasticity estimates falling between 1 and 2.

Comparing the Mexican estimates with those from other countries provides additional insights. For instance, the elasticity of IT in the United States, as reported by Ilzetzki (2011), is 1.47, which is lower than the Mexican estimates but still indicates a strong responsiveness. The United Kingdom, according to Choudhry (1979), shows an elasticity of 1.11 for VAT and 1.45 for IT, values that are comparable to the Mexican context, particularly for IT. These comparisons reveal that Mexico exhibits an elasticity similar to other countries.

Table 2.1: Elasticities from other studies for Mexico and other countries

	VAT	IT	TOTAL
Mexico			
Fonseca & Ventosa-Santaularia (2011)	2.03	2.16	-
Ilzetzki (2011)	-	1.47	1.72
Centro de Estudios de las Finanzas Públicas (2009)	1.88	1.36	-
Cárdenas, Ventosa-Santaularia & Gómez (2008)	1.12	1.15	1.2
Capistrán (1999)	-	1.54	-
Other countries			
United States[a]	-	2.3	-
Japan[a]	-	1.4	-
Germany[a]	-	0.8	-
Netherlands[b]	0.90	1.57	-
Kenya[c]	-	1.47	1.42
United States[c]	-	1.083	1.04
United Kingdom[c]	1.11	1.45	1.17
Malaysia[c]	-	1.84	1.69

[a] Giorno et al. (1995)
[b] Wolswijk (2007)
[c] Choudhry (1979)

3. The tax system in Mexico

Federalized expenditure is financed with resources that the Federal Government transfers to states through federal participations and contributions. These funds from the Federation are used by state governments to supplement their respective expenditures in education, health, social infrastructure, public security, pension systems, public debt, and other areas.

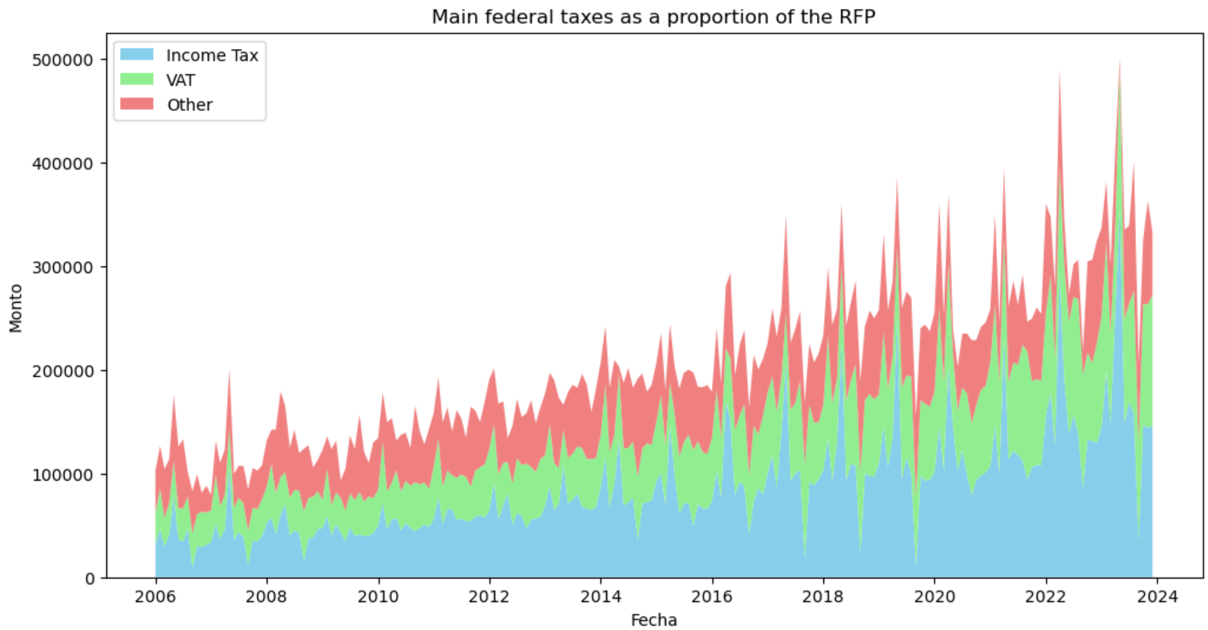
Estimating the income elasticity of tax revenue is highly relevant to the Mexican tax system due to its significant impact on federalized expenditure. Given that a substantial portion of the states' and municipalities' budgets depends on federal transfers (as can be seen in figure 3.1), understanding how tax revenues respond to changes in economic activity is crucial for effective fiscal planning. High elasticity indicates that tax revenues grow more than proportionately with income, which can provide additional resources during periods of economic growth, thereby enabling better funding for essential public services and infrastructure projects.

Moreover, the relevance of income elasticity extends to the stability and predictability of the tax system. Elasticities greater than one suggest a stable relationship between income and tax revenues, providing a reliable basis for forecasting future revenues. The stability of tax revenue is essential for formulating long-term fiscal policies and making informed decisions regarding public spending and investment.

The ability to accurately estimate the elasticity of key taxes, such as VAT and IT, also has policy implications. It allows policymakers to evaluate the effectiveness of existing tax policies and make necessary adjustments to enhance revenue collection. For instance, during economic downturns, understanding the elasticity of tax revenues can help the government design targeted interventions to mitigate revenue shortfalls and maintain fiscal balance.

For these reasons, estimating the income elasticity of tax revenue is a critical aspect of the Mexican tax system. It provides insights into how tax revenues will respond to economic changes, ensuring that federal transfers to states and municipalities are adequate and stable. This understanding helps in designing effective fiscal policies, enhancing revenue collection, and ensuring the efficient allocation of resources across various levels of government.

Figure 3.1: Proportion of the federal taxes due to VAT and IT



Note: Own elaboration based on data from the Ministry of Finance.

