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The effect of legal entropy on value-added tax in Mexico, 1978–2023

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ABSTRACT

This study investigates the relationship between legal entropy (LE) and value-added tax (VAT) in Mexico. Legal entropy is considered a measure of uncertainty or instability within the legal framework, which may influence tax collection and government revenues. To explore this relationship, the study employs a causality approach combined with an autoregressive distributed lag (ARDL) model to assess both short-term and long-term dynamics. The results indicate a unidirectional causal link running from LE to VAT, suggesting that changes in legal uncertainty directly affect tax performance. However, no long-run cointegration is found between the two variables, implying the absence of a stable equilibrium relationship over time. In the short term, a one percent increase in the entropy index is estimated to reduce VAT revenue by approximately 2.06 percent. These findings highlight the potential risks posed by legal uncertainty for fiscal stability and effective tax policy.

1. Introduction

Legal norms can be complex, which means they may be ambiguous or unclear. An example is the Value-Added Tax Law (LIVA) in Mexico, from its original version in 1978 to the amendments it has undergone up to 2023.

LIVA has changed over time, affecting the complexity of the legal framework. In this paper, the method developed by Katz and Bommarito (2014) is used to analyze this complexity. This method creates an indicator called the "entropy index." This index reflects the evolution of the legal complexity of LIVA from its inception to the end of 2023. By observing the value of the index, one can determine whether the language used in the LIVA has become complex.

VAT has been an important source of revenue for the Mexican government since 1983, ranking second after income tax. Since its implementation in 1980, value-added tax (VAT) revenue has consistently increased each year. However, this growth has not exceeded 4% of Gross Domestic Product (GDP), with a maximum of 3.85% reached in 2010. In this regard, public finances need to identify additional factors beyond economic growth that could improve the efficiency of VAT collection, such as the legal entropy variable presented in this paper.

The hypothesis derived from this is that greater entropy in the law regulating the VAT hurts VAT revenue levels. In other words, an inverse relationship between the variable called entropy and the collection of value-added taxes is expected.

Specifically, Givati (2009) defined complexity in a legal text as the uncertainty generated by ambiguity in interpreting established provisions. One aspect that characterizes this ambiguity is the legal language used regarding the precise meaning of legal terms and the relative frequency with which they appear in legal texts. In this regard, the entropy index seeks to capture this component of legal complexity.

In this paper, legal entropy will be measured according to Katz and Bommarito's (2014) methodology, which is based on Shannon (1948). They use information theory to establish entropy as a specific expected value according to the levels of information in the dynamic system.

Consequently, the main goal of this research is to create an index to measure the evolution of legal entropy in the LIVA from its enactment in 1978 through 2023. This index will facilitate a deeper investigation into the relationship between legal

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entropy and VAT revenue. The following sections of this document present a literature review, the research methodology, findings, discussion, and conclusions to contrast the hypothesis of this research.

2. Literature review

By reviewing various supporting articles, contributions that would allow us to understand the relationship between legal entropy and the value-added tax in various economies, not just the Mexican case.

The study of legal complexity dates to the late 20th century, when Long and Swingen (1987) proposed an indicator based on an instrument administered to tax law professionals. The authors concluded that the instrument was robust and reflected the opinions and experiences of the respondents. Similarly, Schuck (1992) addressed US tax law, defining it as a complex legal instrument, as it presented a high content of technicalities, differentiation, uncertainty, and density of language.

In this regard, Kades (1997) applied theoretical elements from mathematics and computer science to justify the complexity of tax regulations based on the concepts of dynamic systems.

Epstein (1996) defined legal complexity based on the concept of compliance costs. In other words, a law is considered complex to the extent that it creates regulatory obstacles that hinder the achievement of a private objective.

In this context, Bourcier and Mazzega (2007) described legal complexity as a dynamic system characterized by the structure of the law, the content of the law, and the density of the legal corpus. The authors concluded that the relevant factors are the number of components, the interaction between them, partial knowledge of the dynamic linkages, limited predictability of the evolution of the legal system, and the addition of new components to tax law.

