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Reexamining Okun's law using state level panel data from Mexico

Reexaminando la Ley de Okun para México mediante el uso de datos panel a nivel estatal

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Abstract

Objective: This paper investigates the validity of Okun's law in Mexico at national and subnational levels using panel data for 32 states from 2000 to 2019, addressing gaps in prior analyses regarding slope heterogeneity, cross-sectional dependence, and endogeneity.
Methodology: Second-generation panel time-series estimators, including Common Correlated Effects Mean Group and Augmented Mean Group, are applied to difference and gap specifications of Okun's law, ensuring robustness to the identified econometric challenges.
Results: Okun's law holds at the national level. Sub nationally, it is valid in 15 states using the difference version and 11 states using the gap version, revealing substantial regional variation.
Limitations/implications: Data constraints limit granularity to annual frequencies; implications emphasize tailored regional policies to mitigate unemployment-output disparities.
Originality/value: This study pioneers robust second-generation estimators for subnational Okun analysis in Mexico, offering reliable coefficients for policy design.
Conclusions: Heterogeneity underscores the need for advanced panel methods; Okun's law remains a key tool for Mexican economic stabilization with nuanced subnational applications.

Keywords: Okun's law, panel data, regional heterogeneity, cross-section dependence, endogeneity.
JEL Classification: E24, E32, C23.

Resumen

Objetivo: Este artículo investiga la validez de la Ley de Okun en México a nivel nacional y subnacional, utilizando datos de panel para las 32 entidades federativas en el periodo 2000–2019, abordando vacíos en análisis previos relacionados con la heterogeneidad de pendientes, la dependencia transversal y la endogeneidad.
Metodología: Se aplican estimadores de series de tiempo de segunda generación en modelos panel, incluyendo Promedio de Grupo con Efectos Correlacionados Comunes (CCEMG) y Promedio de Grupo Aumentado (AMG), a las especificaciones en diferencias y en brechas de la Ley de Okun, garantizando robustez frente a los desafíos econométricos identificados.
Resultados: La Ley de Okun se cumple a nivel nacional. A nivel subnacional, es válida en 15 entidades federativas bajo la versión en diferencias y en 11 entidades bajo la versión en brechas, lo que revela una marcada heterogeneidad regional.
Limitaciones/implicaciones: Las restricciones de datos limitan la granularidad a frecuencias anuales; las implicaciones subrayan la necesidad de políticas regionales diferenciadas para mitigar las disparidades entre desempleo y producción.
Originalidad/valor: Este estudio es pionero en la aplicación de estimadores robustos de segunda generación para el análisis subnacional de la Ley de Okun en México, proporcionando coeficientes confiables para el diseño de políticas públicas.
Conclusiones: La heterogeneidad observada resalta la necesidad de métodos avanzados de panel; la Ley de Okun sigue siendo una herramienta clave para la estabilización económica en México, con aplicaciones subnacionales que requieren un enfoque matizado.

Palabras clave: Ley de Okun, datos de panel, heterogeneidad regional, dependencia transversal, endogeneidad.
Clasificación JEL: E24, E32, C23.

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Introduction

Okun's Law (1962) is a well-known empirical regularity that establishes the negative relationship between unemployment and output growth. Policymakers everywhere are particularly concerned about the significance and strength of this relationship, as it has implications for fiscal and monetary policies in terms of reducing unemployment. A strong relationship would call for expansionary fiscal and monetary policies to reduce unemployment, while a weak relationship would require policy responses that create a more flexible labor market to reduce unemployment (see, for example, Apergis and Rezitis, 2003; Binet and Facchini, 2013).

Since the appearance of Okun's paper in 1962, a myriad of papers have extensively analyzed the validity of Okun's law in the context of many countries, mostly by using the national level time series data. Also, there are studies that examine the validity of Okun's law in the international context by relying on either time series or panel data (see, for example, Balakrishnan *et al.,* 2010; Ball *et al.,* 2013).

Recent line of research on Okun's law follows the seminal work of Freeman (2000), which examines the validity of Okun's law at the sub-national level. Several papers look for the differences in Okun's coefficients across different regions within a country (see, for example, Apergis and Rezitis, 2003; Oberst and Oelgemöller, 2013; Durech *et al.,* 2014; Montero, 2014; Guisinger *et al.,* 2018), while others try to estimate the national level Okun's coefficient by pooling the regional or state level Okun's coefficients (see, for example, Binet and Facchini, 2013; Oberst and Oelgemöller, 2013).

In this paper, we aim to estimate Okun's coefficient for Mexico and each of its 32 states. Several papers have examined the validity of Okun's law in the Mexican context with particular emphasis on its magnitude. Majority of these papers rely on the aggregated information at the national level resulting in time series data and estimation techniques (see, for example, Chavarin, 2001; González Anaya, 2002; Rodríguez & Peredo, 2007; Loría & Gacría-Ramos, 2007; Loría & Leobardo, 2011; Loría *et al.,* 2012; Loría & Ramírez, 2015; Santos *et al.,* 2020) with a few exceptions that use panel data of Mexican states (see, for example, Alarcón & Soto, 2017; Rojas, 2019 and Loría *et al.,* 2021). Out of these studies, some only estimate the model in first differences (see, for example, Chavarin, 2001; Rodríguez & Peredo, 2007; Loría *et al.,* 2012; Loría and Ramírez, 2015; Alarcón and Soto, 2017), while others only estimate the gap model (see, for example, Rojas, 2019). There are also a few studies that estimate all three model specifications proposed by Okun (1962) (see, for example, Loría and García-Ramos, 2007; Loría and Leobardo, 2011; and Santos *et al.,* 2020).

The main problem with estimating time series models using data at the national level is that they do not account for heterogeneity across the Mexican states. Mexican states are well-known for their regional socioeconomic variation, which can potentially affect labor market responses to output growth. At the sub-national level using the state level panel data, this makes analysis highly suitable in the Mexican context. However, the extant studies on Mexico that are based on state level panel data are lacking in terms of addressing the econometric issues that arise while estimating Okun's coefficient, namely, cross-section dependence, heterogeneity of Okun's coefficient, and the endogeneity of the regressor, which collectively result in inconsistent and biased estimates. In our paper, we use state level panel data from 2000-2019 and rely on relatively newer time series panel data estimators developed by Eberhardt & Teal (2010), which allow us to address all three issues mentioned above. For comparison, we also present the estimates obtained from the OLS, Fixed Effects, MG estimator by Pesaran and Smith (1995), and CCEMG by Pesaran (2006). The estimates presented in this paper allow us to gain a better understanding of the existing relationship between production and unemployment and inform policy makers not only at the national level but also at the state level with regards to the interventionist policies to influence output and consequently unemployment.

