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On the Electricity-Output Nexus across the 32 States of Mexico: Insights from a Heterogeneous Panel, 1994-2024

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ABSTRACT

The question of whether electricity consumption (ELE) influences GDP, or vice versa, at the national and international levels, has been the subject of intense analysis by the academic community without a clear answer. Furthermore, additional subnational analyses are lacking to understand the underlying heterogeneity. This paper seeks to understand the dynamics between ELE and GDP in the States of Mexico between 1994 and 2024. After applying diagnostic tests such as cross-sectional dependence, panel unit roots, slope homogeneity, and cointegration, we employ advanced panel cointegration techniques, specifically cointegrating regressions (FMOLS and DOLS) and factor-augmented techniques (CUP-BC and CUP-FM), which we use as robust estimators. The empirical findings indicate a positive long-run association between ELE and GDP in most of the States in Mexico; however, the size of the estimated coefficients varies substantially across them (1.32 for Campeche and 0.103 for Michoacán). The factor-augmented estimators confirm that ELE has a coefficient of around 0.3. In addition, this analysis adopts a heterogeneous non-Granger test to understand short-run causalities. This test shows that ELE causes GDP only in Coahuila, Tlaxcala, and Sinaloa, and GDP causes ELE in Campeche and Yucatán, with weak evidence for Chihuahua and Puebla. However, at the panel level, we obtained weak support for the growth hypothesis between ELE and GDP, whereas strong support for the neutrality hypothesis prevails. Overall, the findings suggest that subnational energy policies should account for State-specific factors relevant to long-term growth and sustainability goals. These results have important implications for State policy design, suggesting the need for State-specific approaches rather than one-size-fits-all solutions.

Keywords: Electricity Use, GDP, Long-run Elasticities, Causality Test, Mexico
JEL Classifications: L94, E20, C19

1. INTRODUCTION

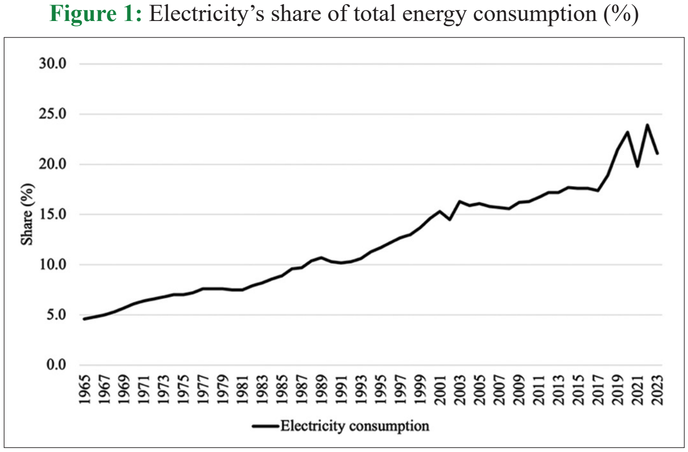
It is well known that human economic activities are changing ecosystems around the planet. Global warming has accelerated due to the ever-expanding annual output, at the expense of environmental degradation. Harkiolakis (2013) states that global warming refers to the sustained rise in temperatures between 0.4°C and 0.8°C over the last 100 years. It is usually argued that the leading cause of warming is greenhouse gases, which trap heat within the atmosphere. Such heat cannot easily escape into outer space and, therefore, ecosystems grow in a perpetual summer. Moreover, natural and human activities produce dangerous gases, such as CO_2, methane, and nitrous oxide (Harkiolakis, 2013). Those gases arise primarily from the combustion of fossil fuels for production, transportation, food processing, and electricity generation (UN, 2023). Carleton et al. (2022) find that warming alone could cause 73 additional deaths per 100,000 people under a high-emissions scenario, to which we are approaching rapidly. Therefore, energy policies must tackle those adverse effects of climate change.

Electricity generation and use sit at the center of the climate change debate because they are both tightly linked to economic activity (Massa and Rosellón, 2020). The use of electricity across economic sectors is tied to higher productivity and lower unit costs, thereby supporting economic dynamism (Massa and Rosellón, 2020). In Mexico, electricity consumption began to grow fast in the early 1990s, and decades later during the period 2018-2024. Figure 1 shows that the participation of electricity in final energy consumption was 5% in 1970, 10% in 1990, 16% in 2010, and 21% in 2023. The Ministry of Energy (Secretaría de Energía, 2024, 64-67) predicts that final consumption will rise by 2.8% annually, based on an estimated GDP growth of 2.4-2.5%. Specifically, the residential sector will grow 2.6%/year, the commercial sector 2.5%, the services sector 2.4%, the agricultural sector 3.5%, the medium-sized businesses 3.0%, and the large industry 2.6%. Regarding net power consumption, the government forecasts that the peninsulas of Baja California and Yucatán will have the highest demand, at 3.4% and 3.8%, respectively, while the remaining regions (Central, West, East, North, Northwest, and Northeast) will have an average of 2.3%. Hence, electricity consumption and its regional heterogeneity will play a fundamental role in shaping Mexico's energy strategy and economic policy.

Power consumption has concentrated in a few Mexican States that also have the highest GDP growth rates. Between 1994 and 2024, the share of total consumption of Nuevo León, Ciudad de México, Jalisco, and Estado de México was 31%. Adding Baja California, Coahuila, Chihuahua, Guanajuato, Sonora, and Veracruz raises the percentage to 61%. By contrast, the share of the poorest economic States, as Chiapas, Guerrero, and Oaxaca, was only 4%. As Mahalingam and Orman (2018) explain, it is important to note differences across States to avoid implementing uniform national policies that may unwillingly stop economic growth. In this study, we provide an answer for the following research questions: Is there a long-term link between electric power use and economic output across Mexican States? What is the direction of the non-Granger causation between ELE and GDP among Mexican States?

Hajko et al. (2019) argue that the interest in the linkage between energy and growth falls into four outcomes: (i) Interdependence, (ii) growth, (iii) conservation, and (iv) neutrality. The first outcome posits bidirectionality between the two variables, whereas the last suggests no relationship between them. The second outcome is the opposite of the third, meaning that electricity drives economic activity. Therefore, policy design depends on which outcome is being supported empirically in a specific country or region. However, on this subject, there is little consensus. For instance, in the Gulf Cooperation Council countries, AlKhars et al. (2020) surveyed 59 papers published between 2006 and 2019. They found that 43% of the papers supported the feedback outcome, 18% growth, 26% conservation, and 13% neutrality. Moreover, in a survey of more than 1,000 papers, Mutumba et al. (2021) found that 18% of studies reported feedback outcomes, 44% reported growth, 27% reported conservation, and 11% reported neutrality.

Figure 1: Electricity's share of total energy consumption (%)



Source: Authors' own elaboration with data from Secretaría de Energía

Few studies have dug deeper into the energy-growth nexus in Mexico. First, at the national level, Massa and Rosellón (2020) examine the linear and nonlinear causality between electricity production and GDP in Mexico with aggregate data for the period 1965-2018. The authors did not find a causal link between the two variables; instead, they argue in favor of a larger role for the private sector in power generation. Gómez et al. (2018) explored the energy-output-external sector link in the Mexican economy over the period 1971-2013 using a production-function setup that considers capital formation, labor, external sector, and energy. Their main result is a mutually dependent causality between the use of energy and economic activity. Mele (2019) focused on renewable use of energy and GDP from 1990 to 2017. Using the Toda-Yamamoto method, the author found evidence consistent with the growth outcome. Second, at the subnational level, taking into account the heterogeneity of the slope or the dependence on the cross-section data.