4. Data

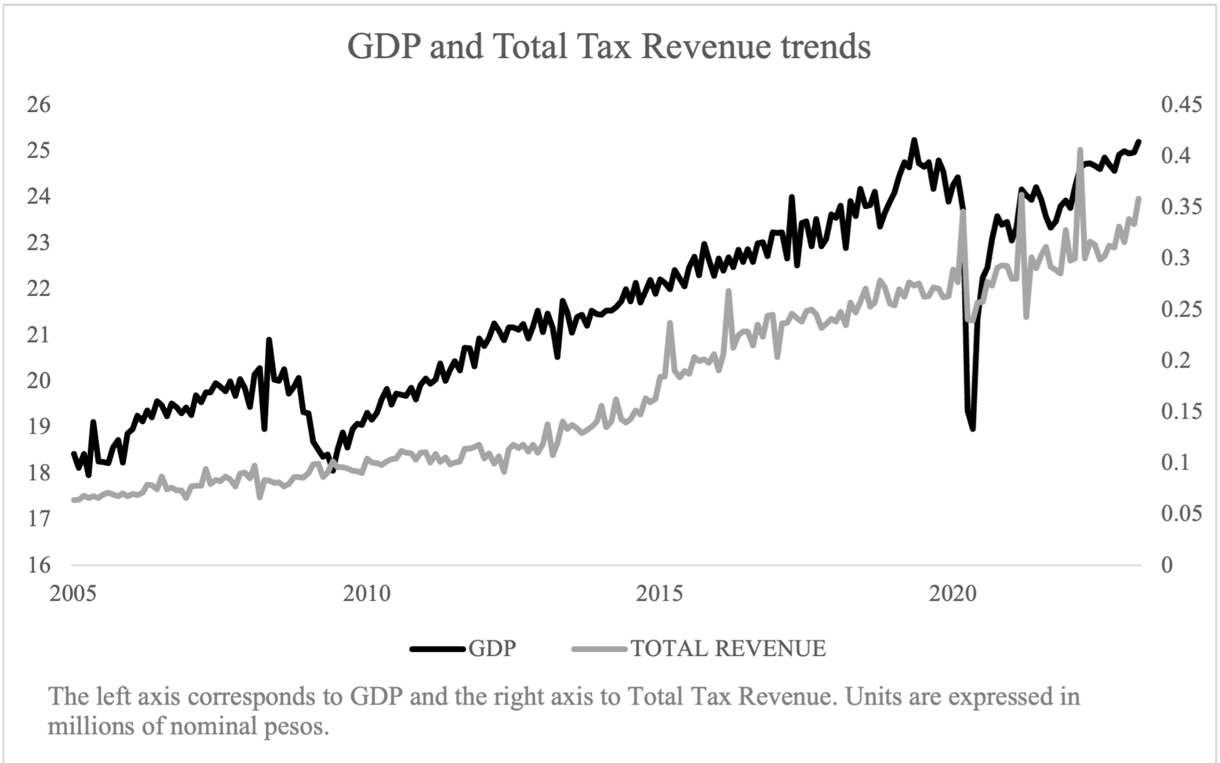
To measures the level of economic production, the General Economic Activity Index (IGAE) published by the National Institute of Statistics and Geography (INEGI) was used. This variable was adjusted to express the nominal GDP of the economy using the Implicit Price Index published by INEGI. The measure of GDP published by the same institution was discarded due to its quarterly frequency and the IGAE is a monthly measure. This allows for estimates obtained with more degrees of freedom, as the other variables are also measured monthly.

Regarding the tax time series (IT, VAT, and total taxes), these were retrieved from the website of the Ministry of Finance and Public Credit (SHCP). Similarly, they are measured in nominal pesos. The National Consumer Price Index (INPC) was used to deflate them. To capture labor market activity, the unemployment rate from INEGI was utilized.

As for other control variables, the WTI crude oil prices series is obtained from the Federal Reserve Bank of St. Louis (FRED). The models also include COVID-19 deaths as a proxy for the pandemic. This data was obtained from the Conacyt page responsible for measuring COVID-19 deaths.

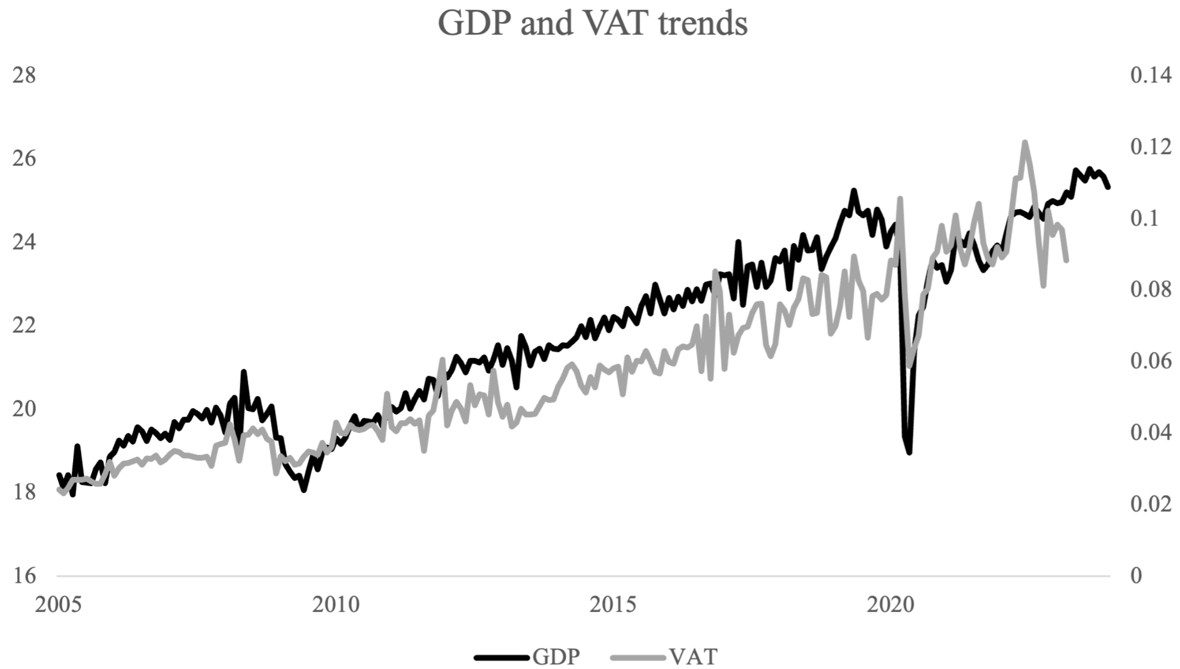
To construct the variable for the 2008 crisis, it was employed the time frame used by the FRED. Thus, the crisis spans from 2008 to the end of 2009.

Figure 4.1: GDP and TTR



Note: Own elaboration based on data from INEGI and the Ministry of Finance.