First, we provide a brief literature review in the context of Mexico. Second, we provide a description of the methodology employed in this paper. Third, this paper presents data description next to the discusses of the estimation results. And finally, we conclude the paper.

Literature Review

Several papers have studied Okun's law for different countries. Our paper is specifically related to the Mexican economy. As such, we present a summary in chronological order of the recent articles regarding Okun's Law in the context of Mexico. In his original work, Okun (1962) formulated his models with unemployment rate as the dependent variable. When referring to Okun's coefficient, we mean the effect of a percentage change in growth rate on unemployment rate. However, few studies, particularly the newer ones, regress output on unemployment rate.

Loría and García-Ramos (2007) estimate the dynamic relationship between unemployment rate and GDP by using annual data from 1970 to 2004 and relying on three time series structural models, namely, Kalman filter, Vector Auto Regression and Cointegration analysis. Their results confirm the validity of Okun's law for the Mexican economy. They estimate that a percentage change in unemployment results in 2.08 to 2.5 percentage point change in output growth.

Rodríguez and Peredo (2007) study the validity of Okun's law by using quarterly data of real GDP and unemployment rate from 1987 to 2003. The authors estimate three specifications based on the original models proposed by Okun using the Kalman and Hodrick-Prescott filters. Their estimations for Okun's coefficients are -2.47, -3.73 and 2.65.

Loría and Leobardo (2011) estimated the three Okun's equations using quarterly data from 1985 to 2006. Regressing GDP on unemployment rate, they found that the coefficients vary from 2.35 to 2.58. Additionally, they found that there is a bi-directional causal relationship between unemployment rate and output growth in all three specifications.

Loría *et al.,* (2012), using the first differences model, analyze the relationship between the national female and male unemployment rates with the country's GDP and find that the male coefficient is twice that of the female coefficient. In addition, they also found evidence of bi-directional causality between the variation in unemployment (of men and women) and economic growth.

Islas and Cortez (2013) used a bivariate model to jointly estimate the permanent and transitory components of the output and unemployment rates with Kalman filter for the time-period 1987-2008. The authors found an Okun coefficient of -1.810.

Loría *et al.,* (2015) estimate a Vector Error Correction Model (VECM) on quarterly data from 1997.3 to 2014.1, while incorporating labor market flexibility index (defined as the ratio of temporary contracts to total employees in the formal market) to analyze its effect on the unemployment rate. Their estimate of Okun's coefficient is -0.12. They also find that the labor flexibility index increases the unemployment rate with an elasticity of 1.28.

Islas and Cortez (2018) used data from 1993 to 2015 and incorporate the effect of informal sector on the relationship between unemployment and output growth. Firstly, they suggested that a regime-dependent specification of Okun's law is more appropriate in the case of Mexico and find that a 1% decrease in cyclical output is accompanied by an increase of approximately 0.31% in unemployment if the system is in a recessive regime, while a 1% increase in cyclical output reduces unemployment by approximately 0.12% when the system is in an expansionary regime. Secondly, they claim that this non-linear relationship may be affected by changes in the informal sector.

Alarcón and Soto (2017) used panel data for the 32 Mexican states from 2003 to 2014. They presented the estimates of pooled, fixed effects and random effects models to estimated an Okun's coefficient of -2.99. Additionally, they estimate Okun's coefficient for each state and find great diversity of parameter estimates obtained in each of the Mexican states.

Rojas (2019) used a panel data of 32 Mexican states from 2005 to 2016. According to the estimates obtained from the random effects model, for each percentage point of growth of the output observed over the potential output, the unemployment is reduced by 0.13 percent. The author concluded that the value of Okun's coefficient indicates a labor market that is not very sensitive to output growth, that is, a rigid labor market that does not allow the output variations to be reflected in employment variations, which the author attributed to the rigid institutional framework that results in high rates of labor informality.

Santos *et al.,* (2020) estimated the three specifications proposed by Okun using time series models with quarterly data for the period 2005.1 to 2020.1. The first differences model shows that if the growth rate of output increases by one percentage point, the unemployment rate will decrease by 0.07 percentage points. The result from the gap model indicates that if the gap between potential and observed output increases by one percentage point, the unemployment rate will increase by 0.12 percentage points. In addition, the estimates of elasticity and trend models suggest that if the gross domestic product increases by 1%, the employment rate will increase by 0.16%.

Loría *et al.,* (2021) estimated Okun's coefficient for each of the 32 states and found significant variation in their estimates. In addition, they analyzed the effects of economic, social and institutional factors in determining unemployment rate's sensitivity to output growth.

Methodology

We estimate the two versions of Okun's law: the difference version and the gap version. The difference version of the model regresses the changes in unemployment rates on output growth rates, whereas the gap version of the model regresses the deviations of unemployment from the natural rate of unemployment on the deviations of output from the potential output. Essentially, the gap version of the model regresses the cyclical unemployment on cyclical output. In this study, we first consider a state-level panel data difference version of the Okun's law as shown below:

$$\Delta U_{i,t} = \alpha_{i,t} + \beta \Delta Y_{i,t} + \varepsilon_{i.t} \qquad (1)$$

Where $\Delta U_{i,t}$ is the change in unemployment rate, $\Delta Y_{i,t}$ is the percent change in real GDP, i denotes a cross-sectional unit (state) $(i = 1, \dots N)$ and t denotes time (year) $(t = 1, \dots T)$ of the panel, and $\alpha_{i,t}$ is the state specific intercept, and $\varepsilon_{i.t}$ is the idiosyncratic error term.

