Okun's law in Mexico: an analysis of heterogeneity among States, 2004–2018

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Abstract

The sensitivity of unemployment to economic activity in the Mexican States (from the beginning of 2004 to the first half of 2018) was evaluated on the basis of Okun's law (1983) as it relates to growth rates. To capture the heterogeneity of the 32 States, the results of individual regressions were compared with fixed effects panel data estimates. The Okun coefficient is significant and possesses the correct sign in 22 States, reflecting a variation between -7.21 and -1.25. The remaining 10 States (with the incorrect sign and an insignificant coefficient) are characterized by poor economic, social and institutional performances. The great recession brought about structural changes in 15 of the 22 States where Okun's law is valid throughout the period. Moreover, in these 22 States, the Rule of Law Index and the rate of critical employment conditions determine the sensitivity of unemployment growth to output growth.

Keywords

Economic growth, unemployment, ECLAC, regional development, local development, labour market, employment creation, structural adjustment, econometric models, Mexico

JEL classification

C21, C22, E24

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I. Introduction

Since Okun published his foundational paper on the measurement of the bidirectional macroeconomic effects of the relationship between output and unemployment (1983, originally published in 1962), the literature has generally concentrated on estimations incorporating distinct particularities —including of individual countries and specific periods—, different econometric techniques and ad hoc functional forms. In some texts, such as that of Blanchard, Amighini and Giavazzi (2012), the Okun coefficient is estimated for individual developed countries and for different periods. The macroeconomic view of this important law has prevailed.

Applied studies that estimate the Okun coefficient for specific countries as it relates to macroeconomics are crucial for the assessment of the quality of economic growth in terms of its effect on the unemployment rate. However, they do not consider the differences in labour productivity between the regions to which these countries belong, according to the definition of structural heterogeneity of the Economic Commission for Latin America and the Caribbean (ECLAC) (Pinto, 1973; Cimoli and Porcile, 2011).

ECLAC (2016) argues that labour productivity is positively associated with economic growth and negatively associated with informality, so the level of structural heterogeneity reflects different trajectories of growth and job creation among regions within the same country. Our work focuses on the ECLAC definition of structural heterogeneity among regions in Mexico.

Thus, accepting the structural heterogeneity hypothesis, it is plausible that the Okun coefficient will vary based on the region of a country being examined; in other words, unemployment will respond differently to changes in output. The asymmetries in the Okun coefficients of the various regions reflect structural aspects of development and growth that characterize their labour markets, such as flexibility, segmentation (Dell'Anno and Solomon, 2008; Islas and Cortez, 2018), institutional frameworks (ECLAC, 2012) and productivity (Friedman and Wachter, 1974).

This has given rise —in several countries and in recent years— to works that estimate Okun's law at the international and subnational levels. For example, Huang and Yeh (2013) estimate a higher Okun coefficient in member countries of the Organisation for Economic Co-operation and Development (OECD). Ball and others (2016) find the same result —a higher Okun coefficient— in developed countries compared to developing countries.

At the subnational level, Melguizo (2015) finds that the level of economic activity in the provinces of Spain plays a key role in the estimation of the Okun coefficient. Guisinger and others (2018) estimate different Okun coefficients for the regions of the United States, which respond significantly to lower rates of union membership, higher levels of educational attainment, and higher female labour force participation rates. In Mexico, the only relevant research is that of Alarcón and Soto (2017), who estimate the Okun coefficient by State, without delving into determinants.

In line with ECLAC (2016), we accept the hypothesis of structural heterogeneity in Mexico based on the existence of structural economic, social and institutional gaps among the 32 States. These give rise to distinct trajectories of labour productivity, economic growth and job creation that, ultimately, yield different Okun coefficients.

One contribution of this work is the incorporation of economic, social and institutional variables that cause structural heterogeneity. The first group of variables explains the level of economic activity measured through GDP growth, per capita GDP, unemployment and total exports. In terms of social variables, we included the rate of critical employment conditions and the crime rate (measured through homicide and kidnapping rates). Finally, we incorporated the institutional factor, expressed through the 2018 Rule of Law Index. Thus, this study adheres to the ECLAC definition of structural gaps at the subnational level; in this case, among the 32 Mexican States.

Another contribution is the estimation of Okun's law for Mexico, as it relates to growth rates from the beginning of 2004 to the second quarter of 2018, which represents the longest and most integrated series derived from the same source of information (INEGI, 2018a and 2018b). The length of the period and the frequency of the data allowed for sufficient degrees of freedom to make robust and economically meaningful individual estimates, which were later compared with fixed effects panel data estimates and with the results of Rodriguez and Peredo (2007), who used the same specification at the national level, but for a much narrower period, from the third quarter of 1988 to the third quarter of 2003.

We also show that the great recession of 2008–2009 caused notable changes in the sensitivity of unemployment to economic activity in 15 of the 22 States in which Okun's law is valid, a group we call G1. Okun's law is no longer valid in a significant number of States, so other theoretical and empirical rationales are needed to explain the dynamics of unemployment from now on.

The last contribution is showing that the validity of Okun's law depends on the Rule of Law Index and the rate of critical employment conditions. This can only be demonstrated in the group of 22 States in which Okun's law is valid (G1). By contrast, and worryingly, the Okun coefficient is insignificant for all the variables analysed in the remaining 10 States (G2).

These results suggest that the implementation of State policies should not only consider economic factors —which are undoubtedly very important— but also, and even more so, social and institutional factors, so that labour markets can respond to variations in local and national economic activity.

The above-mentioned contributions were the outcome of the following strategy. First, the individual Okun coefficients were estimated for the 32 Mexican States and a very important result was highlighted: statistical significance and correct signs were found for only 22 States. This allowed the creation of two groups: 22 States (G1), on the one hand, and 10 States (G2), on the other. The individual analysis was complemented by fixed effects panel data estimates, which took into account the heterogeneity of the States thus grouped (Greene, 2003). The results derived from the individual estimates are supported by and consistent with those obtained from the panel regressions. The analysis of a large number of variables leads to the conclusion that G1 outperforms G2 in the sense that it functions better economically, socially and institutionally, and that the Rule of Law Index and the rate of critical employment conditions determine the Okun coefficient.