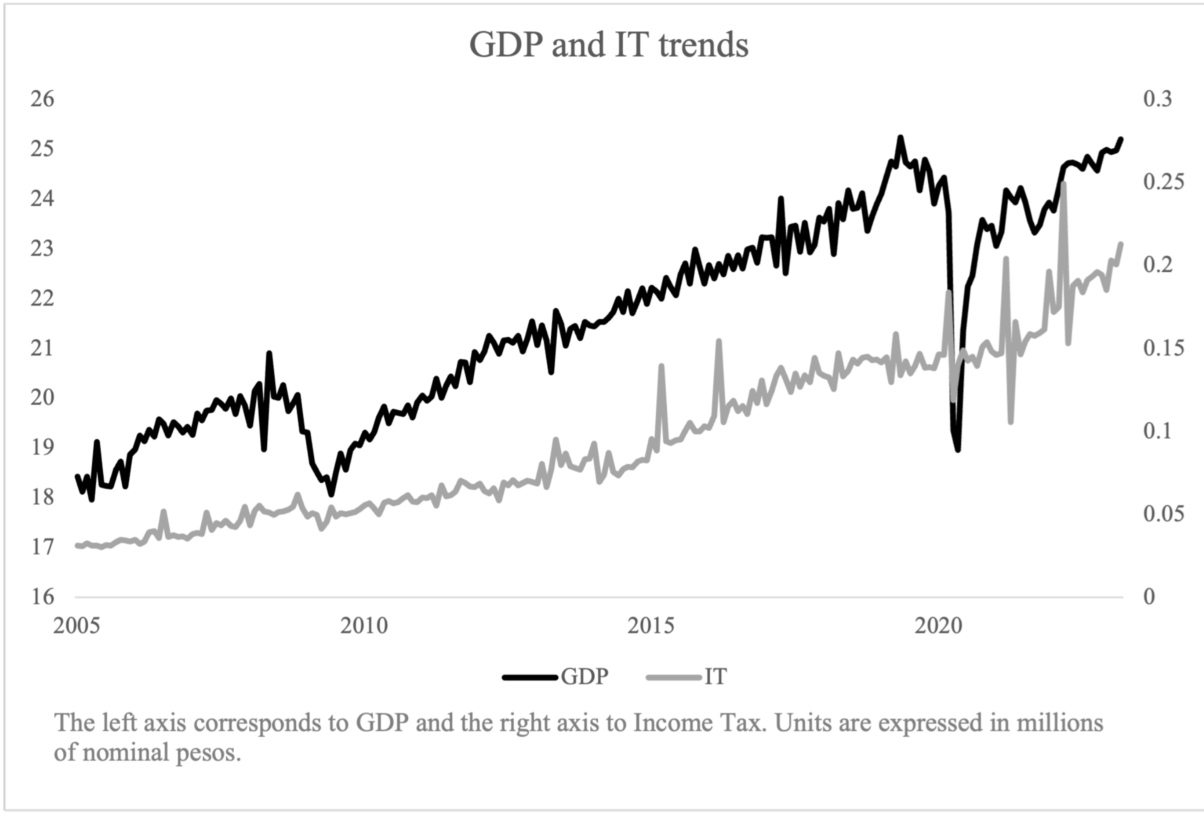
Figure 4.2: GDP and VAT



The left axis corresponds to GDP and the right axis to Value Added Tax. Units are expressed in millions of nominal pesos.

Note: Own elaboration based on data from INEGI and the Ministry of Finance.

Figure 4.3: GDP and IT



Note: Own elaboration based on data from INEGI and the Ministry of Finance.

5. Methodology

In economics, many variables, given their relationships, can linearly group to form a cointegration model. The use of such models can be justified, on one hand, through economic reasoning. Specifically, the variables used in tax elasticity analysis have a clear relationship, as GDP is determined by tax revenue and labor force, measured through the unemployment rate.

Cointegration analysis is based on the argument that various time series can have a statistical relationship even when the individual series are I(1), meaning they have a unit root. The reason why this is possible is that the linear combination of these series causes the system (in error correction form) to converge to a stable solution.

On the other hand, to demonstrate statistically that the variables used in this study are candidates for such a model, the following statistical tests must be conducted: 1) find evidence that all series are I(1), meaning that when the first difference of each series is taken, they become stationary. 2) Conduct a cointegration test with all the variables intended for use. In this study, the Johansen test (Johansen, 1988) is employed. 3) Obtain impulse response functions to confirm that the system indeed converges to a particular solution.

Among the cointegration models are the Vector Error Correction Model (VECM) and the Autoregressive Distributed Lag model with error correction (ARDL ECM). This study obtains estimates using both models to determine if there are substantial differences between them.

The VEC model equation is specified as follows:

$$\Delta y_t = \mu_t + \alpha\beta' y_{t-k} + \sum_{i=1}^{t-k} \Delta y_{t-i} + \epsilon_t$$

Where alpha represents short-term corrections, and beta are the coefficients for long-term relationships. Additionally,

$$y_t = (\text{nominal GDP}, \text{EAP}, \text{Tax})$$

The equation for the ARDL model with Error Correction Mechanism (ECM) is represented by the following equation:

$$TAX_t = \alpha_0 + \sum_{i=1}^{k} \beta_i TAX_{t-i} + \sum_{i=1}^{k} \gamma_i EAP_{t-i} + \sum_{i=1}^{k} \delta_i PIB_{t-i} + \theta ECM_{t-1} + \epsilon_t$$

In both specifications, the parameter k represents the number of lags in the equations, which are determined by finding the lag that takes appropiate control of autocorrelation in the model.

The second part of the article involves estimating a counterfactual to obtain an approximation of the revenue that would have been obtained if the pandemic had never occurred. In the case of the VEC model, the counterfactual was estimated as follows:

- The model is estimated with the complete sample (we called this model Ra).
- The same model is estimated with the sample ending in February 2020, one month before the official declaration of the coronavirus pandemic.
- A revenue forecast is estimated based on the model from step two. These forecasted values are extracted and rejoined with the sample, creating a complete sample again (called Rc).
- The difference Rc-Ra is estimated. This represents the difference between the revenue obtained with the pandemic and what would have been obtained if it had not occurred.

For the ARDL model, the procedure is different. Since ARDL is not capable of generating forecasts for its variables endogenously, econometricians must provide the model with a forecast for each variable. Thus, the issue now is to choose how to estimate the growth of the independent variables: GDP, unemployment rate, and WTI. In the case of the unemployment rate, as the variable grows at an almost constant rate, it was decided to impose a linear trend. For the WTI, an AR(1) model was used. Regarding the GDP, two cases were tested: using an AR(1) model and using the growth rate that the Bank of Mexico forecasted for Mexico's GDP in february 2020 (1.4 % annual growth).

6. Results

To ensure the validity of the estimates, it is crucial to determine the stationarity of the variables used in the analysis. Stationarity implies that the statistical properties of a time series, such as mean and variance, are constant over time. Non-stationary data can lead to spurious regression results, making it imperative to perform unit root tests. In this study, we employ two commonly used unit root tests: the Phillips-Perron (PP) test and the Augmented Dickey-Fuller (ADF) test.