Below is the panel version of Okun's equation following Ball *et al.,* (2013), which accounts for cross section dependence and heterogeneity:

$$\Delta U_{i,t} = \alpha_i + \beta_i \Delta Y_{i,t} + \gamma_i' Z_t + \varepsilon_{i.t} \qquad (2)$$

Where α_i is state level unobserved fixed effects, and β_i is the estimated Okun's coefficient. Z_t is a vector of common and unobserved factors that govern the cross-section dependence, γ_i' is a vector of regression coefficients for unobserved common factors, and $\varepsilon_{i.t}$ is the idiosyncratic error term, which may be correlated across space and time but uncorrelated with regressor. The fixed effects, α_i, in equation (2) above captures the effects of state-specific time-invariant factors on state unemployment. These factors could include demographics, variations in the industrial structures, variations in housing availability and affordability, geographical locations of states, and environmental features. The common unobserved factors, Z_t, capture the effect of those unobserved time-varying variables that uniformly affect the unemployment rates across all states. It could include financial crises, oil price shocks, economic policy measures (monetary policy, fiscal policy, labor market policy, housing policy), and regulatory changes, including labor market regulations. Equation (2) thus captures the factors of unemployment commonly listed in the empirical models of unemployment and isolates the effect of output growth on changes in the unemployment rate.

The difference version of the model assumes that the potential GDP grows at a constant rate and that the natural rate of unemployment is constant (see, e.g., Okun, 1962; Ball *et al.,* 2013). Releasing these rather restrictive assumptions, the second version of the Okun's Law can be modeled as a relationship between deviations in the actual unemployment rate from the natural rate of unemployment (i.e., cyclical unemployment) and deviations in the actual real GDP from the potential GDP (i.e., cyclical GDP growth) resulting in what has been dubbed as the gap model in the extant literature (see, e.g., Ball *et al.,* 2013):

$$U_{i,t} - U^*_{i,t} = \theta_i + \delta_i (Y_{i,t} - Y^*_{i,t}) + \rho_i' K_t + \omega_{i,t} \quad (3)$$

where $U_{i,t}$ is the actual unemployment rate in the i^{th} state in the tth year, $U^*_{i,t}$ is the natural rate of unemployment in the i^{th} state in the t^{th} year, $Y_{i,t}$ is the measure of real GDP in the i^{th} state in the t^{th} year, $Y^*_{i,t}$ is the measure of potential GDP in the i^{th} state in the t^{th} year. The term θ_i is state fixed effects, δ_i is an Okun's coefficient, and $\omega_{i,t}$ is an idiosyncratic error term. K_t is a vector of common and unobserved factors that govern the cross-section dependence (we assume the same set of common unobserved factors as in the difference version of the model), ρ_i' is a vector of regression coefficients for unobserved common factors.

Estimating equations (2) & (3) using the pooled OLS estimator will result in biased and inconsistent estimates for β_i and δ_i, which are Okun's coefficients, due to the presence of (1) state level heterogeneity, (2) cross-sectional dependence, and (3) endogeneity of regressor.
Estimating the above-mentioned equations using the fixed effects estimator differences out the time invariant state fixed effects, α_i and θ_i but does not remove the time varying unobserved common factors, Z_t and K_t and thus yields biased Okun's coefficients.

The mean group (MG) estimator proposed by Pesaran and Smith (1995) allows for the heterogeneity of Okun's coefficients but does not control for the cross-section dependence across states.

The common correlated mean group estimator (CCEMG) proposed by Pesaran (2006) addresses all three issues involving the biasedness and inconsistency of Okun's coefficients, β_i and δ_i in equations (2) & (3) by including the cross-section averages of the dependent and independent variables as additional regressors. Because the relationship is estimated for each state separately, the heterogeneous impact γ_i' and δ_i are also given by the design (see, e.g., Chudik and Pesaran, 2013).

To address the heterogeneity in Okun's slope coefficients, cross-section dependence, and endogeneity of regressors, we introduce estimates based on the Augmented Mean Group (AMG) estimator proposed by Eberhardt and Teal (2010) as an alternative to Pesaran's (2006) CCMG estimator. The AMG estimator involves three steps: (1) Estimating a pooled regression model augmented with year dummies using first difference OLS to obtain coefficients on differenced year dummies, representing an estimated cross-group average of the evolution of unobservable TFP over time, known as the "common dynamic process." (2) Augmenting the group-specific regression model with this estimated TFP process, either as an explicit variable or imposed on each group member with a unit coefficient by subtracting the estimated process from the dependent variable. Each regression model includes an intercept capturing time-invariant fixed effects. (3) Similar to MG and CCEMG estimators, averaging the group-specific model parameters across the panel, with the option to apply weights.

In what follows next, we describe the original Eberhardt & Teal (2010) and subsequent clarifications in Bond & Eberhardt (2013) of the proposed Augmented Mean Group (AMG) estimator.

Consider the panel model for country/group $i = 1, \ldots. N$ and time $t = 1, \ldots. T$:

$$y_{it} = \beta_i' x_{it} + \gamma_i' f_t + c_i + \varepsilon_{it} \quad (4)$$

where f_t is a vector of unobserved common factors (including non-stationary TFP), c_i are time-invariant fixed effects, and β_i are heterogeneous slope coefficients of interest.

Stage 1 – Estimation of the common dynamic process

Run a first-difference pooled OLS regression on the entire panel:

$$\Delta y_{it} = \alpha + \sum_{t=2}^{T} \delta_t \Delta D_t + \sum_{i=1}^{N} \sum_{k=1}^{p} \phi_{ik} \Delta x_{kit} + \Delta\varepsilon_{it} \quad (5)$$

where D_t are year dummies $(D_t = 1$ in year t and 0 otherwise).

The estimated coefficients on the differenced year dummies, $\hat{\delta}_t (t = 2, \ldots, T)$, represent the common dynamic process of the unobservables, denoted $\hat{d}_t$.

Define the level version of this process (with $\hat{d}_1 = 0$ for identification) as:

$$\hat{\mu}_t \equiv \hat{d}_t \text{ (cumulated)}$$

or simply use the estimated coefficient vector $\hat{\delta} = (\hat{\delta}_2, \ldots, \hat{\delta}_T)'$.

This $\hat{\mu}_t$ (or equivalently $\hat{\delta}_t$) is interpreted as a proxy for the evolution of unobserved total factor productivity (TFP) that is common across units.

Stage 2 – Group-specific regressions with the common dynamic process

Two equivalent implementations are available:

AMG-I (explicit inclusion):

$$y_{it} = \beta_i' x_{it} + \lambda_i \hat{\mu}_t + c_i^* + e_{it} \quad (6)$$

AMG-II (impose unit coefficient on the common process and subtract it from the dependent variable):

$$\tilde{y}_{it} \equiv y_{it} - \hat{\mu}_t = \beta_i' x_{it} + c_i^* + e_{it} \quad (7)$$

Both specifications include a group-specific intercept c_i^* that captures time-invariant fixed effects (and any deviation of the true factor loading from 1 in AMG-II). Estimate either equation by OLS (or any suitable estimator) for each group i separately to obtain $\hat{\beta}_i$.