Subsequently, Katz and Bommarito (2014) measured a standard individual's difficulty in understanding the legal framework if greater complexity means a higher cost of compliance. The authors design an indicator with three components: the structure of the law, the language of the law, and interdependence within and with other laws. In this regard, this article analyzes variable language from the perspective of the concept of entropy, which aims to define how many times a word appears throughout the text of the law. This is intended to analyze the legal complexity resulting from the variation in entropy and its consequences for VAT collection.

This concept of entropy can be related to various definitions of information theory that were initially developed in physics and engineering and are now used in various disciplines. Information is a quantity inversely proportional to the probability of an event occurring, and entropy can be considered the expected value of information. These concepts' economic applications are found in deriving the Theil inequality coefficient, the Akaike information criterion, and the maximum entropy estimation method.

Miguel-Velasco et al. (2008) directly applied the concept of entropy by analyzing regional inequalities in Mexico from the perspective of the human development index between 1950 and 2003. To do so, they propose a methodology to measure inequality based on the concepts of absolute and relative entropy of the indicators of development, equity, efficiency, and sustainability of Mexico.

Similarly, García et al. (2014) used the concept of Shannon entropy to propose a measure of market efficiency using the empirical density function of returns. The authors show that under certain conditions of ergodicity and stationarity, the sample entropy converges to the entropy of the dominant state, which validates the use of sample entropy as a measure of efficiency according to the axioms of Artzner et al. (1999).

Other authors approach entropy as a relevant component of complex systems. Thus, Waltl and Matthes (2014) designed various structural indicators of lexicon and correlations and concluded that the average length of a law's paragraphs correlates with readability and, therefore, with its level of complexity. Similarly, Ruhl and Katz (2015) distinguished complexity in terms of the confusion a person experiences when understanding a law. The authors explain that legal complexity increases as the dependencies between the elements of a law increase because a modification in one legal element affects other elements of the law and the element itself. This ambiguity resulting from entropy would be expected to have a negative effect on VAT collection.

As used in information theory, Bacallao et al. (2002) proposed three indices for measuring social health inequalities based on entropy. All three proposed indices employ the Kullback-Liebler and Hoover transformations. The authors point out that indices based on the notion of entropy have the following properties: do not vary with changes in scale; are symmetrical; incorporate the social dimension; and are easy to interpret thanks to the equivalent condition between entropy and a two-class system defined by the authors. In this article, the authors show how entropy can have broad applications within the social sciences.

Within the entropy approach as an element of information theory, Espinosa and Alvarez (2022) stated that text is a raw material, where AI tools allow for analyzing patterns and recognizing hidden ideas in large volumes of text. Text analysis usually has three components: structure, language, and interdependence, with the language component being the element that can be related to the concept of entropy to apply the classic tools of Econophysics.

In other areas of social sciences, Calero (2019) addressed the concept of entropy as a non-neoclassical production function to analyze the behavior of the Nicaraguan macroeconomic system between 2000 and 2010. The author was able to verify that entropy is a non-neoclassical alternative tool that can contribute to macroeconomic analysis robustly.

Likewise, Escola et al. (2021) used the Weighted Entropy Coefficients Method to analyze the weight of each of the four dimensions of Sustainable Development in Ecuador, which are economic, social, environmental, and institutional. The analysis period covers the years 2008-2015. The authors find evidence that the economic subsystem is the one that contributes the most to Sustainable Development, and its indicators have the most significant weight in the entire system. However, the evolution of the social and environmental subsystems shows gradual growth. This paper seeks to support the view that entropy can influence economic activity and legal complexity, which in turn influences VAT collection.

In this context, Rivas (2014) presented three indices to estimate Nicaragua's degree of export diversification. The data set includes annual data from the Central Bank of Nicaragua from 2000 to 2013. The indicators used are the Herfindahl-Hirschman index, the Ojiva index, and the Entropy index. These indices are calculated by product and trade destination, so two values will be obtained for each concentration index: one for products and another for trading partners. It is concluded that the three indices show an increasing trend in export diversification by trade destination. The author demonstrates that entropy can be applied to international trade and, therefore, has an influence on tax collection.