The Phillips-Perron test corrects for any serial correlation and heteroskedasticity in the errors of the test regression. The results of the Phillips-Perron test are presented in the first two columns of Table 6.1. For all variables, including nominal GDP, the unemployment rate, IT, VAT, and total tax revenue, the null hypothesis of a unit root (indicating non-stationarity) cannot be rejected when the variables are in levels. This is evident from the high p-values associated with the test statistics.

However, when the first differences of these variables are considered, the p-values drop to near zero. This strongly rejects the null hypothesis of a unit root, indicating that the first differences of all the variables are stationary. Therefore, all variables are integrated of order one, I(1).

The ADF test is another method used to check for the presence of a unit root in a time series sample. Similar to the PP test, the ADF test results, shown in the third and fourth columns of Table 1, indicate that the null hypothesis of a unit root cannot be rejected for any of the variables in levels, as demonstrated by the non-significant p-values.

When the first differences of the variables are taken, the ADF test statistics are significantly negative, and the p-values indicate that the null hypothesis of a unit root is rejected at conventional significance levels. This confirms that the first differences of all variables are stationary, reinforcing the conclusion from the PP test that all variables are I(1).

The confirmation that all variables are I(1) has important implications for our subsequent analysis. It implies that while the variables themselves are non-stationary, their first differences are stationary, allowing us to proceed with cointegration analysis. Cointegration models are appropriate when dealing with non-stationary series that have a long-term equilibrium relationship, which is the case in this study.

By establishing the stationarity of the first differences, we ensure that our econometric mod-

Table 6.1: Unit root tests (p-values)

Variable	Phillips-Perron		Augmented Dickey-Fuller	
	In levels	First Difference	In levels	First Difference
Nominal GDP	0.442	-14.727	-1.089	-10.018
	(0.861)	(0.000)	(0.72)	(≈ 0)
Unemployment rate	1.0824	-14.829	-1.379	-9.729
	(0.954)	(0.000)	(0.59)	(≈ 0)
IT	2.301	-28.661	0.845	-11.439
	(0.999)	(0.000)	(0.99)	(≈ 0)
VAT	0.652	-19.243	-0.784	-10.933
	(0.902)	(0.000)	(0.82)	(≈ 0)
Total Revenue	2.550	-25.898	0.565	-11.469
	(1.000)	(0.000)	(0.98)	(≈ 0)

Note: The table shows the test statistic and the corresponding p-value in parenthesis. Own elaboration

els, VECM and ARDL ECM, are based on valid assumptions. After establishing that our variables are integrated of order one, I(1), we proceed with cointegration analysis to determine whether there is a long-term equilibrium relationship among them. Cointegration tests are essential as they allow us to assess if non-stationary time series variables move together over time, implying a stable relationship despite short-term fluctuations. In this study, we employ (Johansen, 1988) test, which is robust in determining the number of cointegrating vectors in a multivariate setting.

The Johansen test provides two types of test statistics: the trace statistic and the maximum eigenvalue statistic. Both tests evaluate the null hypothesis that there are r cointegrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors.

The trace test assesses the null hypothesis that the number of cointegrating vectors is r against the alternative hypothesis of more than r cointegrating vectors. The trace statistic is estimated as:

$$\text{Trace statistic} = -T \sum_{i=r+1}^{k} \ln(1 - \lambda_i)$$

where λ_i are the estimated eigenvalues and T is the sample size.

The maximum eigenvalue test evaluates the null hypothesis that there are r cointegrating vectors against the alternative hypothesis of $r + 1$ cointegrating vectors. The maximum eigenvalue statistic is given by:

$$\text{Max eigenvalue statistic} = -T \ln(1 - \lambda_{r+1})$$

where λ_{r+1} is the $(r + 1)$-th largest eigenvalue.

The table 6.2 presenting the Johansen cointegration test results includes both the trace and maximum eigenvalue statistics along with their corresponding p-values for the variables VAT, IT, and total tax revenue. The table compares two null hyphoteses: $\mathcal{H}_0$, there are zero cointegrating vectors; $\mathcal{H}_1$, there is one cointegrating vector.

Table 6.2: Johansen test results (p-values)

Cointegration Test	Test hypothesis	VAT	IT	Total
Trace	$\mathcal{H}_0$	36.57 (0.006)	41.02 (0.001)	83.18 (0.00)
	$\mathcal{H}_1$	4.85 (0.82)	8.12 (0.45)	7.21 (0.55)
Lmax	$\mathcal{H}_0$	31.71 (0.0007)	66.07 (0.00)	82.49 (0.00)
	$\mathcal{H}_1$	3.71 (0.88)	5.49 (0.68)	3.98 (0.85)

Note: The table shows the test statistic and the corresponding p-value in parenthesis. Own elaboration

For all three tax categories—VAT, IT, and total tax revenue—the trace test rejects the null hypothesis of zero cointegrating vectors (H0) at conventional significance levels. The trace statistics for VAT, IT, and total tax revenue are 36.5, 41.02, and 83.1, respectively, all with p-values well below 0.05, indicating strong evidence against the null hypothesis of no cointegration. However, when testing the null hypothesis of at least one cointegrating vector (H1), the test fails to reject the hypothesis for any of the tax categories, as indicated by the high p-values (e.g., 0.82 for VAT).

Similarly, the maximum eigenvalue test results support the presence of at least one cointegrating vector for each tax category. The maximum eigenvalue statistics for VAT, IT, and total tax revenue are 31.7, 66.07, and 82.49, respectively, all with p-values below 0.05, rejecting the null hypothesis of zero cointegrating vectors. However, the test fails to reject the null hypothesis when there is one cointegrating vector (H1), as shown by the non-significant p-values (e.g., 0.88 for VAT).

The Johansen cointegration test results provide evidence of at least one cointegrating vector for VAT, IT, and total tax revenue. This indicates that there is a long-term equilibrium relationship between these tax revenues and the economic variables used in the model (nominal GDP and the unemployment rate). The existence of cointegration implies that, despite short-term deviations, the tax revenues and economic variables will move together in the long run, maintaining a stable relationship. After confirming cointegration, we can proceed to estimate the long-term and short-term dynamics of tax revenues in response to economic changes.

Estimation of Elasticities

The Vector Error Correction Model (VECM) is employed to estimate the long-term relationships and short-term dynamics between tax revenues (VAT, IT, and total tax revenue) and economic variables (nominal GDP and unemployment rate). The VECM not only captures these relationships but also incorporates adjustments towards the long-term equilibrium following short-term shocks. Table 6.3 presents the results of the VECM for VAT, IT, and total tax revenue.

The VECM results are summarized in terms of the endogenous variables (nominal GDP and unemployment rate), the exogenous variables (WTI crude oil prices and COVID-19 deaths), and the Error Correction Mechanism (ECM) coefficients.