This suggests that the high level of precarious employment and institutional deficiencies in G2 perpetuate a vicious circle of high informality, low productivity and weak economic growth, all of which explains the non-significance of Okun's law, thus resulting in poverty that reproduces itself.

The article is divided into six sections in addition to this introduction. The second section presents a review of Okun's law in applied works that consider structural aspects. The third section defines the structural gaps behind the hypothesis of structural heterogeneity in Mexico, and the fourth section analyses the performances of the two groups formed. The fifth section links the econometric analysis of time series with that of panel data. The sixth section analyses and discusses the main results, and the seventh and last section presents our conclusions.

II. Literature review

Okun (1983) argued that there is a dynamic and self-reinforcing cycle of high unemployment, low wages and weak profits, which limits investment in equipment, housing, education and research. To the extent that the process replicates itself in the long run, the cost will be very high in economic terms (lag in potential output) and in social terms (higher unemployment).

Because of the significance of this relationship in economic theory and policy, modern macroeconomic analysis frequently uses Okun's approach to test one of the most important regularities

of macroeconomics: the bidirectional dynamic of unemployment and output. As a result, this relationship is now considered a macroeconomic law. According to Tobin (1980), Okun's law is one of the most reliable empirical regularities of macroeconomics.

However, almost 60 years after the publication of that foundational article, there is no global consensus on the optimal rate of sensitivity of unemployment to output for a developed or emerging economy (Islas and Cortez, 2013), especially considering the economic, social and institutional differences behind the structural heterogeneity among regions.

Ball and others (2016) find that unemployment is more sensitive to economic activity —or reflects a higher Okun coefficient— when per capita GDP and the share of the tertiary sector in the economy are higher. Therefore, it could be said that the degree of economic and technological development is a crucial determinant of the significance and magnitude of the Okun coefficient.

Dell'Anno and Solomon (2008) and Guisinger and others (2018) provide conclusive information on the determinants of the Okun coefficient in terms of labour market composition. They argue that a greater labour supply in the informal economy and a lower female participation rate are reflected in a lower Okun coefficient. In the extreme case, Agénor and Aizenman (1999) argue that the movement of skilled and unskilled workers from the formal sector to the informal sector cancels out the relationship between unemployment and output in the short run.

Dell'Anno and Solomon (2008) note that the relationship between informality and the magnitude of the Okun coefficient is associated with institutional weakness, which is a crucial determinant of structural heterogeneity (Cimoli and Porcile, 2011; ECLAC, 2012). However, they do not establish an econometric relationship between the Okun coefficient and the degree of institutionalization. Their research only points out that the lack of trust in deficient institutions prompts negative behaviour of workers because they opt for informality in the face of tax policy. To the extent that jobs increase in the informal sector, which is the most technologically unsophisticated, aggregate labour productivity will be lower, even if open unemployment is lower. Finally, there will be a negative impact on economic growth's effectiveness in reducing unemployment, i.e., a lower Okun coefficient.

As regards Mexico, Islas and Cortez (2018) suggest that higher informality could be reflected in a lower Okun coefficient. This means that in times of recession, unemployment reacts more strongly to economic activity than in the expansionary phase of the cycle. The same is true for the United States economy (Crespo, 2003).

Islas and Cortez (2018), drawing on the work of Jardin and Stephan (2012), posit that the non-linearity of the Okun coefficient in Mexico derives from the fact that in periods of recession, to the extent that the labour market is flexible, businesses fire employees quickly and aggressively, and do not hire in the same way in periods of expansion. This results in unemployment falling slowly in the recovery period, so that unemployed workers find a way out in informality (Loría, Aupart and Salas, 2016), especially women (Loría, Libreros and Salas, 2011).

Papers on Okun's law in Mexico are not limited to a rereading of the original article (Loría and Ramos, 2007), but have also focused on attributing the magnitude of the Okun coefficient to factors such as labour flexibility (Chavarín, 2001; Loría, Ramírez and Salas, 2015), gender (Loría, Libreros and Salas, 2011), informality (Islas and Cortez, 2018) and the phase of the economic cycle (Islas and Cortez, 2013 and 2018). However, although these studies are commendable in that they incorporate variables that enrich Okun's original analysis (1983), they do not explicitly consider the structural heterogeneity among the 32 States or the factors behind it.

Among the works available, only Alarcón and Soto (2017) have estimated Okun's law for the 32 Mexican States. The results of their research are supported by fixed effects panel data techniques for limited annual data (2003–2014), so when formulating individual estimates, the authors are confronted

with results that are not very robust. Moreover, they do not specifically develop or analyse the economic, social or institutional differences that give rise to structural heterogeneity. Herein lies the contribution of this paper. We recognize, then, that the limitations of the work on Okun's law as applied to Mexico are the motivation for this study.

III. Structural gaps in Mexico

ECLAC (2016) points out that there are economic, social and institutional differences between the 32 States of Mexico, which are called structural gaps. These gaps between regions (between productive sectors, between export-oriented firms and firms that concentrate on the local market, between firms of different sizes, between different skill levels and the sex of the workers, and between formality and informality) produce asymmetries in labour productivity and define structural heterogeneity. The results of the paper indicate that slow growth is associated with low productivity and, in turn, relate this low productivity to the existence of these structural gaps.

This document also recognizes that the heterogeneity among sectors and regions, as well as the significant weight of low-productivity activities in the Mexican economy, act as an obstacle to increasing overall labour productivity. The manufacturing sector, concentrated in the north of the country, reflects the strongest growth and is the most dynamic, recording the largest increase between 1990 and 2012 (2.1%), driven by scale-intensive industries (including the automotive industry). By contrast, the weakest performance was recorded by the primary sector and the States linked to oil activities.

This study identifies a considerable decrease in hours worked in the manufacturing sector in favour of increases in the service sector, particularly in commerce. This translates into labour shifts from sectors of high productivity growth to sectors where labour productivity is weaker, thereby accentuating structural heterogeneity.

ECLAC (2016) concludes that, in general, most States in the north and centre of the country reflect higher labour productivity than those in the south. The States with the highest levels of labour productivity, before and after the great recession, are Querétaro, Aguascalientes, Zacatecas and Nuevo León, while the States that recorded the lowest growth in labour productivity are Campeche and Baja California.