Stage 3 – Panel estimator

The AMG estimator is the (unweighted or weighted) average of the group-specific coefficients:

$$\hat{\beta}_{AMG} = \frac{1}{N}\sum_{i=1}^{N} \hat{\beta}_i \text{ (unweighted, standard)}$$

or, with weights w_i (e.g., inverse of standard errors or precision weights):

$$\hat{\beta}_{AMG}^{w} = \sum_{i=1}^{N} w_i \hat{\beta}_i \quad (8)$$

Standard errors are computed non-parametrically as:

$$SE(\hat{\beta}_{AMG}) = \frac{1}{\sqrt{N(N-1)}} \sum_{i=1}^{N} \hat{\beta}_i - \hat{\beta}_{AMG} \quad (9)$$

The AMG estimator is consistent under cross-sectional dependence driven by a common factor with heterogeneous loadings, slope heterogeneity, non-stationarity of the common factor (e.g., stochastic trend in TFP), and endogeneity of regressors, provided the idiosyncratic errors are weakly dependent.

Monte Carlo simulations demonstrate that this estimator performs comparably to the CCMG estimator in terms of bias or root mean squared error, especially in panels with nonstationary variables (cointegrated or not) and a multi-factor error term (cross dependence), as shown by Eberhardt and Bond (2009).

Data and Summary Statistics

The data for this study is obtained from INEGI's Encuesta Nacional de Ocupación y Empleo (National Accounts for GDP and National Survey of Occupation and Employment) (INEGI, 2025). The description of variables and summary statistics are provided in **Table 1**. The data covers the period of twenty years from 2000-2019 encompassing all Mexican states. **Figure 1** shows the unemployment rate by state while **Figure 2** shows the GDP by state. These figures clearly show the presence of state level heterogeneities in unemployment and GDP statistics.

Results

State-level macro panel data suffers from cross-section dependence (see, Pesaran, 2004) due to global shocks, which heterogeneously impacts states (for example, federal labor policy reform), as well as the local spillover effects that are limited to the states in proximity (for example, state labor law reform). We test for the cross-section dependence among states on the raw panel data. The results of the cross-section dependence test are presented in the second column of **Table 2** on all variables used in our analysis. The results suggest that there is cross-section dependence among states and therefore needs to be taken into account. Additionally, since our panel consists of 20 time periods, the cointegration between the non-stationary unit root variables may result in spurious regression. Thus, to address this we test for the CIPS unit root test (Pesaran, 2007). This test is robust to cross-section dependence. The results are presented in columns 3, 4, and 5 of **Table 2**. The results indicate that the dependent and independent variables are stationary and therefore spurious regression is not a cause for concern.

The parameter estimates of the difference model along with diagnostics tests are presented in **Table 3**. The Okun's coefficient at the national level under various model specifications range from -.009 to -.05. The coefficients are statistically significant at the 1% level for the OLS, FE, MG estimators while not being statistically significant at the conventional levels for the CCEMG estimator. It is statistically significant at the 10% level in the case of CCEMG DYNAMIC GMM estimator. The cross-section dependence (CD) test performed on the residuals in each of the estimated models suggests that cross section dependence is an issue in the case of OLS, FE, MG, and CCEMG models. The null hypothesis of no cross-section dependence is rejected at the 1% level in each model specification. However, we fail to reject the null hypothesis in the case of CCEMG DYNAMIC GMM.

The parameter estimates of the gap model along with diagnostics tests are presented in **Table 4**. The Okun's coefficients at the national level under various model specifications range from -6.40e-06 to .0000332. The coefficients are statistically significant at the 1% level for the OLS, FE, MG estimators and at the 10% level for the CCEMG model while not being statistically significant at the conventional levels for the CCEMG DYNAMIC GMM estimator. The cross-section dependence (CD) test performed on the residuals in each of the estimated models suggests that cross section dependence is an issue in the case of OLS, FE, MG, and CCEMG models. The null hypothesis of no cross-section dependence is rejected at the 1% level in the first three model specifications and at the 10% level in the case of CCEMG. However, we fail to reject the null hypothesis in the case of CCEMG DYNAMIC GMM.

It is evident that in both the difference and gap model, the CCEMG DYNAMIC GMM specification performs best in reducing the cross-section dependence problem. Also, when it comes to addressing the endogeneity of the regressor, the CCEMG DYNAMIC GMM estimator has been shown to be a robust estimator (Neal, 2015). Focusing on the CCEMG-DYNAMIC GMM estimator, our most preferred model, Okun's coefficient is only significant for the difference model (see **Table 3** and **4**). As expected, we obtain a negative relationship between unemployment rate and growth in GDP. The estimated coefficient implies that an increase of one percent in the growth of GDP results in a decrease of -0.05 percent in unemployment rate. The magnitude aligns with other findings in the literature that have found the estimates to be on the lower side (e.g. Islas and Cortez, 2018; Loría and Ramírez, 2015; Santos *et al.,* 2020). Our results suggest that when issues of heterogeneity and cross-section dependence are not accounted for, the parameter is generally overestimated. Also, as expected, the size of the parameter estimate is much smaller in comparison to advanced economies like the United States, where many studies have found that an increase in one percent of output can result in a decrease in unemployment by as much as half a percentage point (e.g. Mankiw, 2020). This is consistent with the finding that developing countries tend to have a less responsive formal labor market. In a cross-country analysis of 71 countries, Ball *et al.,* (2019) found that the Okun's coefficient is about half as large in developing countries as in advanced countries. In particular, they estimated a coefficient of -0.19 for the case of Mexico. They also suggested a number of potential explanations for a small Okun coefficient including the size of informal sector, per capita GDP, share of service sector, labor market regulations and skill mismatch at jobs. On a similar note, Islas and Cortez (2018) found that the size of the informal sector plays an important role in the relationship between growth and unemployment.