In Finance, Bejarano et al. (2023) found that information entropy is a robust tool for analyzing price flow behavior in the financial market. To this end, the authors emphasize the following points: general concepts of chaos theory linked to the financial market, dynamical systems associated with price flows, univariate time series of prices, and information entropy indices that can be applied to price flows.

Devi (2019) investigated Tsallis relative entropy, the generalization of Kullback-Leibler relative entropy to non-extensive systems, as a possible risk measure for investment portfolio construction. The author constructs various portfolios and performs a comparative analysis with the CAPM model, the Kullback-Leibler index, and the classical standard deviation ratio, and finds evidence to affirm that portfolios generated using Tsallis relative entropy show more consistent behavior, both in goodness of fit and in the variation of returns with risk. This analysis shows the applicability of the concept of entropy to investment portfolio risk management and its possible implementation in the economic and fiscal sphere.

Lassance and Vrins (2021) employed the exponential Rényi entropy function, an information-theoretic criterion that measures the degree of uncertainty inherent in a probability distribution, considering higher-order moments. Their portfolio selection application illustrates that minimizing the Rényi entropy implies portfolios that outperform minimum-variance portfolios. This study also highlights the idea that different entropy metrics are applicable to the economic sphere.

Specifically, in the case of Mexico, Moreno Espinosa et al. (2020) determined the impact of economic growth and the legal complexity of the Value-Added Tax Law (VAT Law) on VAT collection between 1980 and 2016. This analysis is based on a least squares model modified by the Box-Cox transformation. The results reveal a positive relationship between economic growth and VAT collection and a negative relationship between the legal complexity index and VAT collection.

In this paper, the analysis focuses on the impact of legal entropy (LE) on Mexico's VAT. An additional contribution to the literature for the Mexican case is the application of the procedure developed by Toda and Yamamoto (1995) to test for Granger non-causality, followed by the estimation of an autoregressive distributed lag (ARDL) model. The objective is to find evidence of Granger causality from entropy to VAT and to verify cointegration between both variables.

The following section explains the methodology used in this article to perform the corresponding estimates that verify the hypotheses raised.

3. Data selection and acquisition

This study uses quarterly time series data on Mexico’s VAT from 1978 to 2023. The data were seasonally adjusted with the TRAMO/SEATS software, as illustrated in Fig. 1.

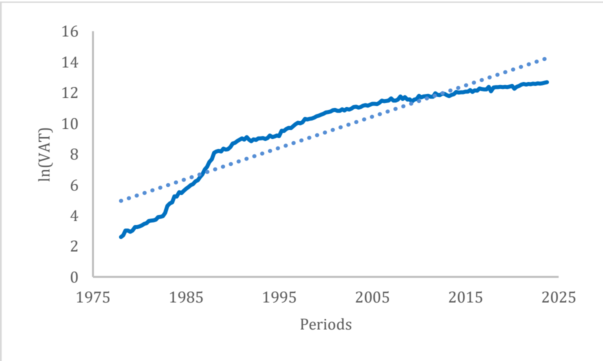

Fig. 1: Value-added tax from 1978 to 2023

For the LE variable, the methodology developed by Katz and Bommarito (2014) was employed to generate a quarterly index that captures the relative frequency of each word in the LIVA across all published versions of this legal framework from 1978 to 2023. Based on the Shannon (1948) and Katz and Bommarito (2014) approach, the goal is to measure the amount of information provided by the probability of occurrence of one or more events.

The Shannon entropy metric for each $t = 1,2,\dots,T$ is expressed as

$$S_t = -\sum_{w_t \in W_t} p_{w_t} \, log_2(p_{w_t})$$

where, p_{w_t} captures the relative frequency of the written words appearing in the legal text at time t, denoted as W_t. Thus, S_t is a measure of uncertainty or disorder in a communication system (Shannon, 1948).

The legal entropy index is normalized by setting the value of 1 as the reference for the first quarter of 1978, and as time progresses, the LE index records changes in entropy for $t = 1,2,\dots,T$, as shown in Fig. 2.