The coefficients for nominal GDP reflect the long-term relationship between tax revenues and economic output. The coefficients are -1.29 for VAT, -1.75 for IT, and -1.68 for total tax revenue. These negative values indicate that as nominal GDP increases, the tax revenues also increase, consistent with economic theory. The magnitudes of these coefficients suggest that a 1% increase in nominal GDP is associated with a 1.29%, 1.75%, and 1.68% increase in VAT, IT, and total tax revenue, respectively. The unemployment rate's coefficients are restricted to be equal to zero, indicating that the unemployment rate is assumed to have no significant long-term relationship with the tax revenues in this model. This should not be interpreted as the unempoyment not having an effect in the model at all. The restriction only means that the relation between unemployment rate and the tax revenue is zero in the long run.

The WTI crude oil prices are included as an exogenous variable for total tax revenue, with a coefficient of 0.358. This positive coefficient suggests that an increase in oil prices is associated with higher total tax revenue, likely due to the significant role of oil-related revenues in Mexico's economy. The inclusion of COVID-19 deaths as a proxy for the pandemic's impact indicates the model accounts for the economic disruptions caused by the pandemic. The presence of this variable helps isolate the effects of the pandemic from the underlying economic trends.

The ECM coefficients (α) capture the speed at which the system returns to equilibrium after a short-term shock. These coefficients are crucial for understanding the short-term adjustments towards the long-term relationship. For VAT, the ECM coefficient is -0.69, indicating that approximately 69.7% of any deviation from the long-term equilibrium is corrected each month. This suggests a relatively rapid adjustment back to equilibrium. For IT, the ECM coefficient is -0.469, indicating that 46.9% of deviations are corrected monthly. This implies a moderate speed of adjustment. For total tax revenue, the ECM coefficient is -0.308, suggesting that 30.8% of deviations are corrected each month, indicating a slower adjustment process compared to VAT and IT.

The VECM results highlight the strong and significant long-term relationships between tax revenues and nominal GDP. The coefficients for GDP suggest that economic growth leads to higher tax revenues, which is essential for fiscal planning and budget projections. The varying speeds of adjustment, as indicated by the ECM coefficients, provide insights into how quickly tax revenues return to equilibrium after economic shocks.

For policymakers, these findings emphasize the importance of fostering economic growth to enhance tax revenues. The rapid adjustment of VAT revenues suggests that consumption taxes respond quickly to economic changes, making them a stable source of revenue. In contrast, the slower adjustment of total tax revenues indicates the need for additional measures to stabilize revenue streams during economic downturns.

Table 6.3: VEC model results for the three tax categories

	Variable	VAT	IT	Total Revenue
Endogenous	Nominal GDP	-1.293 (0.034)	-1.750 (0.052)	-1.683 (0.035)
	Unemployment rate	0	0	0
	Tax	1	1	1
Exogenous	WTI	x	x	-0.358 (0.030)
	COVID deaths	Included	Included	Included
	D2008	Included	Included	Included
ECM	α_1	0	0	0.110 (0.019)
	α_2	0	0	-0.343 (0.178)
	α_3	-0.697 (0.129)	-0.469 (0.087)	-0.308 (0.063)
Lags		6	3	6

Note: The values in parentheses represent standard errors. Own elaboration.

The ARDL model with ECM is also used to estimate the long-run elasticities of VAT, IT, and total tax revenue with respect to economic variables. Table 6.4 presents the long-run elasticity estimates for VAT, IT, and total tax revenue, capturing the responsiveness of these tax revenues to changes in nominal GDP and other variables.

The long-run elasticity of tax revenues with respect to nominal GDP is a critical measure of how tax revenues respond to changes in economic activity. The elasticity of VAT with respect to nominal GDP is 1.229, indicating that a 1% increase in nominal GDP leads to a 1.22% increase in VAT revenue. This positive and significant elasticity reflects the strong relationship between economic growth and VAT revenue. The elasticity of IT with respect to nominal GDP is 1.77, suggesting that a 1% increase in nominal GDP results in a 1.77% increase in IT revenue. This higher elasticity compared to VAT indicates that income tax revenue is more sensitive to changes in economic activity. The elasticity of total tax revenue with respect to nominal GDP is 1.68, meaning that a 1% increase in nominal GDP leads to a 1.68% increase in total tax revenue.

The coefficients for the unemployment rate capture the relationship between labor market conditions and tax revenues. The elasticity of VAT with respect to the unemployment rate is -0.02, indicating that an increase in the unemployment rate has a small negative impact on VAT revenue. This suggests that higher unemployment slightly reduces consumption, leading to lower VAT collection.For IT and total revenue, this coefficient is not statistically significant, indicating that the unemployment rate does not have a strong long-term impact on these taxes.

The ARDL long-run elasticity estimates provide insights into the responsiveness of tax revenues to economic changes. The elasticities with respect to nominal GDP for VAT (1.22), IT (1.77), and total tax revenue (1.68) indicate that tax revenues grow more than proportionately with economic growth. This relationship suggests that economic expansion leads to significant increases in tax revenues.

Table 6.4: ARDL long-run estimates of elasticities for the three tax categories

Variables	Regressions VAT	IT	Total Revenue
Nominal GDP	1.229	1.770	1.683
	(0.034)	(0.092)	(0.067)
Unemployment	-0.020	-0.026	0.001
	(0.009)	(0.022)	(0.018)
Constant	3.99	1.911	2.783
	(0.748)	(0.387)	(0.522)
Non-dynamic regressors			
D2008	Included	Included	Included
COVID deaths	Included	Included	Included
WTI	Not Included	Included	Included
Lags			
	(6)	(3)	(6)

Note: The values in parentheses represent standard errors. Own elaboration.

Estimation of IRFs

Impulse response functions (IRFs) are an important tool for understanding the dynamic behavior of variables in a system following a shock to one of the variables. The way these are calculated differ when dealing with VECM or ARDL models. For the first one, the error terms ϵ_t of the VEC equation is used to Identify the shocks by decomposing them into orthogonal components. This is done using the Cholesky decomposition. Then, the IRFs are computed by simulating the response of the system to a one percent shock in each variable. In the case of the ARDL, there is no need to use a decomposition for the residuals because this model uses a single equation, in contrast to the VECM model.

In the context of this study, the IRFs show the responses of VAT, IT, and total tax revenue to a 1% shock in nominal GDP. For each tax category, there are two IRFs: one from the VEC model (in red) and one from the ARDL model (in blue). Both sets of IRFs exhibit similar behavior, providing evidence of the robustness of the results.