Table 5 lists parameter estimates for each state for the CCEMG-DYNAMIC GMM estimator. The coefficients are negative and significant for fifteen states under the difference model and 11 states under the gap model. However, there is great heterogeneity in the estimates – ranging from -0.018 in Chiapas to -0.63 in Tamaulipas. For the remaining states, the estimates are either positive or statistically insignificant. However, when the estimates are positive, they are generally so for both model specifications. The wide variation in parameter estimates across states reiterates similar findings from other studies that analyze panel data as well (e.g. Loría *et al.,* 2021; Alarcón and Soto, 2017). Investigating the factors that result in regional differences in unemployment rate's response to output growth is beyond the scope of this paper, but other studies that also report such variety have attributed them to a number of factors. For example, in estimating Okun's coefficients for each state in the US, Guisinger *et al.,* (2018) found that indicators of flexible labor markets, namely higher levels of education, lower rate of unionization, and a higher share of non-manufacturing employment are key determinants in unemployment rate's sensitivity to output growth. For Czech Republic and Slovakia, Durech *et al.,* (2014) suggested that the level of unemployment and output, domestic and foreign investments, and R&D and infrastructure spending are possible drivers of regional differences. More specifically for Mexico, Loría *et al.,* (2012) found that states where the parameter estimate is negative have performed better economically, socially as well and institutionally, exhibiting more output growth, higher labor productivity, higher exports, lower crime rates and a higher rule of law index among other things. While the fixed effects in our model specifications control for some of these factors, not all of them are controlled for, and could contribute to the observed regional heterogeneity.

From the viewpoint of policymakers, understanding the factors behind the differences in Okun's law across states seems crucial as it may not be sufficient to simply implement expansionary policies in the event of a negative economic shock, particularly in those regions where unemployment is less sensitive to output growth.

Conclusion

This paper studies Okun's law in Mexican States, applying the difference and gap models for the period 2000-2018 and different panel-time series estimators: fixed effects, mean group, common correlated mean group, common correlated mean group two-stage least squares, common correlated mean group -Generalized Method of Moments, Dynamic Common Correlated mean group GMM. The results show that when all main issues identified in the panel-time series literature are accounted for (i.e., heterogeneity, cross-section dependence, and endogenous regressors), Okun's law at the national level can only be confirmed for the difference model. At the regional level, the results suggest that Okun's law applies in 15 out of 32 states using the difference model. Notable differences between states can be observed. Factors that may explain regional heterogeneity and the relevance of the paper´s findings for economic policy are discussed.

p. 13

Table 1

Summary Statistics

Variable	Description	Source	Mean	S.D.	Min	Max
Unemployment rate $(U_{i,t})$ in state i in year t	Average yearly rate of registered unemployment	Encuesta Nacional de Empleo Urbano 2000-2004 Encuesta Nacional de Ocupación y Empleo 2005-2019	3.87	1.49	0.43	8.33
Real GDP $(Y_{i,t})$ for state i in year t	Real annual GDP	National Accounts for GDP	456.2	474.97	67.73	3128.24

p. 13

Table 2

Variables	Cross-Section Dependence Test	CIPS Test (Lag1)	CIPS Test (Lag2)	CIPS Test (Lag3)
ΔU_{it}	36.23***	-4.374***	-4.301***	-4.397***
ΔGDP_{it}	41.90***	-3.701***	-3.701***	-3.750***
$U_{it} - U_{it}^*$	35.75***	-4.241***	-4.306***	-4.495***
$GDP_{it} - GDP_{it}^*$	44.90***	-4.026***	-4.108***	-4.156***

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%. The second column presents the statistics of the CD test (for explanation, see Pesaran, 2004) under the null hypothesis of no dependence between cross-section units. Eberhardt´s (2017) xtcd Stata code was used for the test. Columns 3, 4, and 5 report the standardized CIPS statistics for all states. The underlying null hypothesis is that there is homogenous non-stationarity or unit root for all states. Different lag specifications of the test are used to control for serial correlation. In the CIPS test, only a constant is used because no visible trend is observed in the variables. See Pesaran (2007) for details of the CIPS unit root test. For the CIPS test, the Stata code pescadf of Lewandowski (2007) is used.

p. 13
p. 14

Table 3
Difference Model, Dependent Variable ΔU_{it}

Variables	**OLS**	**FE**	**MG**	**CCEMG**	**CCEMG-DYNAMIC GMM**
Intercept	.185***	.203***	.204***	-.058*	-0.043
	(0.03)	(0.031)	(0.036)	(0.033)	(0.111)
ΔGDP_{it}	-.064***	-.072***	-.068***	-0.009	-.054*
	(0.007)	(0.007)	(0.014)	(0.011)	(0.03)
R^2 (Within)	0.139	0.139			
RMSE		0.42	0.58	0.44	
CD test	27.70***	26.56***	23.54***	-2.18**	-0.7

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%.

p. 13

Table 4
Gaps Model, Dependent Variable $U_{it} - U^*_{it}$

Variables	OLS	FE	MG	CCEMG	CCEMG-DYNAMIC GMM
Intercept	-3.81e-10	-3.81e-10	-7.51e-11	8.06e-10	0.0042323
	(0.0150896)	(0.0150896)	(4.88e-10)	(5.29e-10)	(0.0032807)
$GDP_{it} - GDP^*_{it}$	-.0000167***	-.0000167***	-.0000239***	-6.40e-06*	-5.77e-06
	(-.0000167)	(-.0000167)	(4.93e-06)	(3.51e-06)	-0.0000106
R^2 (Within)	0.19	0.19			
RMSE			0.33	0.26	
CD test	19.45***	19.45***	16.22***	-1.84*	0.25

Notes: *** significant at 1%, ** significant at 5%, * significant at 10%.