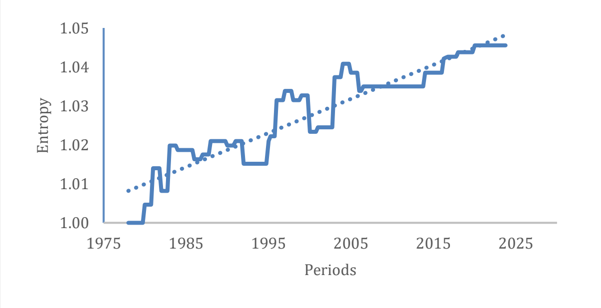

Fig. 2: Legal entropy index 1978-2023

Subsequently, natural logarithm-transformed variables were employed, which allows for interpreting the estimated coefficients in elasticities.

The relationship between the two variables is analyzed using an ARDL model, as this method relaxes the constraint that all variables must have the same order of integration. Moreover, the ARDL model yields more robust results for determining long-term relationships when dealing with small samples. This model mitigates potential endogeneity problems compared to traditional models (Panapoulou and Pittis, 2004).

The ARDL model requires that the variables be either stationary, integrated of order one, or a combination of both (Pesaran et al., 2001). Therefore, a preliminary step before estimating an ARDL model involves conducting unit root hypothesis tests.

The hypothesis tests known as Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and Zivot-Andrews (ZA) are employed to determine the order of integration of the variables. The ADF test uses an autoregressive model in different ways, while the PP test employs a first-order autoregressive model. In both cases, the null hypothesis of the unit root tests is that the analyzed series has a unit root or is non-stationary. Similarly, the ZA hypothesis test asserts that the time series is non-stationary, even if there are possible structural changes. On the other hand, the KPSS test assumes the null hypothesis that the time series is stationary.

Similarly, as a preliminary step to estimating the ARDL model, the causality between legal entropy and the value-added tax, in natural logarithm form, is tested. The procedure developed by Toda and Yamamoto (1995) for the Granger non-causality test is followed, as it has the advantage of being applicable even when the variables are not integrated in the same order or there is no cointegration relationship.

The idea is to extend the VAR model of order k with the maximum order of integration d in the variables:

$$LVAT_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i}\, LVAT_{t-i} + \sum_{i=k+1}^{d} \alpha_{2i}\, LVAT_{t-i} + \sum_{j=1}^{k} \delta_{1j}\, LLE_{t-j} + \sum_{j=k+1}^{d} \delta_{2j}\, LLE_{t-j} + \varepsilon_{1t}$$
$$LLE_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, LLE_{t-i} + \sum_{i=k+1}^{d} \beta_{2i}\, LLE_{t-i} + \sum_{j=1}^{k} \phi_{1j}\, LVAT_{t-j} + \sum_{j=k+1}^{d} \phi_{2j}\, LVAT_{t-j} + \varepsilon_{2t}$$

where, LVAT is the natural logarithm of VAT, LLE is the natural logarithm of LE, ε_{1t} and ε_{2t} are random disturbances, and α_0, β_0, α_{1i}, β_{1i}, α_{2i}, β_{2i}, δ_{1j}, ϕ_{1j}, δ_{2j}, and ϕ_{2j} are coefficients to be estimated. To validate the existence of causality from LLE to LVAT, a Wald test is performed on the coefficients δ_{1j} to check if they are different from zero.

Now, the general ARDL(p) specification between the variables LVAT and LLE is:

$$\Delta LVAT_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta LVAT_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta LE_{t-i} + \beta_3 LVAT_{t-1} + \beta_4 LE_{t-1} + u_t$$

where, β_0, β_{1i}, β_{2i}, β_3, and β_4 are parameters to be estimated, and u_t is a random disturbance.

The calibration of the previous equation requires estimating the optimal lag for the time series. For this, the Akaike Information Criterion (AIC) is used. The optimal lag to estimate the ARDL model corresponds to the minimum AIC value. It is important to note that the Schwarz information criterion (BIC) and the Hannan-Quinn information criterion (HQ) could be used.

Pesaran et al. (2001) showed that the long-term relationship is determined by the joint significance of the coefficients associated with the level variables using an F-test with two boundary thresholds. The upper bound assumes all variables are integrated of order one, while the lower one assumes all variables are stationary. The null hypothesis of the bounds test is that the series are not cointegrated.