In addition, labour productivity in Mexico is negatively correlated with informality and positively correlated with GDP growth and exports. In this paper we also prove that the States with the strongest growth in labour productivity are those with the strongest economic growth, the lowest informality and the highest exports.

It is important to note that labour market conditions, such as composition (informal versus formal work and women's participation rate), increasing precariousness and institutional frameworks, reflect the structural heterogeneity of the country (ECLAC, 2012). The unemployed population tries to survive by offering their labour in precarious and low-productivity jobs, which are associated with micro-businesses and the informal sector. Amid the backdrop of poorly designed labour market institutions, the precariousness of these jobs will persist.

Progress towards more homogeneous labour productivity requires an active State that designs a long-term systemic strategy for industrial, labour, social and environmental policies, and above all, that supports the active participation of the private sector in the framework of development partnerships and agreements.

ECLAC (2012) emphasizes that institutions that foster innovation and learning have virtuous effects on growth and productivity. However, when they encourage unproductive activities, such as the misappropriation of resources, incentives to invest in the economy decline (Mauro, 1995), as does public

confidence in those institutions (Dell'Anno and Solomon, 2008). Consequently, job creation decreases and persons who are already employed in formal jobs have incentives to migrate to the informal sector. There is a very close relationship between productivity and economic growth, which are in turn linked to the increasing precariousness of labour and institutional variables.

Our work coincides with ECLAC (2012 and 2016) in the sense that we find that the significance and magnitude of the Okun coefficient depend on structural gaps, which lead to heterogeneous labour productivity performances. Note that there are no State data series that capture all the structural gaps over a long period of time and that are comparable with employment and output figures.

Even so, our analysis reveals that the Okun coefficient is not statistically significant in States where labour productivity growth is low, such as Morelos, Guerrero and Campeche. Meanwhile, States such as Querétaro, Mexico City and Nuevo León, with high rates of labour productivity growth since 2008, have statistically significant Okun coefficients with the correct sign.

IV. Structural heterogeneity

As we have already mentioned, works on Okun's law for Mexico, in general, neglect the issue of structural heterogeneity by formulating estimates at the macro level with different specifications, periods and frequencies of data. On the basis of the theoretical elements presented in the previous sections, individual regressions were carried out to detect the asymmetries of the Okun coefficient and thus establish a group of the States for which there is conclusive empirical information confirming Okun's law as it relates to growth rates.

Once the individual estimates were made,[2] it was possible to clearly identify two broad groups of States: G1 and G2. Hence, we grouped, respectively, the entities in which β_1 and β_2 are statistically significant with the correct signs and economically acceptable parameters, and the entities that do not present these characteristics. This initial exercise resulted in G1 being composed of 22 States and G2 of the remaining 10 States. The States that make up G1 are Aguascalientes, Baja California, Baja California Sur, Chihuahua, Mexico City, Coahuila, Colima, Mexico State, Guanajuato, Hidalgo, Jalisco, Michoacán, Nayarit, Nuevo León, Querétaro, Quintana Roo, San Luis Potosí, Sinaloa, Sonora, Tamaulipas, Tlaxcala and Veracruz. This grouping made it possible to identify the structural characteristics (differences) of both groups.

An initial examination of the hypothesis of structural heterogeneity is presented in table 1, which does not reflect marked differences in the breakdown of States' productive profiles by sector, except in the tertiary sector, where the figure for G1 is slightly higher than that of G2 excluding Campeche.[3] However, it is striking that the share of the secondary sector in GDP is exactly the same for G1, G2 excluding Campeche and the country as a whole.

The small difference in the share of the primary and tertiary sectors in G1 and G2 appears to determine structural heterogeneity. G1 includes more technological and less agricultural sectors, which is reflected in greater labour productivity and, therefore, in stronger economic growth (Padilla-Pérez and Villarreal, 2015).

Table 2 provides a clearer estimation of the factors behind structural heterogeneity and shows that our classification (G1 and G2) adequately accounts for the substantial differences in economic, social and institutional variables.

[2] See the econometric methodology in the following section.

[3] The States of Campeche and Tabasco should be highlighted, since their eminently oil-producing productive profiles significantly distort the variables of interest, particularly in the case of Campeche, so the subsequent G2 analyses are carried out with and without this State.

Table 1
Mexico: sectoral share of GDP by group of States, 2016
(Percentages)

Sector	National	G1	G2	G2 excluding Campeche
Primary	3	4	5	6
Secondary	32	32	38	32
Tertiary	65	64	57	62
Total	100	100	100	100

Source: Prepared by the authors, on the basis of Center for Public Finance Studies (CEFP), "Evolución de la actividad productiva nacional y de las entidades federativas 2003–2018", *Estudio*, No. 022/2018, Mexico City, 2018.

Table 2
Mexico: economic, social and institutional variables by group of States, first quarter of 2004–second quarter of 2018
(Rates, Mexican pesos, United States dollars and indices)

	National	G1	G2	G2 excluding Campeche
Real GDP growth[a]	0.66	0.74	0.34	0.51
Per capita GDP[b]	150 308	135 959	181 874	97 420
Per capita GDP growth[c]	0.26	0.36	0.05	0.23
Unemployment[d]	4.03	4.38	3.25	3.32
Unemployment growth[c]	0.43	0.36	0.58	0.48
Labour productivity growth[e]	0.20	0.53	-0.18	0.39
Total exports[f]	318 233	244 259	53 318	30 924
Employment in the informal sector[g]	26.6	25.40	29.22	29.59
Employment growth in the informal sector[c]	-0.12	-0.20	0.05	0.07
Critical employment conditions[h]	12.32	12.13	18.02	18.13
Rule of Law Index (2018)[i]	0.3922	0.3923	0.3920	0.3878
Homicide rate[j]	3.84	3.78	3.95	4.22
Kidnapping rate[j]	0.24	0.22	0.27	0.29

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, *Estadísticas históricas de México 2014*, Aguascalientes, 2015; INEGI, "México: exportaciones por entidad federativa 2007–2015", 2015 [online] http://www3.inegi.org.mx/rnm/index.php/catalog/241/related_materials?idPro=; INEGI, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/; Economic Commission for Latin America and the Caribbean (ECLAC), *Productividad y brechas estructurales en México* (LC/MEX/L.1211), Mexico City, 2016; World Justice Project (WJP), *Índice de Estado de derecho en México 2018: perspectivas y experiencias en los 32 estados del país*, Washington, D.C., 2018; Executive Secretariat of the National Public Security System, "Incidencia delictiva", 2021 [online] https://www.gob.mx/sesnsp/acciones-y-programas/incidencia-delictiva-87005?idiom=es.