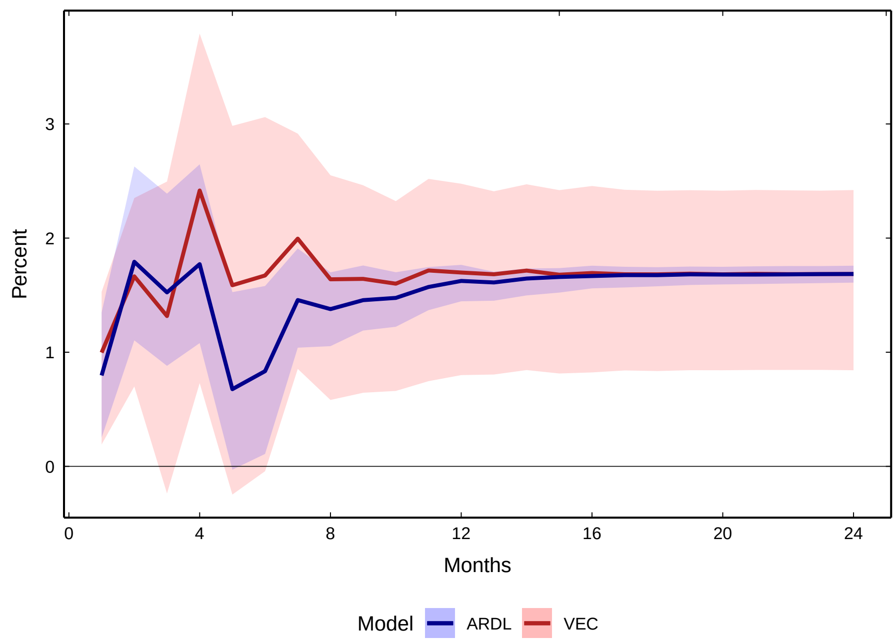
The IRFs from both the VEC and ARDL models of the total tax revenue (figure 6.1) show a positive response to a GDP shock, reflecting the combined effect of increased consumption and income. The similarity in the magnitude and duration of the responses from both models indicates a robust relationship between economic growth and total tax revenue.

Figure 6.2 show how VAT revenue reacts to a sudden increase in GDP. Both the VEC and

ARDL models display a positive initial response, reflecting an immediate increase in consumption and, consequently, higher VAT collection. Over time, the response stabilizes, indicating a new equilibrium level of VAT revenue. The similarity in the response patterns from both models reinforces the reliability of the findings. The confidence intervals, shown with the IRFs, help assess the robustness of the response, with narrower intervals indicating more precise estimates.

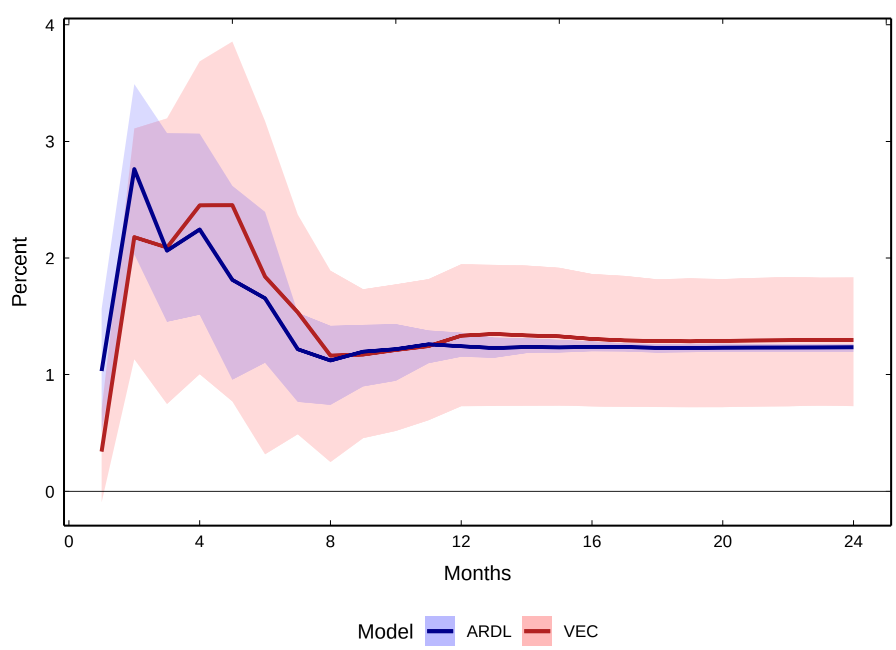
For income tax revenue, the IRFs (figure 6.3) from both the VEC and ARDL models show a positive reaction to a GDP shock. As GDP increases, income levels and employment generally rise, leading to higher income tax collections. The response curves from both models exhibit a similar shape, indicating a rapid initial increase followed by stabilization. This consistency across models suggests that the IT system efficiently adapts to changes in economic activity.

Figure 6.1: IRFs for Total Tax Revenue



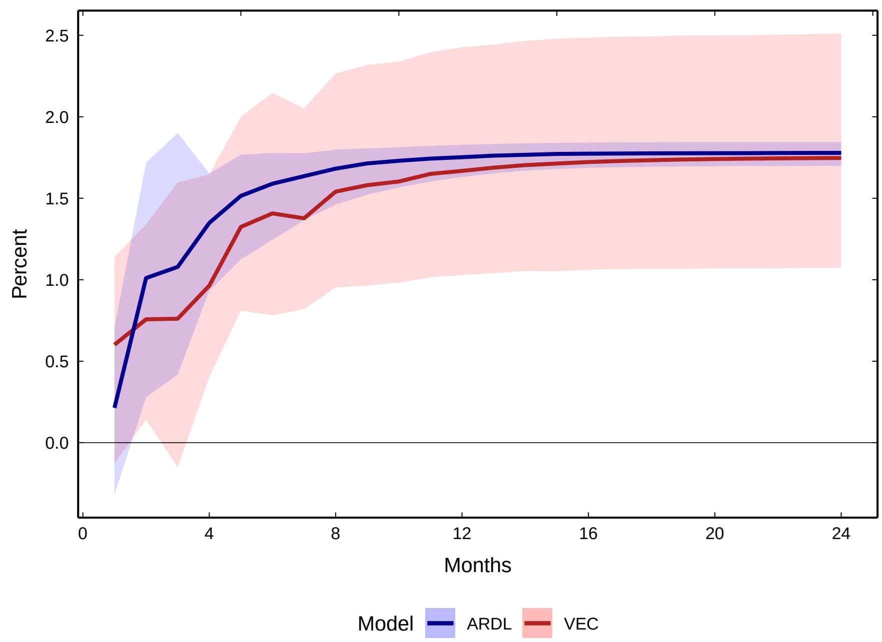
Source: Own elaboration

Figure 6.2: IRFs for VAT



Source: Own elaboration

Figure 6.3: IRFs for IT



Source: Own elaboration based on estimated models.