This paper distinguishes by providing fresh insights at the Mexican subnational level. Unlike Ortega Hernández (2021), this is the first research that uses State-level data on per capita GDP and power consumption for a broader period, i.e., 1994-2024. Regarding the methodology, our analysis accounts for panel data heterogeneity and cross-section dependence (hereafter CSD), which we believe characterize the Mexican economy. For this reason, we selected adequate unit root and cointegration tests. With that in mind, we computed the long-run cointegration relationships with the FMOLS, DOLS, CUP-BC, and CUP-FM tests. Finally, to examine short-run causalities, in line with the diagnostic tests, we make use of the panel causality test by Emirmahmutoglu and Kose (2011), hereafter EK, which allows heterogeneous non-Granger causality at both the panel and State levels. For most Mexican States, our results underscore a positive impact of ELE on GDP in the long term, although there is weak evidence for Baja California Sur, Sonora, and Tlaxcala. For panel results, the CUP-FM and CUP-BC tests give an average coefficient of approximately 0.30, i.e., a 10% increase in ELE raises long-run GDP by about 3%. In the short term, the neutrality hypothesis prevails in most States. However, electric power consumption Granger-causes GDP in Coahuila and Tlaxcala; GDP Granger-causes electricity consumption in Campeche, Chihuahua, Puebla, and Zacatecas; and there is bidirectional causality in Sinaloa.

This paper is organized as follows, section 2 presents a short review of key research and the next three sections outline the empirical method and discuss the results. The concluding section 6 summarizes and delineates some policy implications.

2. A SHORT LITERATURE REVIEW

As outlined in the Introduction, the literature on energy-growth delineates four outcomes (Hajko et al., 2019): (i) Interdependence, (ii) growth, (iii) conservation, and (iv) neutral causality (Table 1).

The first outcome is the most complex because it implies the interplay between energy resources, consumption, and economic activity. Its trickiness lies in the fact that it does not point to a clear policy path (Hajko et al., 2019). Apergis and Payne (2010) studied 20 countries from the OECD club during the

Table 1: Selected literature on the energy-growth nexus

Author (s)	Sample and period	Method (s)	Conclusion
Atems and Hotaling (2018)	174 countries (1980-2012)	System GMM	$\text{RELEG} \xrightarrow{+} \text{GDP}$ $\text{NRELEG} \xrightarrow{+} \text{GDP}$
Apergis and Payne (2010)	20 OECD countries (1985-2005)	Pedroni cointegration test	$\text{RELEC} \leftrightarrow \text{GDP}$
Abul et al. (2019)	6 GCC countries (1980-2014)	Panel VAR and GMM	$\text{GDP} \xrightarrow{+} \text{ENCO}$
Ahmed and Shimada (2019)	30 emerging countries (1994-2014)	FMOLS and DOLS	$\text{RENE} \leftrightarrow \text{GDP}$ $\text{NRENE} \leftrightarrow \text{GDP}$
Asif et al. (2024)	5 BRICS countries (2004-2023)	Fixed effects	$\text{GDP} \xrightarrow{-} \text{ENS}$ $\text{RENE} \xrightarrow{+} \text{ENS}$
Banday and Aneja (2019)	G7 countries (1971-2014)	Panel causality: Dumitrescu y Hurlin (2012) and Emirmahmutoglo and Kose (2011)	$\text{NRENE} \xrightarrow{+} \text{GDP}$
Bekun et al. (2019)	South Africa (1960-2016)	ARDL	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Chen et al. (2019)	103 countries (1995-2015)	Panel threshold model	$\text{RENE} \xrightarrow{+} \text{GDP}$
Dat et al. (2020)	Indonesia (2000-2019)	ARDL	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Doğan and Değer (2018)	E7 countries (1990-2016)	CCE	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Gómez et al. (2018)	Mexico (1965-2014)	ARDL	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Humbatova et al. (2020)	Azerbaijan (1995-2017)	ECM	$\text{ELCO} \xrightarrow{+} \text{GDP}$
Ivanovski et al. (2021)	30 countries (1990-2015)	LLDVE and CCEMG	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Kasperowicz et al. (2020)	29 European countries (1995-2016)	Pedroni cointegration and DOLS	$\text{RENCO} \xrightarrow{+} \text{GDP}$
Khobai et al. (2021)	5 BRICS countries (1990-018)	Pedroni cointegration	$\text{GDP} \xrightarrow{+} \text{ENCO}$
Kilci (2023)	8 European countries (1990-2020)	Panel Fourier Toda Yamamoto	$\text{GDP} \xrightarrow{+} \text{ENCO}$
Lawal et al. (2020)	17 sub-Sharan countries (1971-2017)	System GMM	$\text{ELCO} \xrightarrow{+} \text{GDP}$
Le (2020)	46 developing countries (1990-2014)	AMG, MG, and CCEMG	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Mohammadi et al. (2023)	30 developed countries (1993-2019)	Panel FMOLS and ARDL	$\text{GDP} \xrightarrow{+} \text{RENE}$ $\text{GDP} \leftrightarrow \text{NRENE}$
Ntanos et al. (2018)	25 European countries (2007-2016)	ARDL	$\text{RENE} \xrightarrow{+} \text{GDP}$
Pegkas (2019)	Grece (1990-2016)	ARDL	$\text{RENE} \xrightarrow{+} \text{GDP}$ $\text{NRENE} \xrightarrow{+} \text{GDP}$
Pala (2020)	G20 countries (1990-2016)	Panel cointegration	$\text{ENCO} \overset{+}{\leftrightarrow} \text{GDP}$
Saqib (2021)	14 MENA countries (1987-2019)	Granger and Toda Yamamoto causalities	$\text{ENCO} \xrightarrow{+} \text{GDP}$
Shahbaz et al. (2020)	38 countries	DOLS, FMOLS, and Pedroni cointegration	$\text{RENE} \overset{+}{\leftrightarrow} \text{GDP}$

(Contd...)

Table 1: ***(Continued)***

Author (s)	Sample and period	Method (s)	Conclusion
Shahbaz et al. (2022)	China (1971-2018)	ARDL	GDP $\overset{+}{\leftrightarrow}$ ENCO
Sultan and Alkhateeb (2019)	India (1971-2014)	Johansen cointegration	ENCO↔GDP
Topolweski (2021)	34 European countries (2008-2019)	Arellano-Bond	GDP $\overset{+}{\rightarrow}$ ENCO
Umurzakov et al. (2020)	26 post-communist countries (1995-2014)	Pedroni cointegration, DOLS, and FMOLS	GDP $\overset{+}{\rightarrow}$ ENCO
Wang and Wang (2020)	34 OECD countries (2005-2016)	Panel threshold model (non-linear)	RENE $\overset{+}{\rightarrow}$ GDP
Yıldırım et al. (2019)	6 BRICS-T countries (1990-2014)	Pedroni cointegration	ENCO $\overset{+}{\leftrightarrow}$ GDP
Zuhal and Göcen (2025)	United States (1973-2022)	Spectral Granger causality	RENE↔GDP

Source: Authors' own elaboration

1985-2005 period, using Pedroni panel cointegration techniques and Granger causality tests. Their computations show two-way interactions between renewable energy and GDP. Ahmed and Shimada (2019) analyzed 30 developing economies mixing CSD tests, second-generation unit-root tests, DOLS and FMOLS tests, and the Dumitrescu-Hurlin causality test (Dumitrescu and Hurlin, 2012). Their main finding points to a feedback causality between production and both renewable and non-renewable use. Some other studies that report interdependence outcomes are Le (2020), Pala (2020), Shahbaz et al. (2022), Zuhal and Göcen (2025), Sultan and Alkhateeb (2019), Yıldırım et al. (2019), and Majewski et al. (2022).