p. 14

Table 5
State Coefficients

State	Difference CCEMG Dynamic GMM	GAP CCEMG Dynamic GMM
1 Aguascalientes	.1615734***	.0000738***
	(0.0247737)	(0.0000183)
2 Baja California	-.3508223***	-.0001675***
	(0.1337574)	(0.0000396)
3 Baja California Sur	-.0466193***	-3.67e-06
	(0.0053999)	(4.67e-06)
4 Campeche	0.0067675	-1.51e-06
	(0.0082164)	(1.53e-06)
5 Coahuila	-0.0135552	-5.07e-07
	(0.0429697)	(7.63e-06)
6 Colima	-.1365681***	-.0001295***
	(0.0118674)	(0.0000224)
7 Chiapas	-.0185138*	4.60e-06
	(0.0109492)	(7.04e-06)
8 Chihuahua	-0.0383782	-.0000662***
	(0.0536821)	(0.0000121)
9 Mexico City	-0.0814219	.0000102***
	(0.0622302)	(2.27e-06)
10 Durango	.1343862***	0.0000267
	(0.028184)	(0.0000176)
11 Guanajuato	.2320185***	.0000538**
	(0.0506353)	(0.0000259)
12 Guerrero	-.0811259***	-0.0000181
	(0.0255179)	(0.0000125)
13 Hidalgo	-.0629634*	0.0000117
	(0.0339458)	(8.33e-06)
14 Jalisco	.1847344***	-5.29e-07
	(0.07664)	(5.20e-06)
15 México	-.2677393***	-.0000155***
	(0.0194064)	(1.36e-06)
16 Michoacán	-.1066236***	1.39e-06
	(0.0263926)	(0.000016)
17 Morelos	-0.0235652	-.0000267**
	(0.0310702)	(0.000013)

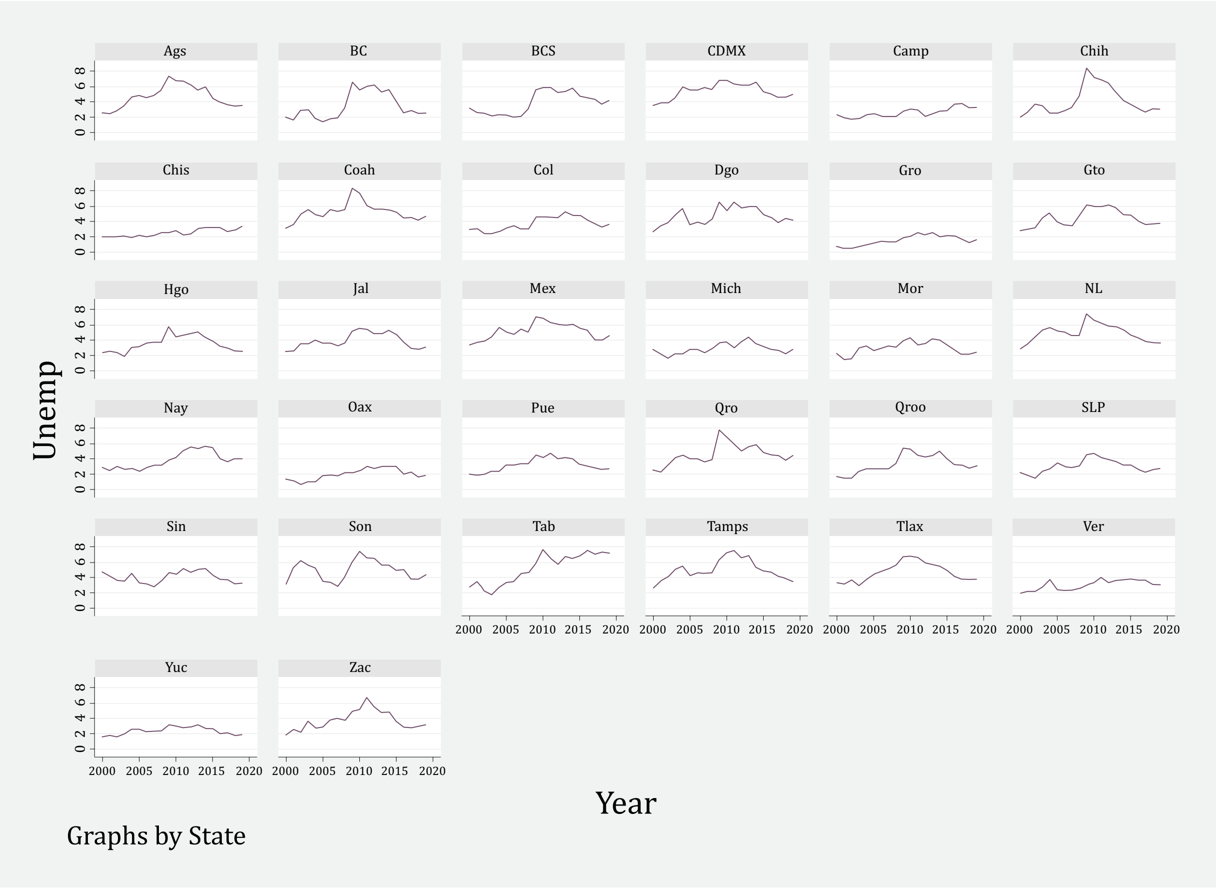
Table 5 (continuation)
State Coefficients

p. 14

State	Difference CCEMG Dynamic GMM	GAP CCEMG Dynamic GMM
18 Nayarit	-.0938635***	-.0001119***
	(0.020232)	(4.93e-06)
19 Nuevo León	-.2562352***	.0000142***
	(0.0376851)	(3.83e-06)
20 Oaxaca	-.0901247***	-.0000266***
	(0.0115577)	(6.39e-06)
21 Puebla	.0344821***	.0000138***
	(0.0130684)	(2.11e-06)
22 Querétaro	.1760309***	.0000524***
	(0.0184393)	(5.49e-06)
23 Quintana Roo	-.0609121***	0.0000111
	(0.014074)	(7.28e-06)
24 San Luis Potosí	0.0145591	-0.0000314
	(0.0386217)	(0.0000255)
25 Sinaloa	.1153441***	.0000622***
	(0.0362173)	(6.58e-06)
26 Sonora	-0.2017832	-.0000232***
	(0.2123509)	(7.23e-06)
27 Tabasco	-0.0812974	-2.96e-06
	(0.0542634)	(0.0000179)
28 Tamaulipas	-.6312283***	-.0000224***
	(0.1827416)	(5.13e-06)
29 Tlaxcala	-.0346789***	-.0000444***
	(0.0047985)	(3.69e-06)
30 Veracruz	-.0652032***	-.0000143***
	(0.0237267)	(4.10e-06)
31 Yucatán	-0.1568433	0.0000211
	(0.1018838)	(0.0000199)
32 Zacatecas	.0971289**	.000165***
	(0.0486176)	(0.0000452)