[a] The Quarterly Indicator of State Economic Activity (ITAEE), an index of physical volume with a base year of 2013 (INEGI, 2018b), was used for States' real GDP. Average growth for the entire period.

[b] Real GDP in Mexican pesos at 2013 prices per inhabitant of the corresponding State (INEGI, 2018b). Arithmetic average for the period.

[c] Average growth for the entire period.

[d] Percentage of the economically active population that did not work even one hour during the reference week of the National Occupation and Employment Survey (ENOE) but expressed their willingness to do so and carried out some activity to obtain employment (INEGI, 2018a). Arithmetic average for the period.

[e] Calculated with the index of total average labour productivity using the index of physical volume by State and the index of the employed population by State, both with 2008 as the base year (ECLAC, 2016). Average growth from 2005–2014.

[f] Mining and manufacturing industry exports (INEGI, 2015a and 2015b). Sum of the averages by State in millions of United States dollars at current prices from 2007–2017.

[g] Proportion of the population employed in non-agricultural economic units operated without accounting records and on the basis of household or personal funds, without being incorporated as a business (INEGI, 2018a). Average growth for the entire period.

[h] Percentage of the employed population in one of the following situations: (i) works less than 35 hours per week owing to labour market conditions; (ii) works more than 35 hours with an income below the minimum wage, or (iii) works more than 48 hours with an income of up to two minimum wages (INEGI, 2018a). Arithmetic average for the period.

[i] Measures society's perception of adherence to the rule of law. Based on a survey of 25,600 citizens (800 in each State), measurement of the rule of law as perceived by respondents. The index measurement includes eight factors: limits to government power, corruption, open government, fundamental rights, order and security, regulatory compliance, civil justice and criminal justice (WJP, 2018). Values close to 1 indicate greater adherence to the rule of law.

[j] Number of cases per 100,000 inhabitants in each State (Executive Secretariat of the National Public Security System, 2021).

G1 reflects better performances in all indicators except the unemployment rate, which may be because in these States there are institutions that promote productive activities, so there are fewer precarious jobs (ECLAC, 2012). As a result, although unemployment is higher, their labour markets benefit from a greater level of formal employment, so it is plausible that the records of open unemployment in G1 are more reliable because they more accurately reflect the functioning of labour markets.

With regard to economic variables, it should be noted that G1, in particular, reflects weaker growth in the unemployment rate and stronger linkages with international markets. The latter can be seen through the average value of exports,[4] which is considerably higher in G1 than in G2 excluding Campeche (US$ 244,259 versus US$ 30,924). Thus, although the productive contribution of the secondary sector is the same, the stronger linkage with international trade (five times greater) and what this implies in terms of competitiveness and productivity, and perhaps the slight difference in terms of the tertiary sector, together with its greater technical intensity, explain very different trajectories of growth and development.

All the variables in G2 have a negative impact on the Okun coefficient to the extent that the three groups of variables reflect poor performances, so it is plausible that this group faces a poverty trap[5] that can condemn the corresponding States to weak development and low steady-state economic growth. If this is the case, it is likely that they experience multiple externalities and social dysfunctionalities which, in turn, give rise to greater distortions, such as marginality and criminality.

V. Econometric aspects

The original version of Okun's law (1983) is expressed through three equations. However, in most of the applied literature, multiple variants have been used, all with the aim of best capturing the effects of economic activity on unemployment.

In this work, the econometric practice is correct insofar as the statistical results are robust for the largest number of States.[6] We find economically and statistically consistent and significant results only with the specification of the variables algebraically transformed into annualized growth rates (real GDP and unemployment). An additional advantage of this specification is that, since the variables are stationary, there are no cointegration problems and, therefore, no spurious relationships.

For time series:
$$\dot{u}_t = \beta_1 + \beta_2 \dot{Y}_t + \varepsilon_t \quad (1)$$

For panel data:
$$\dot{u}_{it} = \beta_{1i} + \beta_2 \dot{Y}_{it} + \varepsilon_{it} \quad (2)$$

Both models are based on quarterly series for the period from the first quarter of 2004 to the second quarter of 2018, where $\dot{u}_t$ and $\dot{u}_{it}$ represent annualized quarterly growth in the unemployment rate; $\dot{Y}_t$ and $\dot{Y}_{it}$ represent the annualized quarterly growth of the Quarterly Indicator of State Economic Activity; β_1 and β_{1i} are the constant terms representing the natural rate of growth in unemployment; β_2 represents the Okun coefficient, which measures the sensitivity of unemployment growth to economic growth; ε_t and ε_{it} are the error terms that capture the idiosyncratic errors of each State and, in equation (2), the

[4] From the manufacturing and mining sectors.

[5] See Basu (2003) and Azariadis and Stachurski (2005) for more details on the concept of the "poverty trap".

[6] A total of seven different specifications of Okun's law were tested: (i) first differences; (ii) difference and gap in GDP as a percentage of potential; (iii) difference and gap in GDP as the difference between real and potential GDP in monetary units; (iv) unemployment gap and GDP gap (as a percentage of potential); (v) unemployment gap and GDP growth; (vi) unemployment growth and GDP gap (as a percentage of potential) and (vii) specification with variables in annualized growth rates, the only one that produced robust results.

error composed of the specific individual effect and the remainder of the disturbance; t represents the period of each variable and i refers to the individual (State).

The main advantage of complementing the Okun's law analysis with the time series and panel data methods is that it allows us to consider differences among States. In particular, the fixed effects panel data model allows us to calculate β_1 for each State and to obtain an estimate of β_2 at the national and group level that considers the individual effects of each State, while the time series model allows us to estimate β_2 for each State.