Estimation of counterfactuals

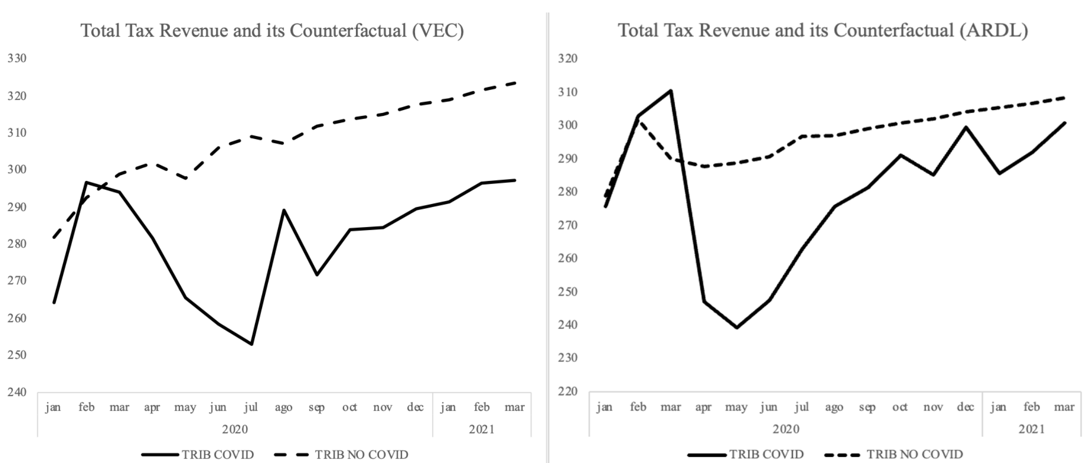
The graphs 6.4, 6.5 and 6.6 compare the counterfactual scenarios estimated using both the VEC and ARDL models. These counterfactuals estimate what the tax revenues (total taxes, VAT, and IT) would have been if the COVID-19 pandemic had not occurred.

For Total Tax Revenue, both the VEC and ARDL models show a significant divergence between actual and counterfactual revenues, highlighting the impact of the pandemic on total tax revenues. The close alignment between the counterfactuals from the VEC and ARDL models indicates that both models provide consistent estimates.

Similarly, the graphs for IT revenue present a comparison of actual revenues with the counterfactual scenarios. Both the VEC and ARDL models indicate a significant decline in IT revenues during the pandemic, with the counterfactual scenarios showing higher revenues had the pandemic not occurred. The alignment between the VEC and ARDL estimates confirms the reliability of the models in capturing the impact of the pandemic on IT revenues.

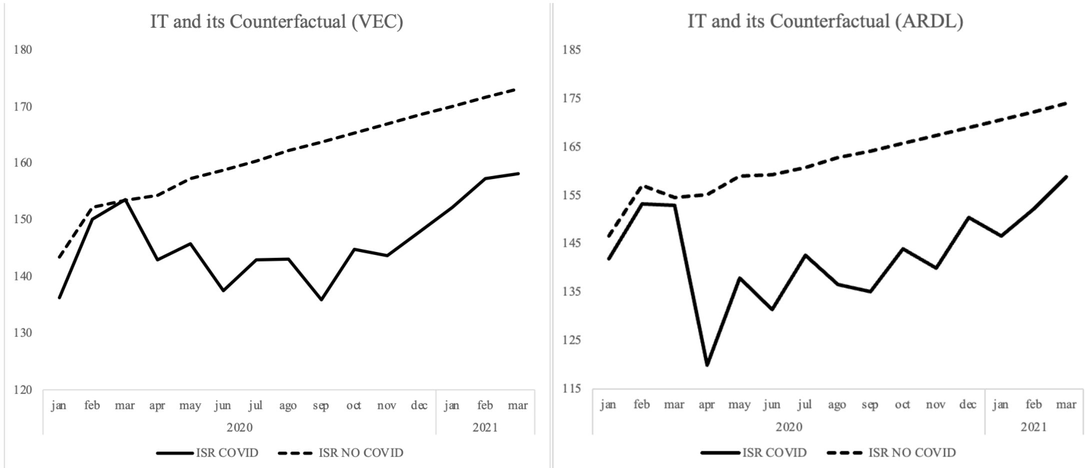
Finally, the graphs for VAT revenue compare the actual revenues with the counterfactual scenarios. Both models depict a notable drop in VAT revenues due to the pandemic, with the counterfactual scenarios showing higher revenues in the absence of the pandemic. The consistency in the patterns across both models suggests that the estimated impact of the pandemic on VAT revenue is robust.

Figure 6.4: Counterfactuals for TTR



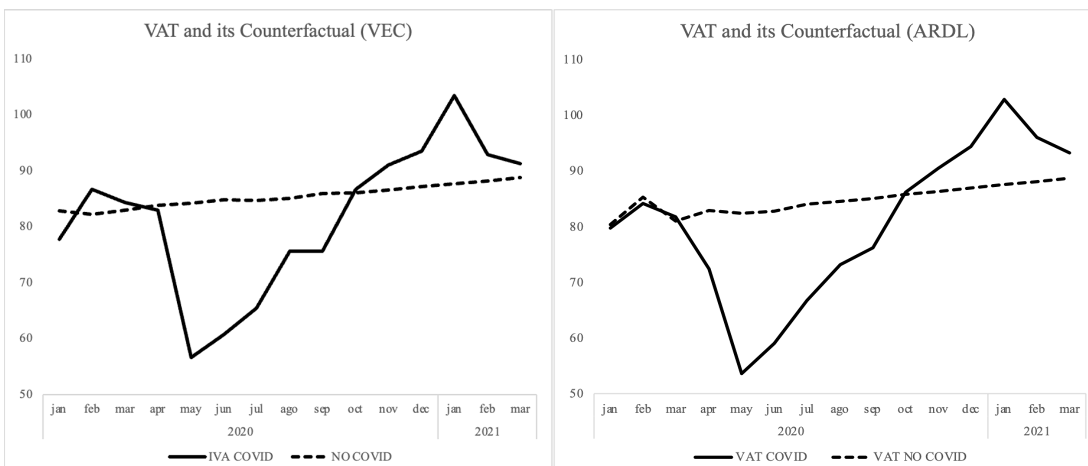
Source: Own elaboration based on estimated models.

Figure 6.5: Counterfactuals for IT



Source: Own elaboration based on estimated models.

Figure 6.6: Counterfactuals for VAT



Source: Own elaboration based on estimated models.