It's worth noting that the ARDL specification was selected for several key reasons. First, it facilitates combining variables that are stationary at levels with those that are stationary only after differencing. Second, the ARDL model allows for a clear decomposition of the relationship between variables into short- and long-run effects and is also useful for checking for cointegration. Unlike other cointegration approaches such as the Johansen test, ARDL offers significant advantages: it performs well even with small sample sizes and allows for considering different lags for each regressor, which contributes to the model's greater explanatory power (Pesaran et al., 2001).

4. Results

Considering the time series of the natural logarithm of the value-added tax (LVAT) and the natural logarithm of entropy (LLE), unit root tests are conducted to determine if the time series is stationary.

Table 1 displays the unit root test outcomes for the variables LVAT and LLE at levels and first differences. For the first-differenced variables, the p-values are consistently below the 5% significance threshold across the ZA, ADF, and PP tests. In contrast, the KPSS test yields a p-value above this threshold. Collectively, these findings suggest that both variables are integrated of order one (I(1)) at a 95% confidence level.

Table 1: Unit root tests for LVAT and LLE

Variable	ADF	PP	KPSS	ZA
LVAT	-1.654	-2.062	4.071	−4.016
	-0.771	-0.765	0	-0.215
LLE	-1.846	-1.841	0.598	-4.108
	-0.357	-0.361	0	-0.197
DLVAT	4.261	21.837	0.014	−8.116
	0	0	-0.178	0
DLLE	2.875	9.926	0.031	-7.018
	0	0	-0.163	0

Considering the general ARDL(p) specification between LVAT and LLE, the goal is to estimate the effect of these variables. In Table 2, the smallest value of the Akaike information criterion (AIC) corresponds to the second lag, so the ARDL model presented in this study uses two lags for the LVAT and LLE variables.

Table 2: Optimal lag for the ARDL model

LVAT	LLE	AIC
2	2	222.55
1	2	228.46
1	1	227.84

Under the optimal lag, the estimated model is as follows:

$$\Delta LVAT_t = \beta_0 + \beta_{11}\Delta LVAT_{t-1} + \beta_{12}\Delta LVAT_{t-2} + \beta_{21}\Delta LLE_{t-1} + \beta_{22}\Delta LLE_{t-2} + \beta_3 LVAT_{t-1} + \beta_4 LLE_{t-2} + u_t$$

Newey-West robust standard errors were used to strengthen the model's inference, considering an Inverse Gaussian Normal density function for the random disturbance in the ARDL model. In Table 3, the coefficient link between the two variables is negative and significant at the 5% significance level. This coefficient indicates an inverse relationship between the two variables.

Table 3: VAR, ARDL, and OLS models

Variable	ARDL (Newey-West)	OLS (Prais-Winstein)	VAR (One equation, 1/4 lags)
ΔLVAT(-1)	0.671*** (0.276)	0.164** (0.074)	0.132*(0.071)
ΔLVAT(-2)	0.339* (0.251)	0.225*** (0.074)	0.201**(0.068)
ΔLVAT(-3)			0.191** (0.612)
ΔLVAT(-4)			0.301** (0.598)
ΔLLE(-1)	-2.06** (0.931)	-1.44* (0.624)	-0.933* (0.564)
ΔLLE(-2)	-1.603*** (0.444)	-2.95** (1.182)	-2.91** (1.466)
ΔLLE(-3)			-0.736* (0.441)
ΔLLE(-4)			-5.31 (1.441)
LVAT	0.484* (0.303)		
LLE	-0.069** (0.033)		
Constant	0.034* (0.026)	0.032*** (0.008)	0.025*** (0.001)
R-squared	0.897	0.234	0.285
Observation	184	184	184

Standard errors in parentheses; *, **, ***: 1%, 5%, 10% significance levels respectively

To perform robustness checks, a regression model was estimated using the Prais-Winsten transformation to correct for serial correlation. A vector autoregressive (VAR) was also estimated under four optimal lags, paying special attention to the equation whose dependent variable is the first difference of LVAT. The signs of the estimated coefficients were consistent, supporting the inverse relationship between the variables analyzed in this study. It should be noted that the DOLS or FMOLS specifications were not considered, since the variables do not exhibit cointegration, as shown in Table 4.