The next empirical outcome maintains that energy is a key part in the production process. As an illustration, Bercu et al. (2019) studied some Central and Eastern European countries with the FMOLS estimation technique; their evidence was consistent with the growth outcome. Doğan and Değer (2018) assessed the E7 economies of Brazil, China, Indonesia, Russia, and Turkey using the common correlated effects model. The authors report that a one percentage increase in energy use brings about a 0.12% increase in output. Not only does evidence vary at the country level, but also at the sectoral one. Based on the case of the Azerbaijan's economy (1995-2017), Humbatova et al. (2020) found that higher electricity consumption was associated with gains in energy generation, mining, construction, agriculture, hunting and forestry, and commercial and public services; however, there are losses in the industrial, transport, warehousing, and telecommunications sectors. We should note that many studies focusing on renewable energy (generation and consumption) also tend to back the growth outcome. For more examples, see: Ivanovski et al. (2021), Atems and Hotaling (2018), Pegkas (2020), Kasperowicz et al. (2020), and Wang and Wang (2020).

The third outcome argues that economic activities drive energy usage. This outcome is the most critical in the current debate about climate change. When the conservation hypothesis holds in a country or region, energy-saving policies can cut consumption without decelerating growth. In this regard, the evidence is abundant. Abul et al. (2019) support the outcome, based on data from six Middle East countries (1980-2024). Banday and Aneja (2019) examined G7 countries from 1971 to 2014 to test the long-term causal relationships between the consumption of non-fossil fuels, fossil fuels and GDP. The Dumitrescu-Hurlin and EK tests showed varied country results: in Germany, France, and the UK, GDP is associated with higher renewable energy consumption, but not in the US, Canada, Italy, or Japan.

On the other hand, Khobai (2021) tackles the analysis of the BRICS using Pedroni and Granger causality tests. The author's evidence indicates that economic growth rates lead to energy consumption. Kilci (2023) used a state-of-the-art approach to study eight European countries from 1990 to 2020. The Toda-Yamamoto Fourier panel causality tests disclosed the conservation outcome in all countries except Finland. Finally, some other related research includes Topolweski (2021), Umurzakov et al. (2020), and Saqib (2021).

The last empirical outcome concerns neutral causality, in which energy and GDP are independent. That is, the effect of energy on GDP may be neutral because its cost is usually low. Regarding the empirical evidence, this outcome has received the least support. Alam et al. (2011) studied the case of India and found no evidence of long-term causality between economic activity and energy use. However, the neutrality outcome is rather interesting because policymakers could pursue energy-saving and energy efficiency measures without hurting long-term output.

In summary, the literature on the energy-growth nexus is extensive and does not offer a clear verdict (AlKhars et al., 2020; Mutumba et al., 2021). This study aims at contributing to the debate by applying advanced cointegration tests and panel estimations to data from Mexico's 32 States.

3. EMPIRICAL STRATEGY

3.1. Nature of Data and Descriptive Statistics

Empirically, this study links per capita electricity use to per capita GDP across the Mexican States. Electricity use is measured in Megawatt-hours (MWh), and GDP is in constant Mexican pesos (2018 = 100). The annual data covers the period 1994-2024. State GDP data come from the country's national office of statistics (Instituto Nacional de Estadística y Geografía, INEGI). State-level electricity consumption comes from the Secretaría de Energía and

Presidencia de la República (2013); also, see Table A1. Population data come from the Consejo Nacional de Población (CONAPO). We convert the two series to per capita values by dividing each State's values by its annual population. Finally, we expressed the two variables in natural logarithms.

Table 2 reports the descriptive statistics for ELE and GDP for all Mexican States over 1994-2024, yielding 992 observations per variable (32 × 31). ELE has standard deviation of 0.827, a mean of 1.753, and it ranges from 0.308 MWh (Chiapas) to 3.959 MWh (Sonora); it shows mild right-skewness (0.670) and relatively low kurtosis (−0.405). On the contrary, GDP shows a much wider spread with a standard deviation of 154,176 pesos, a mean of 196,401 pesos, a min value of 59,007 for Chiapas and a max value of 1,318,539 pesos for Campeche; it is highly right-skewed (skewness = 4.580) and has very high kurtosis equal to 25.455, which suggests extreme observations in some years.

3.2. Cross-Sectional Dependence Test

We identify two reasons why validating cross-sectional dependence is a key first decision in panel data modeling. Having CSD is sufficient for selecting the appropriate unit-root, cointegration, and causality tests. Ignoring it would lead to spurious results because the error terms are correlated. In practice, as in Mexico, local economies are likely to face common shocks at once. For instance, as Lee et al. (2023) say, nationwide recessions, technological shifts, external shocks from the global or the US economy, or energy shocks due to extreme weather—in 2024, intense heat waves hit Mexico, causing blackouts throughout the country. The test is written as follows (Pesaran, 2004):

$$CSD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\psi}_{ij}\right) \tag{1}$$

$$\hat{\psi}_{ij} = \frac{\sum_{i}^{T}\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}}{\sqrt{\sum_{t=1}^{T}\hat{\varepsilon}_{it}^{2}\sum_{t=1}^{T}\hat{\varepsilon}_{jt}^{2}}} \tag{2}$$

where the null is cross-sectional independence, $\hat{\psi}_{ij}$ is the calculated pairwise correlation with State i and j = i + 1,…, N Mexican States involved; and T is the time variable (Apergis and Payne, 2020).

3.3. Panel Unit Root Test

The next step in the methodology is to apply a unit-root test that considers CSD across Mexican States, such as Pesaran's (2007) second-generation test. In this approach, H_0: $\rho = 0$, or the null hypothesis that a series has a unit root, and H_1: $|\rho|<1$, that is, the alternative hypothesis that it does not. Therefore, the cross-sectionally augmented Dickey-Fuller (CADF) equation can be written as in:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \varphi_i \bar{y}_{t-1}\sum_{j=0}^{k}\varphi_{ij\Delta}\bar{y}_{i,t-j} + \sum_{j=0}^{k}\varphi_{ij\Delta}y_{i,t-j} + \varepsilon_{it} \tag{3}$$

We note that $\bar{y}_{t-1} = N^{-1}\sum_{i=1}^{N} y_{i,t-1}$ and that β_i helps to estimate the ADF coefficients. After rearranging the statistic proposed by Im et al. (2003), the average CADF statistics, Pesaran (2007) obtains the augmented CIPS statistics (Apergis and Payne, 2020):

$$CIPS = \frac{1}{N}\sum_{t=1}^{N} t_i(N,T) \tag{4}$$

Table 2: Descriptive statistics of the variables under study

Statistics	ELE	GDP
Obs.	992	992
Mean	1.753	196400.585
Standard deviation	0.827	154175.535
Minimum	0.308	59007.015
Maximum	3.959	1318539.091
Skewness	0.670	4.580
Kurtosis	−0.405	25.455

Source: Authors' own elaboration using Stata 18

3.4. Slope Homogeneity Tests

Assuming slope homogeneity in panel data can produce biased outcomes. Swamy (1970) introduced an approach to test whether the slope coefficients in a cointegration regression are homogeneous. Pesaran and Yamagata (2008) improved the previous test with the following two delta statistics:

$$\tilde{\Delta} = N^{1/2}\left(\frac{\tilde{S}-k}{N\sqrt{2k}}\right) \sim \chi_k^2 \tag{5}$$

$$\tilde{\Delta}_{adj} = N^{1/2}\left(\frac{\tilde{S}-k}{Nv(T,k)}\right) \sim N(0,1) \tag{6}$$