Estimation of Revenue Loss

Table 6.5 presents the estimates of revenue loss for each type of tax—total taxes, VAT, and IT—expressed in millions of nominal pesos. These estimates are crucial for understanding the fiscal impact of the COVID-19 pandemic on Mexico's tax revenues. The revenue loss is estimated using both the VEC model and the ARDL model, under different scenarios. Each table allows for a comparison of the estimated revenue loss under various assumptions.

The first panel presents the revenue loss from total taxes, comparing the actual revenues with the counterfactual scenario where the pandemic did not occur. The VEC model estimates a revenue loss of 307,023.38 million pesos, which is 1.18% of GDP. This estimate indicates a significant impact of the pandemic on total tax revenues, reflecting the economic contraction during the pandemic period. Using the ARDL model with ARIMA forecasts for GDP growth, the estimated revenue loss is 216,908.31 million pesos, or 0.83% of GDP. This lower estimate compared to the VEC model suggests a less severe impact under this forecasting method. When the ARDL model is used with the Bank of Mexico's GDP growth forecast of 1.4%, the estimated revenue loss is 309,778.70 million pesos, or 1.00% of GDP. This estimate is closer to the VEC model's result, indicating a significant fiscal impact.

The second panel presents the revenue loss from VAT, highlighting the impact of the pandemic on consumption-related tax revenues. The VEC model estimates a VAT revenue loss of 74,527.82 million pesos, which is 0.28% of GDP. This indicates a substantial decline in consumption and related tax revenues due to the pandemic. The ARDL model with ARIMA forecasts estimates a VAT revenue loss of 56,375.15 million pesos, or 0.22% of GDP. This lower estimate suggests a relatively smaller impact on VAT revenues. Using the ARDL model with Banxico's GDP growth forecast, the estimated VAT revenue loss is 88,091.61 million pesos, or 0.33% of GDP. This higher estimate underscores the significant effect of the pandemic on consumption.

The third panel presents the revenue loss from IT, reflecting the impact of the pandemic on income-related tax revenues. The VEC model estimates an IT revenue loss of 172,988.19 million pesos, or 0.66% of GDP. This reflects the negative impact of the pandemic on income levels and income tax collections. Using the ARDL model with ARIMA forecasts, the estimated IT revenue loss is 203,468.01 million pesos, or 0.78% of GDP. This higher estimate indicates a significant impact on income tax revenues. The ARDL model with Banxico's GDP growth forecast estimates an IT revenue loss of 227,086.79 million pesos, or 0.87% of GDP. This result highlights the substantial decline in income tax revenues due to the pandemic.

Table 6.5: Revenue Loss from Taxes

Tax Type	Model	With COVID	Without COVID	Loss	Loss as % of GDP
Total Taxes	VEC	$2,771,334.963	$3,078,358.341	$307,023.3776	1.18
Total Taxes	ARDL ARIMA	$2,739,967.68	$2,956,875.99	$216,908.30821	0.83
Total Taxes	ARDL Banxico	$2,739,967.68	$3,049,746.38	$309,778.69988	1.00
VAT	VEC	$858,943.12	$933,470.95	$74,527.82	0.28
VAT	ARDL ARIMA	$768,400.65	$824,775.81	$56,375.15	0.22
VAT	ARDL Banxico	$753,964.04	$842,055.65	$88,091.61	0.33
IT	VEC	$1,437,927.636	$1,610,915.825	$172,988.1885	0.66
IT	ARDL ARIMA	$1,390,633.84	$1,594,101.85	$203,468.007	0.78
IT	ARDL Banxico	$1,390,633.84	$1,617,720.63	$227,086.79	0.87

Source: Own elaboration based on estimated models.

7. Conclusions

The objective of the study was to estimate the income elasticities of the main taxes in Mexico and to assess the revenue loss due to the COVID-19 pandemic. By employing two different econometric models, VECM and ARDL, this study provided estimates of tax elasticities and quantified the fiscal impact of the pandemic. The consistency of results across different models adds to the reliability of the findings and offers insights for policymakers.

The income elasticities for VAT, IT, and total tax revenue were found to be greater than one, indicating that tax revenues grow more than proportionately with GDP. Specifically, the elasticity estimates from the VECM for VAT, IT, and total tax revenue were 1.51, 1.39, and 1.45, respectively. The ARDL model produced similar estimates, with elasticities of 1.57 for VAT, 1.53 for IT, and 1.44 for total tax revenue. The IRFs from the two models also shows a similar dinamic of tax revenues when the GDP changes.

The revenue loss estimates due to the COVID-19 pandemic were substantial across all tax categories. The VECM estimated a total tax revenue loss of approximately 1.18% of GDP, while the ARDL model with ARIMA forecasts estimated a loss of 0.83% of GDP. The ARDL model with Banxico GDP forecasts showed a similar loss of 1.0% of GDP. For VAT, the losses ranged from 0.28% to 0.33% of GDP, and for IT, the losses ranged from 0.66% to 0.87%.

The findings of this study have several implications for fiscal policy in Mexico. First, the high elasticities of tax revenues with respect to GDP indicate that economic growth is crucial for increasing tax revenues. Policymakers should prioritize measures that stimulate economic growth, as this will lead to more substantial and sustainable increases in tax revenues. This includes policies that promote investment, enhance productivity, and support sectors that drive economic expansion.

Second, the significant revenue losses due to the COVID-19 pandemic highlight the vulnerability of the tax system to economic shocks. To mitigate the impact of such shocks, it is essential to build a more resilient tax system. This can be achieved by diversifying the tax base, improving tax compliance, and enhancing the efficiency of tax administration. Additionally, creating fiscal buffers, such as stabilization funds, can help manage revenue shortfalls during economic downturns.

Third, the consistent results across different econometric models emphasize the importance of using robust methodologies for fiscal analysis. By employing both the VECM and ARDL models, this study provides a comprehensive understanding of the long-term and short-term dynamics of tax revenues. Policymakers should consider using multiple models and approaches to validate their fiscal projections and policy evaluations.

While this study provides significant insights into the income elasticities of the main taxes in Mexico and the fiscal impact of the COVID-19 pandemic, there are several avenues for further research that could deepen our understanding of the findings. Future research could benefit from a more disaggregated analysis of tax categories. Analyzing the impact of economic shocks on tax revenues across different sectors could also offer valuable information. For instance, understanding how sectors like manufacturing, services, and agriculture contribute to overall tax elasticity would help tailor fiscal policies to support the most responsive sectors, thereby optimizing revenue collection. Finally, integrating behavioral factors, such as tax compliance and evasion, into the models could enhance the understanding of how economic conditions influence tax revenues. Behavioral responses to tax policies and economic changes can significantly affect revenue outcomes, and incorporating these factors would provide a more comprehensive analysis.

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