In fact, a hypothesis test was conducted using the Wald statistics to verify the existence of a long-term relationship between the variables (cointegration). The null hypothesis states that there is no cointegration. At the 10% significance level, there is no evidence of a long-term relationship, as the p-value exceeds 0.10, as shown in Table 4.

The lack of cointegration in the reference period can be explained by the fact that regulatory changes do not result in permanent adjustments to the VAT rate or its revenue. This is because VAT has been subject to changes on several occasions for fiscal or political reasons that are independent of the legal environment. However, common short-term movements have been detected, which underpins the link estimated in this study.

Table 4: Wald cointegration test in ARDL

F-test (Wald statistic) for testing cointegration	
F-statistic	1.880
p-value	0.497

H0: No cointegration between LVAT and LLE

The previous estimates support this research's hypothesis: entropy's effect on the VAT is negative, and there is no long-term relationship. A 1% increase in the level of entropy in period t is expected to reduce VAT by 2.06%. Additionally, the VAT level has a two-period lag effect of -1.60%. These findings highlight the importance of language in VAT legislation and how to design the law and its regulations to avoid a negative impact on VAT revenue. Furthermore, under the concepts of physics and information theory, an increase in legal entropy is indicative of ambiguity or complexity in the legal system. This translates into greater difficulty in VAT collection and the implementation of public policies, as evidenced by the negative relationship found between the two variables in the short term. This situation not only weakens trust in institutions but also increases the cost of legal compliance. This inverse relationship between VAT collection and legal entropy can be attributed to the fact that legislation is often imprecise, inadequately formulated, or excessively technical, resulting from responding to current political circumstances rather than long-term fiscal planning that considers the idiosyncrasies of the Mexican context. Therefore, the problem lies not in legal tradition but rather in a political vision that prioritizes short-term interests.

5. Conclusions

The analysis of the entropy index shows an upward trend since the enactment of the VAT law in 1978. This complexity arises from the additions and amendments made to the body of the law since its publication and throughout 46 years of legal validity.

Furthermore, the entropy analysis indicates that, given the positive trend and the fluctuations surrounding it, the level of entropy presented a relative frequency for each word used differently from that presented by the law in 1978, which is reflected in the distribution of words.

Additionally, the estimates confirm the inverse relationship between legal entropy and value-added tax, as a 1% increase in the entropy index in period t is expected to result in a 2.06% decrease in VAT in period t+1. Quantifying this relationship contributes to the study of VAT in Mexico under non-economic factors, since entropy would represent a relevant factor, but one that is indirectly linked to economic activity.

The effects of the entropy level on VAT are more short-term than long-term, as confirmed by the unit root tests showing that the time series are non-stationary at levels and that there is no cointegration.

Finally, this study has some limitations. The estimates are robust only in the short term, and the sample size is small despite using quarterly data. Therefore, future research should explore other estimation techniques for comparison purposes. For example, entropy indices based on information theory but different from Shannon's (1948) approach could be used, such as the Rényi or Tsallis entropy metrics. Not to mention, the Hoover or Kullback-Leibler indices could be used for comparison purposes. This would allow the study to be extended to other countries or other laws within the Mexican legal framework.

List of abbreviations

ADF	Augmented Dickey-Fuller
AIC	Akaike information criterion
ARDL	Autoregressive distributed lag
BIC	Bayesian information criterion
CAPM	Capital asset pricing model
DLLE	First-differenced logarithm of legal entropy
DLVAT	First-differenced logarithm of value-added tax
DOLS	Dynamic ordinary least squares
FMOLS	Fully modified ordinary least squares
GDP	Gross domestic product
HQ	Hannan-Quinn information criterion
LE	Legal entropy
LIVA	Value-added tax law (Mexico)
LLE	Logarithm of legal entropy
LVAT	Logarithm of value-added tax
OLS	Ordinary least squares
PP	Phillips-Perron
VAR	Vector autoregression
ZA	Zivot-Andrews

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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