Where N is the number of Mexican States, S is Swamy's test statistic, and k is the number of explanatory variables. We reject the null of slope homogeneity when the P-value is below 0.05 (Hussain et al., 2022), and therefore, the cointegrating estimates are homogeneous. In addition, Blomquist and Westerlund (2013) introduced a robust Heteroskedasticity- and Autocorrelation-Consistent (HAC) estimator that accounts for heteroskedasticity and autocorrelation. The test is given by the following two equations:

$$\Delta_{HAC} = N^{1/2}\left(\frac{S_{HAC}-k}{N\sqrt{sk}}\right) \sim \chi_k^2 \tag{7}$$

$$\left(\Delta_{HAC}\right)_{adj} = N^{1/2}\left(\frac{S_{HAC}-k}{Nv(T,k)}\right) \sim N(0,1) \tag{8}$$

As with the previous statistic, we fail to accept the null of slope homogeneity when $P < 0.05$.

3.5. Cointegration Tests

Cross-sectional dependence, heterogeneity, and $I(1)$ variables are the reasons why we chose Westerlund's (2007) second-generation panel cointegration test. In the method, the mean-group tests (Gt and Ga) analyze the hypothesis that at least one panel unit is cointegrated. Moreover, the panel-group tests (Pt and Pa) examine the hypothesis that the whole panel is cointegrated (Alvarado et al., 2021; Charfeddine and Kahia, 2019).

The cointegrating equation is as follows:

$$\Delta y_{it} = \gamma_i dt + \sigma_i \left(y_{it-1} - \alpha' x_{i,t-1} \right) + \sum_{j=1}^{p} \sigma_{ij} y_{it-j} + \sum_{qi}^{pi} y_{ij} \Delta x_{it-j} + \varepsilon_{it} \tag{9}$$

where y_{it} is the response variable, dt is the residual that helps assess the time trajectory of the variable, and $y_{it-1} - \alpha' x_{i,t-1}$ shows the presence of cointegration. Also, the component σ_i computes the long-term correction equilibrium (Alvarado et al., 2021).

It is worth noting that Westerlund (2007) is appropriate for our research because it is entirely consistent with the empirical characteristics of our data. Unlike residual-based panel tests, this approach calculates cointegration directly through error-correction rather than through auxiliary regressions. If bootstrapping is introduced (i.e., 800 repetitions in our case), the cointegration test is robust to CSD.

3.6. Long-Run Panel Cointegrating Equations

Next, we compute the long-run cointegration between GDP and ELE. We rely on FMOLS (Pedroni, 2001) and DOLS (Kao, 1999) because their results are consistent and efficient, even in the presence of non-stationarity, endogeneity, and serial correlation (Fatima et al., 2024). The first method corrects for endogeneity and serial correlation with a semi-parametric correction; thus, it is suitable for small samples. The second method adds regression leads and lags to the differenced regressors. The goal is to ameliorate endogeneity and improve finite-sample performance (Ahmed et al., 2022; Merlin and Chen, 2021).

However, FMOLS and DOLS cannot address the CSD problem. Therefore, for robustness purposes, we employ the CUP-FM and CUP-BC estimators.[1] Regarding their advantages, they accommodate for autocorrelation, heteroskedasticity, and endogeneity issues (Wen et al., 2023). Bai et al. (2009) introduced a model with interactive fixed effects, where CSD arises from unobserved common stochastic trends. The baseline model is as follows:

$$y_{it} = x_{it}' \beta + \lambda_i' f_t + \mu_{it} \tag{10}$$

where x_{it} and y_{it} are $I(1)$ variables, f_t is a vector of unobserved common factors, λ_i are factor loadings, and μ_{it} is the disturbance. The main specification of the cointegrating relationship is written as follows:

$$\hat{\beta}_{CupFM} = \left[\sum_{i=1}^{n} x_i' M_{\hat{F}} x_i \right]^{-1} \sum_{i=1}^{n} \left[x_i' M_{\hat{F}} y_i^{+} - T\left(\hat{\Delta}_{\varepsilon ui}^{+} - \hat{\bar{\sigma}}_i' \hat{\Delta}_u^{+} \right) \right] \tag{11}$$

$$\hat{F}V_{nT} = \left[\frac{1}{nT^2} \sum_{i=1}^{n} \left(y_i - x_i \hat{\beta}_{CupFM} \right) \left(y_i - x_i \hat{\beta}_{CupFM} \right)' \right] \hat{F} \tag{12}$$

1 We thank Prof. Chihwa Kao (Department of Economics, University of Connecticut) for generously sharing the Gauss code used to implement the CUP estimators.

The CUP-FM estimator of (β, F) is obtained through an iterative procedure that alternates between solving equations (11) and (12). Endogneity and serial correlation are therefore corrected at each iteration of the estimation process (Bai et al., 2009).

3.7. Panel Causality Test

As stated above, we use the EK panel causality test proposed by Emirmahmutoglu and Kose (2011). Among its advantages, it builds on the Toda-Yamamoto framework. It allows for slope heterogeneity, mixed orders of integration, and unit-specific lag structures without requiring prior unit-root or cointegration testing. The starting point is a unit-specific VAR model estimated in levels:

$$z_{i,t} = \mu_i + A_{i1} z_{i,t-1} + \cdots + A_{ik_i} z_{i,t-k_i} + \mu_{i,t} \tag{13}$$

Where $z_{i,t}$ is a vector of endogeneous variables and k_i denotes the optimal lag length for unit i.

Granger non-causality is tested through linear restrictions on the stacked coefficient vector. To ensure valid inference under integration and cointegration, the EK test estimates a lag-augmented VAR (LA-VAR):

$$z_{i,t} = \mu_i + \sum_{j=1}^{k_i} A_{ij} z_{i,t-j} + \sum_{l=k_i+1}^{k_i + d_{max} i} A_{il} z_{i,t-1} + u_{i,t} \tag{14}$$

while testing only the original lag coefficients. Individual modified Wald statistics are then computed for each cross-sectional unit. For panel-level inference, unit-level P-values pi are combined using the Fisher meta-statistic proposed by (Fisher, 1933):

$$\lambda = -2 \sum_{i=1}^{N} \ln\left(p_i \right) \tag{15}$$

which follows a χ^2 distribution with $2N$ degrees of freedom under the null hypothesis of no Granger causality.

To account for cross-sectional dependence, bootstrap critical values are used. Although the EK procedure provides both unit-specific and panel-wide causation results, rejection of the panel null reflects the existence of causality in at least one cross-sectional unit. Overall, the EK test offers a flexible and robust framework for assessing short-run causal relationships in heterogeneous panel data.

4. EMPIRICAL RESULTS

We previously tested for cross-sectional dependence using the CIPS test, as described above. As seen in Table 3, the test strongly rejects cross-section independence for the two variables under analysis (CD = 48.77 for ELE and 75.49 for GDP). The average pairwise correlations are 0.393 for electricity and 0.609 for gross

Table 3: Results from the cross-sectional dependence tests

Statistic	ELE	GDP
CSD test	48.77***	75.49***
Corr.	0.393	0.609
Abs. (corr.)	0.552	0.620

H_0: cross-section independence. ***denote significance at the 1% level. Estimates are computed using the *xtcd* command in Stata 18 domestic product, with average absolute correlations around 0.5-0.6, which implies meaningful common shocks or contagion across Mexican States.