Although in this paper we consider both econometric techniques complementary, and therefore that they enrich the analysis, an estimation using the panel method can be considered more efficient because it provides more information about the data, more variability, less collinearity between variables and more degrees of freedom (Klevmarken, 1989; Hsiao, 2014).

For estimation on the basis of equation (1), the selection criterion for G1 was that β_1 and β_2 had to be, individually and jointly, statistically significant at a confidence level of at least at 10% and that β_2 had to be less than 0 and β_1 greater than 0; in other words, that they also made economic sense. Thus, G1 = 22 States and G2 = 10 States.

VI. Analysis and discussion of results

Table 3 shows the results of G1 exclusively. The numbers in parentheses correspond to the t-statistics of β_1 and β_2 and, in the case of the F-statistic, to the joint significance (probability) of the regressors in each model.

Table 3
Mexico: estimation of Okun's law in growth rates in G1 States, first quarter of 2004–second quarter of 2018

State	β_1	β_2	R^2	F-statistic
Aguascalientes	10.42 (2.73)	-1.85 (-3.08)	0.145	9.49 (0.00)
Baja California	23.24 (5.19)	-7.21 (-8.23)	0.563	67.74 (0.00)
Baja California Sur	16.03 (2.93)	-1.32 (-2.14)	0.076	4.60 (0.03)
Chihuahua	19.44 (3.91)	-4.8 (-5.04)	0.313	25.46 (0.00)
Mexico City	7.88 (3.23)	-2.62 (-3.91)	0.214	15.28 (0.00)
Coahuila	5.07 (1.91)	-1.81 (-5.06)	0.314	25.66 (0.00)
Colima	16.23 (3.11)	-3.01 (-2.87)	0.128	8.23 (0.00)
Mexico State	10.49 (3.89)	-3.17 (-5.08)	0.316	25.82 (0.00)
Guanajuato	8.42 (2.17)	-2.19 (-2.83)	0.125	8.01 (0.00)
Hidalgo	21.32 (3.80)	-4.83 (-4.13)	0.234	17.10 (0.00)
Jalisco	11.37 (3.44)	-3.47 (-4.57)	0.272	20.90 (0.00)
Michoacán	10.71 (1.87)	-2.28 (-1.70)	0.049	2.90 (0.09)
Nayarit	12.66 (3.62)	-2.05 (-3.59)	0.188	12.94 (0.00)
Nuevo León	11.82 (3.78)	-3.66 (-5.86)	0.380	34.37 (0.00)

Table 3 (concluded)

State	β_1	β_2	R^2	F-statistic
Querétaro	26.9 (4.50)	-4.96 (-4.93)	0.303	24.31 (0.00)
Quintana Roo	18.64 (3.93)	-2.71 (-4.16)	0.236	17.34 (0.00)
San Luis Potosí	13.41 (2.33)	-2.6 (-2.16)	0.077	4.69 (0.03)
Sinaloa	8.78 (2.28)	-2.20 (-2.78)	0.121	7.72 (0.00)
Sonora	7.21 (1.77)	-2.12 (-2.75)	0.119	7.57 (0.00)
Tamaulipas	3.98* (1.29)	-1.71 (-2.43)	0.096	5.94 (0.01)
Tlaxcala	4.77 (2.13)	-1.25 (-4.09)	0.230	16.76 (0.00)
Veracruz	6.16 (2.01)	-1.48 (-1.77)	0.053	3.15 (0.08)

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/.

Note: The t-statistics of β_1 and β_2 and the probability of the F-statistic are shown in parentheses. An asterisk (*) indicates that the coefficient is not significant at the confidence level of 10%.

The following results are derived from this table:

(i) The 22 States show economically and statistically sound results, although there are important differences in R^2.

(ii) The low values of Baja California Sur, Michoacán, San Luis Potosí and Veracruz stand out. However, the F-test does not allow us to accept that β_1 and β_2 are equal to zero. The case of Veracruz is the most delicate, because of the value of acceptance at 10%.

(iii) The considerable asymmetry of β_2, which varies between -7.21 (Baja California) and -1.25 (Tlaxcala) is immediately striking.

(iv) The reading of β_1 and β_2 allows us to answer the question about the rate of growth in output required for the unemployment rate not to increase. Thus, in Mexico City, Coahuila and Nuevo León, for example, economic growth of around 3% is required, and in Nayarit, Quintana Roo and Baja California Sur, just over 6%. This point is proved by evaluating the ratio β_1/β_2.

(v) It is plausible that, to the extent that $|\beta_2|$ is greater, there are more efficient institutions, less precarious jobs and, consequently, more efficient labour markets in terms of higher productivity (ECLAC, 2012).

Meanwhile, the time series regression for the entire country and the entire period yields a more sensitive coefficient than that of most of the G1 States. However, there are serious specification problems, as well as non-linearity, according to the Ramsey RESET test:

$$\dot{u}_t = 9.46 - 3.62 * \dot{Y}_t + \varepsilon_t \quad (3)$$
$$t \quad (4.88) \quad (-6.52)$$

R^2 = 0.43; F = 42.51(0,00); DW = 0.58; JB = 12.19(0.00); LM(4) = 10.41(0.00); ARCH(2) = 1.18(0.31); ARCH(4) = 2.54(0.51); White(n.c.) = 0.62(0.43); White(c) = 0.38(0.68); RESET(1) = 10.69(0.00); RESET(2) = 6.96(0.00).[7]

[7] These results contrast with those obtained with the same specification by Rodríguez and Peredo (2007) for the period between the third quarter of 1988 and the third quarter of 2003. These authors estimate an Okun coefficient of -2.47.

A second econometric exercise —which is an important contribution, since it is not carried out in the referenced works— consists of testing the hypothesis of structural change. This is done for G1 only, with the Bai and Perron (1998) test, which allows the detection of endogenous breaks (see table 4).