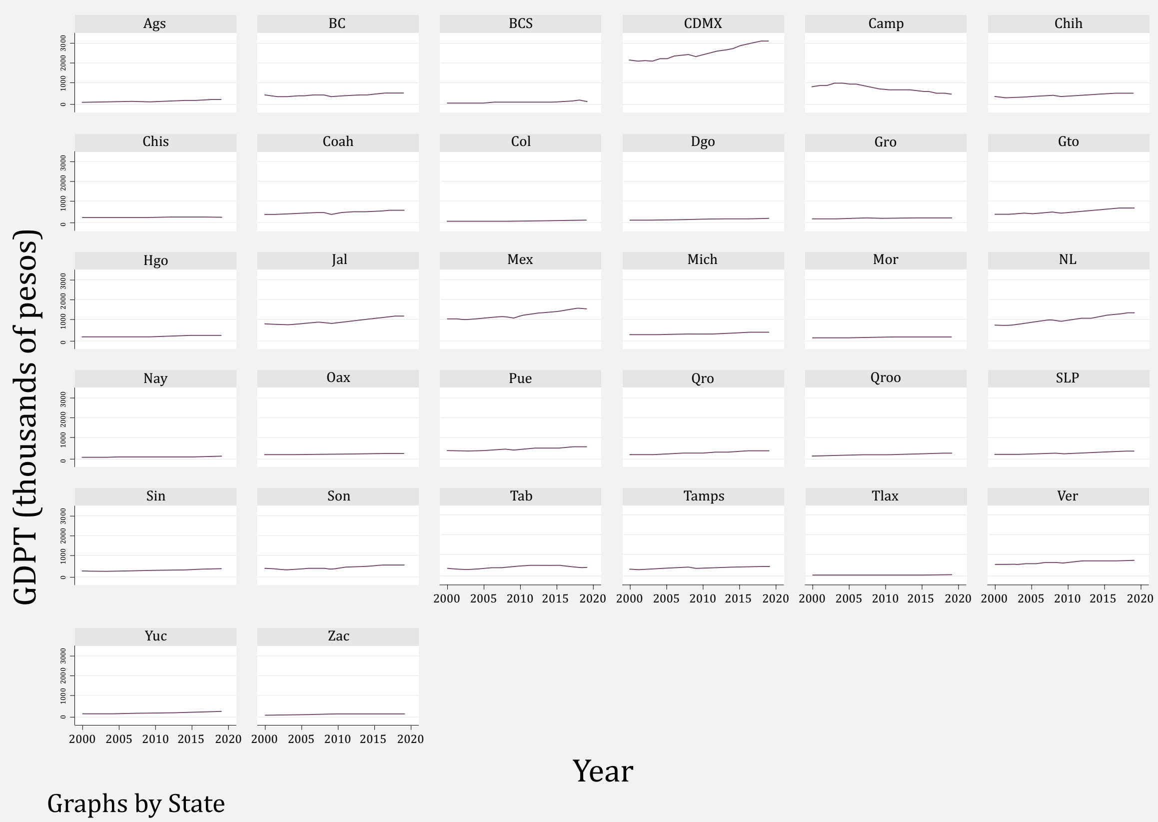
p. 13

Figure 1
Unemployment by State



p. 13

Figure 2
GDP by State



Referencias

Alarcón Osuna, M. A., y Soto Zazueta, I. M. (2017) Heterogeneidad estructural en la estimación de la Ley de Okun para el caso mexicano. *Realidad, Datos y Espacio. Revista Internacional de Estadística y Geografía*, 8(3): 62-79. https://www.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/nueva_estruc/revista_rde/889463856801.pdf

Apergis, N., & Rezitis, A. (2003). An examination of Okun's law: evidence from regional areas in Greece. *Applied Economics*, 35(10): 1147-1151. DOI: 10.1080/0003684032000066787

Balakrishnan, R., Das, M., & Kannan, P. (2010). Chapter 3, Unemployment dynamics during recessions and recoveries: Okun's law and beyond. In: Rebalancing growth. *IMF World Economic Outlook*, April 2010. https://www.imf.org/-/media/websites/imf/imported-flagship-issues/external/pubs/ft/weo/2010/01/pdf/_c3pdf.pdf

Ball, L., Furceri, D., Leigh, D., & Loungani, P. (2019). Does one law fit all? Cross-country evidence on Okun's law. *Open Economies Review*, 30(5): 841-874. DOI: 10.1007/s11079-019-09549-3

Ball, L. M., Leigh, D., & Loungani, P. (2013). Okun's law: fit at fifty? *NBER Working Papers* (w18668). DOI. 10.3386/w18668

Barreto, H. & Howland, F. (1993). *There are two Okun's law relationships between output and unemployment*. Wabash College, Crawfordsville, IN. https://www.researchgate.net/publication/228421484_There_Are_Two_Okun's_Law_Relationships_between_Output_and_Unemployment

Binet, M. E., & Facchini, F. (2013). Okun's law in the French regions: a cross-regional comparison. *Economics Bulletin*, 33(1): 420-433. https://shs.hal.science/halshs-00812549v2

Bond, S. R., & Eberhardt, M. (2013). Accounting for unobserved heterogeneity in panel time series models. *University of Oxford*, 1(11): 1-12. https://lezme.github.io/markuseberhardt/BEMC.pdf

Chavarín Rodríguez, Rubén (2001). El costo del desempleo medido en producto. Una revisión empírica de la Ley de Okun para México. *El Trimestre Económico*. 68 (270): 209-231. https://www.jstor.org/stable/20857058

Chudik, A., & Pesaran, M. H. (2013). Econometric analysis of high dimensional VARs featuring a dominant unit. *Econometric Reviews*, 32(5–6): 592–649. DOI: 10.1080/07474938.2012.740374

Durech, R., Minea, A., Mustea, L. & Slusna, L. (2014). Regional evidence on Okun's law in Czech Republic and Slovakia. *Economic Modelling*, 42: 57-65. DOI: 10.1016/j.econmod.2014.05.039

Eberhardt, M. & Bond, S. (2009). *Cross-section dependence in nonstationary panel models: a novel estimator*. https://mpra.ub.uni-muenchen.de/17692/1/MPRA_paper_17692.pdf

Eberhardt, M. & Teal, F. (2010). Productivity analysis in global manufacturing production. University of Oxford. *Economics Series Working Papers* (515) https://ora.ox.ac.uk/objects/uuid:ea831625-9014-40ec-abc5-516ecfbd2118/files/m3956c6620e1981138f3168c388d1c793

Freeman, D. G. (2000). Regional tests of Okun's law. *International Advances in Economic Research*, 6(3), 557-570. DOI: 10.1007/BF02294972