The next step is to apply the slope homogeneity test to check whether slope coefficients are the same across cross-sectional units in our panel of States (Table 4). The four test statistics $\tilde{\Delta}, \tilde{\Delta}_{adj}, \Delta_{HAC}$, and $(\Delta_{HAC})_{adj}$ are highly significant with $P < 0.05$, which leads to a strong rejection of the null slope homogeneity. Therefore, these results are robust evidence of slope heterogeneity in our panel data, even after accounting for small-sample bias and potential heteroskedasticity and autocorrelation through HAC corrections using a Bartlett kernel.

Table 5 displays the computations of the second-generation panel unit root test for the variables under study. The test was run without and with a deterministic trend, allowing for 0, 1, and 2 lag lengths. For the results without a trend, we accept that there is a unit root for either variable at any lag specification. The corresponding values for ELE at 0, 1, and 2 lags are −0.127, 1.050, and 2.386; for GDP, the values are 0.060, −0.240, and 1.678. For the specification with trend, the values for electricity are −2.384, −2.017, and 0.480, rejecting the null hypothesis at the second lag only; for GDP, we fail to reject the null of a unit root at any lag. With first differences, the two variables become $I(1)$. The values for ELE range from −6.458 to −19.367 for the specification with only a constant, and from −4.004 to −17.24 for the specification with a trend. Given the size of our sample data ($N = 32$, $T = 31$), we chose two lags as the preferred specification.

Given that CSD and slope heterogeneity were validated in our sample and that the variables are $I(1)$, we use Westerlund's (2007) technique to assess the long-run cointegrating properties between the variables. In Table 6, it is seen that we reject the no cointegration null using the z-values, Gt, Pt, and Pa. But, based on robust P-values that were computed with 800 repetitions, the group-based coefficients (Gt and Ga) and the panel-based ones (Pt and Pa) failed to accept the hypothesis of no cointegration at the 5% significance level. Hence, this evidence indicates a long-run relationship between the variables across Mexican States. Rejecting the null under both group and panel statistics points to having cointegration at the panel level as well as across units.

In Table 7, we report the results for both the State and panel levels. First, let us describe the individual results from the FMOLS and DOLS regressions. We grouped the States into five regions based on proximity for better understanding. The Northern Border region has the States of Nuevo León, Tamaulipas, Chihuahua, Coahuila, Baja California, and Baja California Sur. Here, the estimated long-run coefficients range from 0.24 (Sonora) to 0.99 (Baja California Sur). These high coefficients for this region are consistent with the States' industrial specialization. However, the DOLS results for Sonora and Baja California Sur give a weak long-run relationship; in particular, the DOLS coefficient for Sonora is negative and insignificant. The second region is the North-Central region, with the States of Zacatecas, Durango, San Luis Potosí, Guanajuato, Querétaro, and Aguascalientes. The first cointegrating method yielded coefficients ranging from 0.194 (Zacatecas) to 0.797 (Querétaro). As in the Northern Border region, the estimates are in line with the manufacturing orientation of the States.

The Central region, which is more oriented toward the tertiary sector, encompasses Puebla, Morelos, Tlaxcala, Ciudad de México, Hidalgo, and Estado de México. Here, the results are varied. The DOLS results are lower than those from FMOLS. It is interesting to note that Puebla's elasticity is lower than Mexico City's, indicating that electricity's effect on growth is more substantial in the country's capital. Tlaxcala is an exception in this group because there is no evidence of long-term cointegration under either estimation method. In the West Pacific States of Colima, Jalisco, Michoacán, Nayarit, and Sinaloa, the economic orientation is mixed. For instance, agriculture is strong in Michoacán, Sinaloa, and Nayarit, whereas manufacturing and services (trade, transport, and tourism) are critical in Jalisco and Colima. Such a mixed economic structure may explain the observed heterogeneity in the estimated results. Jalisco and Nayarit exhibit the bigger coefficients; unlike Michoacán, whose coefficients range from 0.67 to 0.103. It seems, then, that in this State, electricity plays little role in the production process. Finally, the Southern States exhibit the highest dispersion in the estimated long-run elasticities under FMOLS and DOLS. The predominance of the oil industry may explain Campeche's high coefficient —it represents more than

Table 4: Slope homogeneity tests

Statistic	Value
$\tilde{\Delta}$	36.766*** (0.000)
$\tilde{\Delta}_{adj}$	38.686***(0.000)
Δ_{HAC}	21.486*** (0.000)
$(\Delta_{HAC})_{adj}$	22.607*** (0.000)

Variable partially out: Constant. HAC kernel: Bartlett. Average bandwidth: 3. Estimates are computed using the *xthst* command in Stata 18

Table 5: Unit root test results

Specification	Lags	Level	1st diff.
a) Without deterministic trend			
ELE	0	−0.127	−19.367***
	1	1.050	−11.732***
	2	2.386	−7.020***
GDP	0	0.060	−17.787***
	1	−0.240	−10.602***
	2	1.678	−6.458***
b) With deterministic trend			
ELE	0	−2.384	−17.240***
	1	−2.017	−9.241***
	2	0.490	−3.837***
GDP	0	1.115	−15.530***
	1	0.151	−8.367***
	2	1.141	−4.004***

Note: ***, ** and * refer to significance at the 1%, 5%, and 10%, respectively.

Table 6: Results from the cointegration test

Statistic	Value	Z-value***	Robust P-value
Gt	−2.77	−2.92***	0.04**
Ga	−13.30	−1.07	0.04**
Pt	−15.77	−4.37***	0.02**
Pa	−12.78	−3.54***	0.01**

Note: ** and *** refer to significance at the 5% and 1%, respectively. Estimates are computed using the xtwest command in Stata 18.

Table 7: Long-run estimation results: FMOLS, DOLS, CUP-BC, and CUP-FM

A. OLS based	FMOLS: $\hat{\beta}$	t-stat	DOLS: $\hat{\beta}$	t-stat
Northern border				
Baja California	0.738***	8.110	0.439***	2.946
Baja California Sur	0.989***	4.920	0.698	1.469
Chihuahua	0.608***	12.160	0.424***	4.038
Coahuila	0.487***	5.729	0.388***	17.636
Nuevo León	0.606***	8.912	0.627***	7.125
Sonora	0.240**	2.162	−0.237	−1.261
Tamaulipas	0.553***	13.825	0.538***	14.541
North Central				
Aguascalientes	0.566***	14.895	0.584***	7.122
Durango	0.687***	6.303	0.693***	7.071
Guanajuato	0.220**	2.075	0.236***	6.211
Querétaro	0.797***	15.327	0.722***	28.880
San Luis Potosí	0.287***	3.588	0.254***	5.907
Zacatecas	0.194***	3.959	0.262***	12.476
Central				
Ciudad de México	0.418***	19.905	0.311***	6.911
Hidalgo	0.413***	22.944	0.375***	6.250
México	0.475***	6.690	0.218***	2.759
Morelos	0.442***	12.629	0.396***	12.375
Puebla	0.587***	14.317	0.518***	12.950
Tlaxcala	0.042	0.609	−0.015	−0.429
West Pacific				
Colima	0.188***	2.984	0.491***	4.676
Jalisco	0.495***	8.839	0.311***	4.092
Michoacán	0.103***	2.784	0.067***	2.393
Nayarit	0.627***	20.226	0.571***	11.896
Sinaloa	0.423***	10.846	0.343***	6.236
South				
Campeche	1.320***	12.816	1.244***	12.078
Chiapas	0.093	1.409	0.143**	2.014
Guerrero	0.128***	3.765	0.134***	3.190
Oaxaca	0.566***	6.659	0.605***	8.403
Quintana Roo	0.437***	7.667	0.217***	3.014
Tabasco	0.241***	2.231	0.365***	2.724
Veracruz	0.499***	19.192	0.606***	8.657
Yucatán	0.659***	22.724	0.658***	11.964
Panel	0.473***	53.22	0.412***	41.606
B. Factor augmented	**CUP-FM**	**t-stat**	**CUP-BC**	**t-stat**
Panel	0.311***	22.980	0.296***	21.686