Table 4
Mexico: estimation of Okun's law in growth rates in the 15 G1 States that experienced structural changes, first quarter of 2004–second quarter of 2018

State	Period of significance	β_1	β_2	R^2	F-statistic
Aguascalientes	Q1 2004–Q1 2010	21.9 (5.34)	-2.23 (-3.30)	0.24	11.56 (0.00)
Baja California Sur	Q3 2007–Q4 2009	70.3 (9.74)	-2.96 (-4.01)	0.66	16.08 (0.00)
	Q1 2010–Q2 2018	2.3* (0.69)	-0.89 (-2.37)	0.14	5.63 (0.02)
Chihuahua	Q1 2004–Q3 2009	38.8 (4.65)	-5.74 (-4.03)	0.43	16.24 (0.00)
Mexico City	Q1 2004–Q4 2006	28.6 (3.80)	-5.59 (-3.17)	0.50	10.06 (0.00)
	Q1 2007–Q2 2018	5.3 (2.31)	-2.59 (-3.93)	0.26	15.50 (0.00)
Coahuila	Q1 2004–Q4 2009	10.8 (2.30)	-2.46 (-4.05)	0.42	16.44 (0.00)
Mexico State	Q1 2004–Q4 2009	16.0 (4.21)	-3.9 (-4.19)	0.42	17.62 (0.00)
Hidalgo	Q1 2004–Q3 2009	41.6 (4.36)	-6.34 (-3.28)	0.33	10.79 (0.00)
Jalisco	Q1 2004–Q1 2016	14.2 (4.65)	-3.40 (-4.88)	0.33	23.87 (0.00)
Nayarit	Q1 2004–Q4 2005	77.3 (3.87)	-7.64 (-4.06)	0.73	16.50 (0.00)
	Q1 2006–Q2 2015	13.4 (5.48)	-1.28 (-2.89)	0.18	8.39 (0.00)
	Q3 2015–Q2 2018	-2.1* (-0.44)	-3.61 (-2.56)	0.39	6.58 (0.02)
Nuevo León	Q1 2004–Q1 2010	23.5 (4.65)	-4.45 (-5.21)	0.54	27.24 (0.00)
Querétaro	Q1 2004–Q1 2009	28.1 (2.43)	-4.47 (-2.29)	0.21	5.25 (0.03)
	Q2 2009–Q1 2011	74.1 (12.45)	-12.61 (-12.11)	0.96	146 (0.00)
Quintana Roo	Q2 2009–Q2 2018	20.2 (6.72)	-5.01 (-10.15)	0.74	103.05 (0.00)
Sinaloa	Q1 2004–Q4 2005	43.9 (4.25)	-11.95 (-5.08)	0.81	25.87 (0.00)
	Q1 2006–Q2 2018	6.2 (1.67)	-1.43 (-1.90)	0.07	3.64 (0.06)
Tamaulipas	Q1 2004–Q2 2011	15.1 (3.12)	-2.43 (-2.80)	0.21	7.85 (0.00)
Tlaxcala	Q1 2004–Q1 2011	15.9 (5.59)	-1.45 (-4.62)	0.44	21.42 (0.00)

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/.

Note: Only periods in which the Okun coefficient is significant at a confidence level of at least 10% are recorded. The β_1 and β_2 statistics and the probability of the F-statistic are shown in parentheses. An asterisk (*) indicates that the coefficient is not significant at the confidence level of 10%.

The table above produced the following results:

(i) In 15 States there is at least one structural change during the entire period examined, which implies that the parameters are stable in only 7.

(ii) In only 5 States of 15, Okun's law remains valid until the second quarter of 2018, which is the final observation of the analysis. These States are: Baja California Sur, Mexico City, Nayarit, Quintana Roo and Sinaloa. In the remaining 10 States, this law ceased to be valid at some point after the great recession.

(iii) In States that experienced multiple structural changes, such as Baja California Sur, Mexico City, Nayarit and Sinaloa, this law remains valid, but with notable changes in the magnitude of β_2. The Okun coefficient increased significantly in Nayarit in the final period, while in Baja California Sur, Mexico City and Sinaloa, it decreased.

(iv) In these four States, R^2 for the final period reflecting significance decreases notably.

(v) Querétaro[8] is a unique case, with two regimes (first quarter of 2004 to first quarter of 2009 and second quarter of 2009 to first quarter of 2011), the second of which reflects significant growth in R^2 (from 0.21 to 0.96),[9] but Okun's is no longer valid as of the second quarter of 2011.

The Bai and Perron test (1998) and the Quandt-Andrews test (derived from the Quandt test (1960) and presented in Andrews (1993)) for the entire country show that there is structural change in the fourth quarter of 2011,[10] so two period regressions were carried out.

The estimate for the period from the first quarter of 2004 to the fourth quarter of 2011 indicates that the Okun coefficient is significant, with the correct sign and of a magnitude similar to that of the entire period. It displays a better fit, although it presents problems of serial autocorrelation up to order 4. Given the type of model, it is plausible that this is pure autocorrelation; in other words, given its theoretical construction, it lacks systematic information:[11]

$$\dot{u}_t = 14.49 - 3.56 * \dot{Y}_t + \varepsilon_t \quad (4)$$
$$t \quad (6.05) \quad (-5.90)$$

R^2 = 0.53; F = 34.82(0.00); Wald = 48.05(0.00); JB = 2.10(0.34); ARCH(2) = 0.28(0.75); ARCH(4) = 0.83(0.51); White(n.c.) = 0.13(0.71); White(c) = 0.13(0.87); Reset(1) = 2.68(0.11); Reset(2) = 1.77(0.18).

The estimates for the period between the first quarter of 2012 and the second quarter of 2018 reflect no statistical significance, which again reveals that after the great recession, Okun's law ceased to be valid when considering the country as a whole, as was the case for several G1 States:

$$\dot{u}_t = -1.88 - 1.72 * \dot{Y}_t + \varepsilon_t \quad (5)$$
$$t \quad (-0.62) \quad (-1.59)$$

R^2 = 0.09; F = 2.54(0.12); Wald = 2.69(0.11); JB = 1.18(0.55); ARCH(2) = 0.54(0.58); ARCH(4) = 1.43(0.26); White(n.c.) = 0.17(0.67); White(c) = 0.49(0.61); Reset(1) = 0.48(0.82); Reset(2) = 0.28(0.75).