González Anaya, J. A. (2002). *Labor market flexibility in thirteen Latin American countries and the United States: revisiting and expanding Okun coefficients*. Stanford, CA: Stanford University, Center for Research on Economic Development and Policy Reform. https://kingcenter.stanford.edu/sites/g/files/sbiybj16611/files/media/file/136wp_0.pdf

Guisinger, A. Y., Hernandez-Murillo, R., Owyang, M. T., & Sinclair, T. M. (2018). A state-level analysis of Okun's law. *Regional Science and Urban Economics*, 68, 239-248. DOI: 10.1016/j.regsciurbeco.2017.11.005

Instituto Nacional de Estadística y Geografía [INEGI] (2025). *Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad*. México: INEGI. https://www.inegi.org.mx/programas/enoe/15ymas/

Islas C., A., & Cortez, W. W. (2013) Relaciones dinámicas del producto y el empleo en México: una evaluación de sus componentes permanentes y transitorios, *Revista de la CEPAL*, (111): 167-182. https://repositorio.cepal.org/server/api/core/bitstreams/c0ac872c-3a9a-41c9-8afc-19c4ce65b739/content

Islas Camargo, A. & Cortez, W. W. (2018) Can the informal sector affect the relationship between unemployment and output? An analysis of the Mexican case. *CEPAL Review*, (126): 137-153. https://repositorio.cepal.org/server/api/core/bitstreams/c183cb62-5573-4348-bc96-3c4a653584d7/content

Lewandowski, P. (2006). *PESCADF: Stata module to perform Pesaran's CADF panel unit root test in presence of cross section dependence*. https://ideas.repec.org/c/boc/bocode/s456732.html

Loría, E. & García-Ramos, M. (2007). La ley de Okun: una relectura para México, 1970-2004, *Estudios Económicos*. 22(1): 19-55. https://www.jstor.org/stable/40311523

Loría, E. & Leobardo de Jesús (2011). The robustness of Okun's law – evidence from Mexico: a quarterly validation, 1985.1–2006.4. In G. Ángeles Castro H. Ríos-Bolivar, I. Perrotini Hernández (eds.) *Market liberalism, growth and economic development in Latin America*, (pp. 264 – 276). London: Routledge (Routledge Studies in Development Economics).

Loría, E., Libreros, C. & Salas, E. (2012). La ley de Okun en México: una mirada de género, 2000.2-2011.1. *Investigación Económica*, 71(280): 121-140. https://www.scielo.org.mx/scielo.php?pid=S0185-16672012000200005&script=sci_arttext

Loría Díaz de Guzmán, E. G., Ramírez Guerra. E.-A. & Salas, E. (2015). La ley de Okun y la flexibilidad laboral en México: un análisis de cointegración, 1997Q3-2014Q1, *Contaduría y Administración*. 60: 631-650. https://dialnet.unirioja.es/descarga/articulo/5482245.pdf

Loría, E., Rojas, S., & Martínez, E. (2021). Okun's law in Mexico: an analysis of heterogeneity among States, 2004-2018. *CEPAL Review*, (134): 135-152. https://repositorio.cepal.org/server/api/core/bitstreams/1bc01bfa-cadb-4e36-8db3-6c4c8d04e678/content#page=136

Mankiw, N. G. (2020). *Principles of macroeconomics*. 8 ed. Toronto: Cengage Learning.

Montero Kuscevic, C. M. (2014). Okun's law and urban spillovers in US unemployment. *The Annals of Regional Science*, 53: 719–730. DOI: 10.1007/s00168-014-0640-2

Neal, T. (2015). Estimating heterogeneous coefficients in panel data models with endogenous regressors and common factors. Workblacking paper (2009): 1-29. https://www.semanticscholar.org/paper/Estimating-Heterogeneous-Coefficients-in-Panel-Data-Neal/fd-9267f4dfb7ad3e00b16caabf497f71dd49d89f

Oberst, C., & Oelgemöller, J. (2013). Economic growth and regional labor market development in German regions: Okun's law in a spatial context. FCN Working Papers (5/2013). DOI: 10.2139/ssrn.2240260

Okun, Arthur M (1962). Potential GNP: its measurement and significance. *Proceedings of the Business and Economics Statistics Section of the American Statistical Association*, pp. 98–104. Alexandria, VA: American Statistical Association. Reprinted as *Cowles Foundation Paper* 190. https://milescorak.com/wp-content/uploads/2016/01/okun-potential-gnp-its-measurement-and-significance-p0190.pdf[1]

[1] Available in Spanish at: https://es.scribd.com/document/738087492/Potential-GNP-Its-Measurement-and-Significance-espanol-traducido-en-Google. Also published as a chapter in *Economics for policymaking: selected essays of Arthur M. Okun* (pp.145-158). Cambridge, MA: MIT Press, 1983.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels. *IZA Discussion Papers*, (1240). Institute for the Study of Labor (IZA). https://repec.iza.org/dp1240.pdf

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*: 74(4): 967-1012. DOI: 10.1111/j.1468-0262.2006.00692.x

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2): 265-312. DOI: 10.1002/jae.951

Pesaran, M. H., & Smith, R. (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, 68(1): 79-113. DOI: 10.1016/0304-4076(94)01644-F

Rodríguez López, P. & Peredo y Rodríguez, F. J. (2007). Estimación de la ley de Okun para la economía mexicana. Análisis Económico, 22(51): 59-79. https://www.redalyc.org/pdf/413/41311486004.pdf

Rojas Manzo, S. M. (2019) Estimación de la ley de Okun para la economía mexicana desde un enfoque panel, 2005–2016. El Semestre de las Especializaciones, 1(1): 69-93. https://www.depfe.unam.mx/especializaciones/revista/1-1-2019/03_EA_Rojas-Manzo_2019.pdf

Santos Zúñiga, H., Amarillas Urbina, V. & Aguilera Fernández, A. (2020). Crecimiento económico y desempleo en México: una aplicación de la Ley de Okun. In: J. Gasca Zamora, H. E. Hoffman Esteves (coords.). Factores críticos y estratégicos en la interacción territorial. Desafíos actuales y escenarios futuros, (pp. 211-225). México: UNAM y Asociación Mexicana de Ciencias para el Desarrollo Regional. https://ru.iiec.unam.mx/5219/1/3-141-Santos-Amarillas-Aguilera.pdf