FMOLS and DOLS report cross-section–specific long-run coefficients and include both a constant and a linear trend. The DOLS specification incorporates leads and lags of the first differences of the regressors, with lag length selected using the Akaike Information Criterion (AIC). The CUP-FM and CUP-BC estimators control for unobserved common factors and therefore accommodate CSD. *, **, and ***refer to significance at the 10%, 5%, and 1% levels, respectively. FMOLS and DOLS estimates are obtained using the *xtcointreg* command in Stata 18, while CUP-FM and CUP-BC estimates were computed using GAUSS 21

80% of the State's GDP. Yucatán and Oaxaca also have sizable and statistically significant coefficients. In contrast, the evidence for Chiapas is relatively weak, indicating a less stable long-run electricity-growth nexus.

Overall, the panel results from the four estimators are similar. The FMOLS method gives a coefficient of 0.473, which is close to the 0.412 from the DOLS method. Finally, the CUP-BC estimator is 0.311, and the CUP-BC estimator is 0.296, or a robust average of 0.3. That is, without including other explanatory variables like capital and labor, as in the neoclassical production function, an increase of 10% in the consumption of electricity enlarges GDP by 3% in the long term. The size of the coefficient underscores the crucial role energy plays in the economies of Mexican States.

Furthermore, Table 8 shows the estimations from the EK panel causality test. As before, we grouped the results into the five regions of Northern Border, North Central, Central, West Pacific, and South. For the first region, we found that ELE Granger-causes GDP only in Coahuila; that is, the evidence supports the growth hypothesis. Therefore, the government can implement energy policies in accordance with the State profile: Promoting energy efficiency, avoiding energy conservation, improving and securing the electricity supply, etc. However, in the State of Chihuahua, the opposite is true: GDP Granger causes ELE, even though the evidence is weak; thus, the evidence supports the conservation hypothesis. In the North Central region, we found that the neutrality outcome prevails across all the States. In the Central region, in the State of Tlaxcala, ELE drives GDP, and in Puebla, GDP causes ELE, although the evidence is weak. In the West Pacific region, we observe evidence of interdependence in the State of Sinaloa. Moreover, finally, in the South, our results point to the prevalence of conservation hypothesis in Campeche and Yucatán. In general, across most Mexican States, our results indicate neutrality dominates in the short-run GDP-ELE causality. When looking at the whole panel, the Fisher-type statistics accept the null hypothesis of no Granger causality in either sense at the 5% significance level; however, there was marginal evidence of an ELE → GDP relationship at the 10% significance level. As such, these results suggest a highly heterogeneous, localized relationship of causality that masks significant distributional differences among States.

5. GENERAL DISCUSSION OF THE FINDINGS

Our long-term results indicate that electricity significantly affects economic activity in Mexico. On the one hand, the panel-wide estimates yielded a robust elasticity of approximately 0.3. In contrast, Žiković et al. (2020) examined the relationship between energy and economic growth in Croatia, using data from 21 counties. The Pooled Mean Group estimator produced a coefficient for electricity of 1.268; however, the GMM method calculated a smaller coefficient of 0.129. Furthermore, our results are more in accordance with Zhao et al. (2023), who conducted detailed research on the GDP-energy consumption link using data from 30 Chinese provinces during 2000-2019. Their national estimations using FMOLS generated a coefficient for electricity consumption of 0.221. Moreover, in the Eastern, Central, and Western regions, the coefficient ranged from 0.155 to 0.239.

Regarding our disaggregated results, the economic specialization of each State may explain the size of the estimated coefficients (Table 9). Data from INEGI show that in the Northern Border States in 2024, the primary sector accounted for 3.4% of GDP, whereas the secondary and tertiary sectors 42% and 54.5%, respectively. In the North Central States, the participation rates were 5.4%, 42%, and 52.2% across the three sectors. Therefore, the energy-intensive industrial sector in these two regions plays a vital

Table 8: EK causality test results

States	H_0: ELE$\nrightarrow$GDP			H_0: GDP$\nrightarrow$ELE		
	k	*W*	P-value	*k*	*W*	P-value
Northern Border						
Baja California	2	0.316	0.854	2	1.845	0.398
Baja California Sur	1	0.000	0.987	1	0.254	0.614
Chihuahua	1	0.011	0.918	**1**	**3.188**	**0.074**
Coahuila	**2**	**7.271**	**0.026**	2	0.469	0.791
Nuevo León	2	0.900	0.638	2	0.096	0.953
Sonora	3	5.510	0.138	3	2.420	0.490
Tamaulipas	3	2.375	0.498	3	0.784	0.853
North Central						
Aguascalientes	1	0.479	0.489	1	0.457	0.499
Durango	2	2.035	0.361	2	0.940	0.625
Guanajuato	2	1.694	0.429	2	0.077	0.962
Querétaro	2	3.401	0.183	2	0.213	0.899
San Luis Potosí	2	1.210	0.546	2	0.721	0.697
Zacatecas	1	0.132	0.717	1	0.091	0.763
Central						
Ciudad de México	2	3.808	0.149	2	1.173	0.556
Hidalgo	2	2.505	0.286	2	0.390	0.823
México	2	1.241	0.538	2	0.168	0.920
Morelos	3	2.729	0.435	3	4.696	0.195
Puebla	2	0.830	0.660	**2**	**5.475**	**0.065**
Tlaxcala	**3**	**12.456**	**0.006**	3	2.876	0.411
West Pacific						
Colima	3	0.932	0.818	3	1.052	0.789
Jalisco	2	3.558	0.169	2	0.576	0.750
Michoacán	2	0.443	0.801	2	2.395	0.302
Nayarit	2	0.042	0.979	2	0.643	0.725
Sinaloa	**3**	**11.108**	**0.011**	**3**	**6.971**	**0.073**
South						
Campeche	3	3.711	0.294	**3**	**10.484**	**0.015**
Chiapas	1	0.579	0.447	1	0.045	0.832
Guerrero	3	5.107	0.164	3	5.125	0.163
Oaxaca	1	0.151	0.698	1	0.721	0.396
Quintana Roo	1	0.027	0.869	1	1.101	0.294
Tabasco	3	5.215	0.157	3	0.126	0.989
Veracruz	1	2.610	0.106	1	0.089	0.766
Yucatán	3	6.214	0.102	**3**	**26.642**	**0.000**
Test statistic			**79.636**			76.805
P-value			**0.090**			0.131
Critical values (%)	1	5	10	1	5	10
	108.687	95.602	89.629	109.041	95.680	89.336

k is the lag and W is the Wald statistic. Estimates are computed using the TSPDlib package implemented in GAUSS 21

Table 9: Sectoral composition of GDP across Mexican regions 2024 (%)

Region	Sector		
	Primary	Secondary	Tertiary
Northern Border	3.4	42.0	54.5
North Central	5.4	42.4	52.2
Central	2.5	29.6	67.9
West Pacific	8.6	20.7	70.6
South	4.5	24.7	70.8
Campeche	1.5	78.1	20.5
Tabasco	1.8	61.0	38.0

Source: Authors' own calculations with data from INEGI

economic role. However, in the Central States, the services sector accounts for 68%, whereas the secondary sector 30%. It is well known that the services sector is a major consumer of electricity for lighting, cooling, and heating. Still, it consumes far less than the secondary sector does, excluding transportation. Data from the Secretaría de Energía indicate that in 2023, the industry accounted for 23% of final consumption, whereas the services sector only 3%.