These structural changes appear to reflect profound transformation in labour markets, which entails significant changes in hiring and firing behaviour, particularly in terms of the reduction of incentives

[8] State that stands out nationally for showing the best indicators presented here.

[9] In fact, no state reflects such a high coefficient of determination.

[10] Maximum LR (maximum likelihood ratio), F-statistic (fourth quarter of 2011) = 12.66(0.00), maximum Wald F-statistic (fourth quarter of 2011) = 25.33(0.00), Ho = no structural change.

[11] In order to estimate a robust model in terms of homoscedasticity and no serial autocorrelation, we employ the Newey-West method (which uses the HAC weighting matrix) (IHS Global, 2019), which corrects for heteroscedasticity and autocorrelation standard errors.

to hire personnel. This comes amid uncertainty that the recovery phase following the great recession may not be permanent or strong. These changes could also derive from shifts in the capital-labour ratio, as well as changes in labour productivity in State economies, so the recovery phase has been accompanied by a smaller impact on employment. This hypothesis is in line with the non-linearity of Okun's law documented by Islas and Cortez (2013 and 2018).

In order to reinforce these results, table 5 presents the correct specification tests of the panel models for G1, G2 and all 32 States.

Table 5
Mexico: correct specification tests with panel data by group, first quarter of 2004–second quarter of 2018

Evidence	Hausman	Pesaran	Wald	Breusch-Pagan	Wooldridge
Ho:	Strict exogeneity	IID errors	Homoscedastic errors	Panel variations equal to zero	No first-order autocorrelation
National	$\chi^2(1) = 13.21$ prob = 0.00	prob = 0.00	$\chi^2(32) = 854.92$ prob = 0.00		F-stat = 57.31 prob = 0.00
Group 1	$\chi^2(1) = 21.36$ prob = 0.00	prob = 0.00	$\chi^2(22) = 476.22$ prob = 0.00		F-stat = 27.886 prob = 0.00
Group 2	$\chi^2(1) = 0.19$ prob = 0.65			chibar2(01) = 0.02 prob = 0.43	F-stat = 36.21 prob = 0.00

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/.

The following results stand out for the 32 States as a whole and for G1:

(i) The Hausman test (1978) shows that there is correlation between individual effects and explanatory variables; i.e. strict exogeneity is not met, so estimation by the less efficient, but robust, fixed effects method is preferable. This test indicates that unemployment in each State depends not only on economic performance, but also on other variables, e.g. social and institutional variables such as the rate of critical employment conditions and the Rule of Law Index, which we test below.

(ii) The Pesaran test (2004) shows cross section dependence, so estimation is robust but not efficient and may reflect bias in standard errors. This test shows that the growth of economic activity in one State influences the unemployment rate in other States.

(iii) The Wald test (Greene, 2003) shows that there is heteroscedasticity of residuals and, therefore, that there are structural changes in the period under review, which is consistent with the results presented in table 4.

(iv) The Wooldridge serial correlation test (Drukker, 2003) shows that there is first-order serial autocorrelation, so the recorded standard deviations of the estimation coefficients are lower than the actual figures, and the recorded R^2 is higher than the actual figure. This test shows that the current level of unemployment depends on the past performance of economic activity.

For G2, the Hausman test (1978) and the Breusch and Pagan test (1979) indicate that a pooled estimation is preferable because there is no panel effect, since the individual effects of economic activity on unemployment do not show a particular behaviour. The panel estimation of G2 also reflects first-order autocorrelation.

Based on the above-mentioned tests, the most efficient estimates for the 32 States as a whole and for G1 are those obtained using the fixed effects method with robust standard errors and controlling for serial correlation and, for G2, those based on a pooled estimate controlling for serial correlation and among individuals (Cameron and Trivedi, 2010) (see table 6).

Table 6
Mexico: panel estimates of Okun's law in growth rates, first quarter of 2004–second quarter of 2018

Method	States	β_1	β_2	R^2	F-statistic
Fixed effects	National	8.01 (0.0000)	-1.34 (0.0000)	0.0808	60.92 (0.0000)
	G1	9.28 (0.0000)	-1.70 (0.0000)	0.1640	89.43 (0.0000)
Pooled estimate	G2	2.27* (0.479)	-0.09* (0.707)		

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/.

Note: The probability of β_1, β_2 and the F-statistic are shown in parentheses. An asterisk (*) indicates that the coefficient is not significant at the confidence level of 10%. The nature of pooled estimation does not allow us to obtain R^2 or the F-statistic.

The estimates in table 6 indicate that for the 32 States as a whole and for G1, the unemployment rate falls by 1.34% and 1.70% for each percentage point of economic growth, respectively. However, unemployment grows at a natural rate (constant β_1) of 8.01% and 9.28%, respectively, in the absence of other factors, implying that economic growth must be 6.0% (8.01/1.34) and 5.4% (9.28/1.70), respectively, to keep the unemployment rate stable in these groups of States.

Meanwhile, as demonstrated in the first econometric exercise, the estimation of Okun's law for G2 based on pooled effects is not significant; i.e., it is confirmed that economic growth does not have an impact on the trend in unemployment.

Another method is fixed effects panel estimation incorporating dichotomous variables (dummies), which may be less efficient, as it does not control for serial correlation problems, but allows us to compare the States' unemployment rates through the estimated β_1.

In this case, the fixed effects panel estimation for G1 shows marked differences in the labour markets (see table 7), as the magnitude of β_1 varies (natural rates of unemployment growth), while the Okun coefficient common to G1 is -2.59.