In the West Pacific region, participation rates are even higher: 8.6% in the primary sector, 21% in the secondary sector, and 71% in the services sector. The primary sector is more relevant in Michoacán (15%), whereas the services sector in Nayarit (75%). However, in Jalisco, the industry's participation is at 30%. Finally, the Southern region, excluding Campeche and Tabasco, is more concentrated in the services sector, particularly tourism (71%). In Campeche and Tabasco, the oil industry dominates; the secondary-sector participation rates were 78.1% and 61%, respectively.

Regarding short-run causalities, our estimates support the neutrality of GDP and ELE in most Mexican States, with weak support for the growth hypothesis in the whole panel. The findings of this research partially align with those of Mahalingam and Orman

(1978), who studied the US economy using State-level data from 1978 to 2014. When their model included only GDP and energy, 17 States supported bidirectionality, 16 growth, seven conservation, and 10 neutrality. Furthermore, when the model incorporated capital and labor, 21 States supported bidirectionality, 14 growth, nine conservation, and seven neutrality. However, other studies did not find support for neutrality. Shahbaz et al. (2020) analyzed the GDP-energy nexus in China with nonparametric time series, panel data methods, and nonparametric Granger causality tests. The short-run causation indicated support for the GDP-energy hypothesis in eight provinces, for the energy-GDP hypothesis in another eight provinces, and bidirectional causation in the last 14 provinces.

6. CONCLUSION

The objective of this paper was to examine the GDP-ELE nexus in a sample of Mexican States from 1994 to 2024. In conclusion, we observed several empirical features that informed the selection of appropriate estimation methods. The panel data exhibited cross-sectional dependence and heterogeneity, which are indicative of the complex, interrelated economic activities of the Mexican economy. Second, we chose a unit-root test that considered CSD, such as the CIPS unit root test. After determining the correct characteristics of the data through diagnostic testing, we applied a robust cointegration test that accounted for CSD via bootstrapping. We then conducted cointegrating regressions using FMOLS, DOLS, and the factor-augmented estimators CUP-FM and CUP-BC. Lastly, the short-run causality was analyzed with a heterogeneous panel causality test.

The results indicate that electricity contributes significantly to GDP in the long run at both the national and State levels, except in Baja California Sur, Sonora, and Chiapas, for which the evidence is weak. Additionally, we did not find long-term evidence for Tlaxcala. The heterogeneous Granger causation test confirmed the growth hypothesis for Coahuila and Tlaxcala, the conservation hypothesis for Yucatán and, marginally, for Chihuahua and Puebla, and interdependency for Sinaloa. For the remaining States, neutrality is confirmed. Nonetheless, these results stipulate that uniform energy policies are unlikely to be effective nationwide. The economic structure across States varies significantly. Also, States are endowed differently. For example, Campeche and Tabasco are rich in oil and natural gas; Sonora, Chihuahua, Coahuila, and others are rich in metallic minerals; and Oaxaca, Michoacán, Nayarit, Chiapas, and Oaxaca are rich in renewable energy resources. Results could be further improved if policies acknowledge sectoral differences across regions and States.

While not conclusive, this study allows us to continue deepening the ELE-GDP linkage in the Mexican economy. As Mahalingam and Orman (2018) noted, further studies should include capital and labor in models, as these factors may alter long- or short-term causation. An additional line of future research is to employ nonparametric methods, as the ELE-GDP link may not be linear.

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APPENDICES

Table A1: Per capita electricity consumption (MWh)

Year	AGS	BCN	BCS	CAM	COA	COL	CHP	CHI	CMX	DGO	GTO	GRO	HGO	JAL	MEX	MIC
1994	1.217	2.107	2.046	0.744	2.300	1.969	0.308	1.811	1.388	1.025	1.034	0.540	1.094	1.103	0.969	1.016
1995	1.293	2.156	1.970	0.746	2.368	2.030	0.323	1.869	1.378	1.152	1.052	0.557	0.989	1.082	0.936	1.124
1996	1.421	2.393	2.232	0.715	2.642	2.261	0.327	1.944	1.340	1.226	1.091	0.543	1.031	1.121	1.017	1.183
1997	1.471	2.565	2.269	0.780	2.885	2.205	0.339	2.034	1.404	1.288	1.147	0.567	1.155	1.159	1.054	1.367
1998	1.619	2.547	2.251	0.845	3.178	1.996	0.351	2.182	1.431	1.318	1.164	0.590	1.244	1.262	1.063	1.464
1999	1.664	2.746	2.387	0.842	3.327	2.182	0.360	2.248	1.439	1.465	1.252	0.614	1.300	1.329	1.105	1.585
2000	1.782	3.014	2.462	0.891	3.513	2.237	0.379	2.426	1.522	1.551	1.382	0.654	1.391	1.403	1.147	1.669
2001	1.753	3.022	2.437	0.963	3.642	2.044	0.403	2.428	1.557	1.520	1.378	0.686	1.373	1.416	1.116	1.463
2002	1.786	2.900	2.303	1.005	3.681	2.303	0.422	2.451	1.495	1.543	1.397	0.719	1.385	1.430	1.106	1.545
2003	1.719	2.954	2.311	1.089	3.527	2.051	0.427	2.499	1.493	1.533	1.380	0.748	1.381	1.415	1.055	1.686
2004	1.710	2.994	2.397	1.108	3.261	2.115	0.440	2.489	1.489	1.591	1.406	0.766	1.258	1.406	1.048	1.803
2005	1.870	2.953	2.518	1.142	3.261	2.298	0.459	2.651	1.489	1.661	1.499	0.794	1.220	1.448	1.073	1.717
2006	1.929	3.093	2.656	1.160	3.275	2.395	0.467	2.729	1.486	1.610	1.540	0.800	1.256	1.486	1.057	1.747
2007	1.943	3.069	2.768	1.204	3.270	2.423	0.484	2.768	1.504	1.696	1.572	0.822	1.241	1.503	1.055	1.794
2008	1.884	3.066	2.969	1.267	3.300	2.413	0.503	2.702	1.546	1.683	1.610	0.788	1.215	1.506	1.032	1.779
2009	1.804	2.900	2.901	1.333	3.270	2.347	0.518	2.651	1.555	1.629	1.654	0.788	1.153	1.498	0.995	1.356
2010	1.823	2.802	2.796	1.304	3.298	2.260	0.518	2.780	1.469	1.679	1.696	0.772	1.146	1.506	1.036	1.546
2011	1.955	2.875	2.962	1.369	3.593	2.290	0.543	3.008	1.506	1.745	1.836	0.781	1.289	1.567	1.071	1.643
2012	1.950	2.951	2.968	1.402	3.520	2.410	0.540	3.043	1.552	1.689	1.839	0.788	1.310	1.585	1.094	1.611
2013	1.878	2.842	2.949	1.415	3.559	2.469	0.541	3.042	1.597	1.669	1.797	0.777	1.284	1.563	1.096	1.594
2014	1.991	2.929	2.963	1.435	3.542	2.460	0.549	3.143	1.566	1.716	1.849	0.786	1.229	1.546	1.094	1.511
2015	2.015	2.939	3.014	1.462	3.468	2.469	0.567	3.255	1.580	1.708	1.900	0.815	1.313	1.603	1.105	1.414
2016	2.013	2.996	3.137	1.503	3.344	2.528	0.597	3.335	1.577	1.827	1.976	0.837	1.340	1.644	1.101	1.443
2017	2.060	3.011	3.100	1.444	3.364	2.681	0.559	3.387	1.473	1.725	1.998	0.822	1.314	1.646	1.057	1.631
2018	2.021	2.946	3.282	1.411	3.391	2.749	0.555	3.400	1.445	1.766	1.950	0.858	1.282	1.619	1.049	1.639
2019	2.027	2.784	3.254	1.483	3.453	2.778	0.591	3.430	1.382	1.832	1.936	0.881	1.265	1.644	1.020	1.627
2020	1.832	2.819	3.050	1.438	2.955	2.805	0.567	3.471	1.217	1.705	1.808	0.883	1.180	1.533	0.927	1.491
2021	1.835	3.066	3.240	1.484	2.813	2.818	0.570	3.400	1.215	1.758	1.625	0.879	1.135	1.539	0.950	1.053
2022	1.917	3.288	3.349	1.485	2.887	2.828	0.574	3.364	1.286	1.767	1.650	0.892	1.126	1.578	0.973	1.018
2023	2.053	3.309	3.571	1.629	2.688	2.940	0.607	3.417	1.320	1.795	1.700	0.914	1.088	1.644	0.998	1.036
2024	1.854	3.439	3.599	1.683	2.550	2.802	0.577	3.505	1.368	1.742	1.627	0.904	1.205	1.685	0.981	1.010

Source: Authors' own calculations based on data from INEGI, CONAPO, Secretaría de Energía, and Presidencia de la República (2013).

Table A1: ***(Continued)***

Year	MOR	NAY	NLE	OAX	PUE	QUE	QRO	SLP	SIN	SON	TAB	TAM	TLA	VER	YUC	ZAC
1994	0.872	0.600	2.619	0.385	0.878	1.614	1.766	1.372	1.113	2.800	0.762	1.739	0.916	1.030	0.989	0.961
1995	0.898	0.610	2.701	0.401	0.855	1.615	1.730	1.349	1.118	2.908	0.750	1.817	0.931	1.137	0.974	1.015
1996	0.865	0.634	2.932	0.435	0.933	1.740	1.681	1.436	1.153	3.195	0.727	1.866	1.074	1.229	0.964	1.016
1997	0.939	0.634	3.087	0.424	0.990	1.867	1.834	1.484	1.196	3.323	0.763	1.944	1.158	1.290	1.041	1.118
1998	1.024	0.679	3.202	0.447	1.055	1.940	1.910	1.546	1.273	3.246	0.835	2.026	1.191	1.323	1.100	1.125
1999	1.107	0.720	3.398	0.462	1.091	2.071	1.940	1.579	1.318	3.377	0.829	2.156	1.260	1.319	1.144	1.113
2000	1.240	0.783	3.584	0.503	1.126	2.131	2.076	1.692	1.363	3.497	0.930	2.309	1.367	1.349	1.192	1.128
2001	1.215	0.827	3.504	0.533	1.115	2.106	2.146	1.702	1.427	3.468	0.987	2.507	1.394	1.239	1.243	1.237
2002	1.229	0.857	3.541	0.557	1.159	2.092	2.204	1.712	1.481	3.325	1.036	2.522	1.417	1.231	1.254	1.202
2003	1.228	0.882	3.082	0.559	1.150	1.989	2.219	1.787	1.543	3.400	1.064	2.446	1.392	1.215	1.294	1.204
2004	1.230	0.935	3.076	0.574	1.131	2.039	2.283	1.903	1.604	3.520	1.130	2.490	1.475	1.197	1.331	1.056
2005	1.279	0.988	3.173	0.586	1.160	2.056	2.203	1.934	1.652	3.669	1.163	2.512	1.601	1.259	1.358	1.124
2006	1.286	1.036	3.304	0.588	1.176	2.025	2.376	1.958	1.771	3.625	1.182	2.572	1.624	1.288	1.403	1.142
2007	1.316	1.069	3.283	0.583	1.210	2.073	2.665	1.981	1.808	3.719	1.216	2.568	1.621	1.304	1.445	1.162
2008	1.338	1.121	3.300	0.607	1.251	2.059	2.826	1.955	1.875	3.576	1.245	2.543	1.527	1.311	1.495	1.168
2009	1.329	1.139	3.188	0.620	1.156	1.991	2.759	1.776	1.948	3.436	1.313	2.505	1.367	1.256	1.496	1.325
2010	1.326	1.132	3.263	0.593	1.205	2.117	2.698	1.836	1.948	3.393	1.244	2.508	1.385	1.283	1.427	1.684
2011	1.345	1.173	3.540	0.637	1.231	2.327	2.712	1.976	2.034	3.830	1.330	2.636	1.473	1.361	1.506	1.986
2012	1.371	1.181	3.624	0.641	1.229	2.321	2.723	2.142	2.027	3.959	1.404	2.617	1.457	1.404	1.495	1.929
2013	1.370	1.191	3.346	0.628	1.217	2.348	2.754	2.114	2.032	3.897	1.400	2.537	1.433	1.341	1.519	1.815
2014	1.372	1.216	3.394	0.637	1.209	2.343	2.805	2.120	2.129	3.443	1.405	2.507	1.426	1.315	1.529	1.808
2015	1.322	1.280	3.392	0.653	1.199	2.337	2.897	2.085	2.171	3.440	1.415	2.559	1.416	1.350	1.622	1.528
2016	1.394	1.308	3.451	0.659	1.190	2.380	2.937	2.248	2.254	3.511	1.514	2.558	1.449	1.353	1.681	1.394
2017	1.409	1.295	3.103	0.644	1.192	2.348	2.853	2.079	2.313	3.542	1.359	2.477	1.417	1.190	1.661	1.392
2018	1.408	1.292	3.198	0.662	1.192	2.374	2.837	2.087	2.333	3.532	1.347	2.514	1.319	1.258	1.670	1.298
2019	1.281	1.335	3.048	0.694	1.147	2.344	2.877	2.095	2.366	3.539	1.366	2.546	1.197	1.235	1.765	1.475
2020	1.238	1.287	2.709	0.685	1.032	1.990	2.287	1.988	2.373	3.651	1.383	2.393	1.089	1.171	1.607	1.466
2021	1.251	1.358	2.815	0.692	1.046	1.936	2.564	1.859	2.422	3.600	1.376	2.353	1.076	1.188	1.644	1.424
2022	1.167	1.419	3.078	0.709	1.057	2.010	2.768	1.752	2.403	3.775	1.463	2.452	1.106	1.221	1.718	1.467
2023	1.188	1.525	3.096	0.747	1.025	2.096	3.014	1.779	2.631	3.904	1.639	2.525	1.036	1.299	1.881	1.519
2024	1.188	1.552	3.028	0.757	1.036	1.983	3.117	1.856	2.694	3.817	1.703	2.378	1.000	1.328	1.946	1.544

Source: Authors' own calculations based on data from INEGI, CONAPO, Secretaría de Energía and Presidencia de la República (2013)