Table 7
Mexico: fixed effects panel estimation (dichotomous variables) for G1 States, first quarter of 2004–second quarter of 2018

β_2 = -2.59 (0.0000)		
State	β_1	Standard error
Aguascalientes	13.83 (0.0000)	0.74
Baja California	13.72 (0.0000)	0.08
Baja California Sur	23.3 (0.0000)	1.17
Chihuahua	12.7 (0.0000)	1.87
Mexico City	7.84 (0.0000)	0.96
Coahuila	7.09 (0.0000)	0.00
Colima	14.91 (0.0000)	0.24
Mexico State	8.82 (0.0000)	0.13
Guanajuato	9.91 (0.0000)	0.40

Table 7 (concluded)

β_2 = -2.59 (0.0000)		
State	β_1	Standard error
Hidalgo	14.98 (0.0000)	0.10
Jalisco	8.69 (0.0000)	0.19
Michoacán	11.57 (0.0000)	0.04
Nayarit	14.56 (0.0000)	0.32
Nuevo León	8.29* (0.1080)	0.28
Querétaro	16.06 (0.0000)	0.76
Quintana Roo	18.1 (0.0000)	0.85
San Luis Potosí	13.42 (0.0000)	0.39
Sinaloa	9.86 (0.0000)	0.05
Sonora	8.77 (0.0004)	0.26
Tamaulipas	5.44 (0.0000)	0.34
Tlaxcala	6.49 (0.0052)	0.48
Veracruz	8.29 (0.0696)	0.24

Source: Prepared by the authors, on the basis of National Institute of Statistics and Geography, "Encuesta Nacional de Ocupación y Empleo (ENOE), población de 15 años y más de edad", 2018 [online] https://www.inegi.org.mx/programas/enoe/15ymas/; INEGI, "Indicador trimestral de la actividad económica estatal", 2018 [online] https://www.inegi.org.mx/temas/itaee/.

Note: The probability of β_1 and β_2 is indicated in parentheses. An asterisk (*) indicates that the coefficient is not significant at the confidence level of 10%.

The results shown in table 7 are consistent with the individual estimates presented in table 3, since the States of Hidalgo, Querétaro and Quintana Roo are among the five States with the highest β_1, while Coahuila, Tamaulipas, Tlaxcala and Veracruz are the States with the lowest β_1, according to both econometric techniques.

Finally, in order to incorporate the determinants of the Okun coefficient (β_2), multiple cross section regressions were run for G1 and G2 with the economic, social and institutional variables presented in table 2. On that basis, we tested the hypothesis that the Okun coefficient of G1 (dependent variable) responds to the Rule of Law Index and the rate of critical employment conditions in a significant and economically meaningful way for each State i. No significance was found for the country as a whole or for G2 with any of the variables presented in table 2.

To test the above hypothesis, the Newey-West homoscedasticity- and autocorrelation-consistent (HAC) covariance matrix was used to obtain efficient estimators free of heteroscedasticity and serial autocorrelation (IHS Global, 2019):

$$CO_i = 0.12 * TCCO_i - 10.64 * IED_i + \varepsilon_i \quad (6)$$

$$t \quad (2.01) \qquad (-6.15)$$

R^2 = 0.24; JB = 3.66(0.15); State i = 1, 2, 3, ..., 22.

It is shown that greater adherence to the rule of law makes economic growth more effective in reducing the unemployment rate; i.e., the result is a higher Okun coefficient in absolute terms. Meanwhile, to the extent that employment in precarious conditions is greater, as expressed by the rate of critical employment conditions, the magnitude of the Okun coefficient decreases.

VII. Conclusions and final comments

Okun's law has generally been estimated at the macro level on the basis of various specifications, functional forms and frequencies of temporal data, which implies that the heterogeneity among countries and among States or regions within a country is not taken into account.

Amid this backdrop, in this paper we estimate Okun's law for the 32 States of Mexico over the longest and most consistent period possible (first quarter of 2004 to second quarter of 2018). We incorporate into the analysis three groups of variables (economic, social and institutional) that give rise to the structural heterogeneity among these States (ECLAC, 2016). The incorporation of these variables allows us to confirm that they determine the significance and magnitude of the Okun coefficient.

On the basis of the specification of Okun's law in growth rates, we find the following:

(i) The labour market response to growth in economic activity is significant and possesses the correct sign in only 22 States (G1). These States have performed better economically (in terms of economic growth, labour productivity growth, lower unemployment growth, higher per capita GDP, higher exports and lower informality), socially (lower crime rates and less precarious employment) and institutionally (higher Rule of Law Index).

(ii) Estimating Okun's law with time series and fixed effects panel data, we find conclusive information on asymmetries in the Okun coefficient in G1, which reflect different degrees of labour market response to GDP growth, as the Okun coefficient ranges from -7.25 to -1.25.

(iii) In G2, where Okun's law is not valid, no conclusive panel effect data were found, meaning that the variance owing to the individual effect is not significant. Furthermore, this group reflects homogeneity in terms of very poor results in all the variables analysed, as the economic, social and institutional performances are weak.

(iv) The Okun coefficient not only differs among G1 States, but also varies over time. The Bai and Perron test (1998) for structural change shows that the effect of the great recession of 2008–2009 has conditioned the magnitude and significance of the Okun coefficient in most of the States in this group.

(v) These differentiated results in G1 denote different levels of economic growth required to keep the unemployment rate stable and, therefore, demonstrate the heterogeneity in this group.

(vi) Of all the attempts to identify the determinants of Okun's law on the basis of economic, social and institutional variables, only the Rule of Law Index and the rate of critical employment conditions explain the magnitude and significance of the Okun coefficient in G1 notably and in an economically meaningful way. Thus, it can be said that greater adherence to the rule of law and fewer precarious jobs make economic growth more effective in reducing unemployment; i.e., translate into a higher Okun coefficient (in absolute terms).

Beyond the different magnitudes of the Okun coefficient estimated by the econometric methods used here, a key finding is that the improvement of institutional frameworks and the reduction of precarious labour conditions, as measured by the Rule of Law Index and the rate of critical employment conditions, respectively, are crucial for strengthening the functioning of labour markets in G1 and, possibly, for unemployment growth to regain its sensitivity to output growth in G2. This would increase the efficiency

of economic growth in reducing unemployment at the national level and, through Okun's law, could generate virtuous effects on economic growth and on the other variables analysed in this work.

The results indicate, crucially, that the implementation of development policies at the State and municipal levels should not only be economic in nature, but —more importantly— should have a strong social and institutional orientation that addresses the serious issue of structural heterogeneity. Thus, a key finding is that the best institutional reform, which must be implemented urgently, is to strengthen the rule of law. This will have to improve employment conditions in labour markets and thus generate virtuous effects on labour productivity, economic growth and development.

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