The effects of corruption on innovation and growth in Mexico

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Abstract

This research reviews the Grease the Wheels (GTW) and Sand the Wheels (STW) hypotheses and the effects of corruption on innovation and economic growth. The study used principal component analysis methodologies and structural equation modeling. Employing the former, it is concluded that both hypotheses could be fulfilled, but only for some of the country's federal states. Meanwhile, in the case of structural equations, it is concluded that corruption facilitates innovative activity and economic growth (GTW). This has implications since it is shown that higher budgets for science and technology do not necessarily lead to better results in this field.

Keywords: corruption; innovation; economic growth; principal components; structural equations.

1. INTRODUCTION

In recent decades, studies regarding technological change and innovation have increased. One of the leading exponents in this field was Schumpeter, who argued about the process of "creative destruction". According to this author, companies that generate innovations impose new ways of doing things, which can drive companies that do not do so out of the market. Therefore, as he pointed out, technological change drives capitalism (Schumpeter, 1939 and 1942).

According to this school of thought, others have followed, such as the evolutionary (Lovera *et al.*, 2008), neoclassical (Solow, 1957; Mankiw *et al.*, 1992), institutionalist (North, 1990) and structuralist (Floto, 1989) schools of thought. However, the innovative process is subject to socio-political conditions and not only to economic conditions. Corruption can generate uncertainty in businesses and long-term technological development projects in developing countries (Murphy *et al.*, 1993; Karaman and Sylwester, 2020). This phenomenon also affects some states in the American Union and other developed countries (Alt and Lassen, 2003; Glaeser and Saks, 2006; Riaz *et al.*, 2018). In this respect, corruption can inhibit regional development and is considered a relevant issue in terms of innovation and economic growth.

There are two competing hypotheses to explain the effects of corruption on innovation. The first suggests that businesses can benefit from corrupt environments since corruption helps overcome bureaucratic obstacles and provides access to valuable resources, referred to as Grease the Wheels (GTW). The second suggests that corruption impedes innovative processes since it resembles a tax that makes them more costly, generating a bias towards profit-driven, less innovative activities, which is referred to as Sand the Wheels (STW) (Huang and Yuan, 2020; Ellis *et al.*, 2020; Karaman and Sylwester, 2020).

Corruption is a multidimensional problem that extends beyond the economy. It affects fundamental aspects of a society's development, such as justice, the quality of public services, confidence in institutions, investment, security, and quality of life. Expanding research in this area could have crucial implications for anti-corruption policies and sustainable development.

This study aims to test these hypotheses in the Mexican context through a macro-level study using principal component analysis and structural equation modeling. The results support the GTW hypothesis by demonstrating a positive effect of corruption on innovation and economic growth.

This paper is composed of several sections: first, a review of the literature on the relationship between corruption, innovation and economic growth; then a description of the methodology used, followed immediately by a presentation of the results; and finally, a discussion of the conclusions, evaluating the ability of the hypotheses to determine whether any of them can explain the effects of corruption on innovation in Mexico and whether this affects economic growth.

2. REVIEW OF THE LITERATURE

The effects of corruption on the economy

This section presents a varied view of corruption. Examples include Leff's (1964) perspective, which describes it as "an unlawful (if not criminal) influence on the formation and implementation of policies," or Mauro's (1995) definition, which relates it to "the degree to which business transactions involve questionable payments."

These definitions address corruption from different perspectives, either as sales made by government agents for their personal gain, as proposed by Shleifer and Vishny (1993) or as the abuse of public power and/or authority for private gain, according to Anokhin and Schulze (2009).

The dimensions of corruption are also mentioned, ranging from large amounts of money to small bribes, as noted in the work of Habiyaremye and Raymond (2013). Other definitions, such as that of Cárdenas *et al.* (2018), emphasize individual decision-making, whether in the public or private sphere, seeking a benefit of any kind that can be legally penalized.

It should be noted that corruption can occur in both the public and private sectors, as indicated by Tomaszewski (2018). Furthermore, Riaz et al. (2018) highlight its negative impact on economies, while its detrimental nature as an institution is also underlined, according to Riaz and Canter (2020).

Finally, Transparency International (Faraz and Canter, 2020) describes it as "the abuse of entrusted power for private gain" and classifies it into large, small and political categories. In turn, Merino (2022) suggests that corruption is a consequence of the various manifestations of the capture of the State.

This literature review highlights that corruption can occur in both public and private spheres and refers to the abuse of power to obtain private benefits through bribes, diversion of resources and obtaining contracts. This involves secrecy and agreement between two parties and usually occurs when there is a high level of inelasticity of demand from private parties concerning the provision of public goods or services (Habiyaremye and Raymond, 2013).

Thus, for this study, corruption could be defined as abusing power, often secretly, to obtain personal or private benefits through bribes, diversion of resources and obtaining contracts. It can occur in public and private sectors and may involve illegal or questionable transactions. Therefore, corruption involves the improper manipulation of authority for personal or third-party gain.

According to the World Economic Forum, corruption has cost approximately US$2.6 trillion annually, equivalent to 5% of global GDP (Iorio and Segnana, 2022).In addition, the World Bank (2020) reports that companies and individuals pay more than US$1 trillion in bribes each year. In Mexico, the average cost of an act of corruption is MXN$2,799 per adult victim and MXN$12,243 per business victim, according to Deloitte (2021). The importance of this issue is reflected in the inclusion of a corruption chapter in the recent Treaty between Mexico, the United States, and Canada (T-MEC) due to its impact on trade between the three North American countries (Deloitte, 2021). The effects include job losses, elimination of competition and investment, and inefficient allocation of resources, all of which can affect the economic growth of companies and nations (Habiyaremye and Raymond, 2013; Griffiths and Kickul, 2008; Sena *et al.*, 2018).

Classic studies, such as those by Rose-Ackerman (1975), Shleifer and Vishny (1993), and Mauro (1995), have characterized corruption as a market structure arising from institutional and market imperfections. These studies conclude that corruption inhibits economic growth and distorts markets more significantly than an additional tax. Mauro (1995) introduces econometric analyses, demonstrating that corruption, in some cases, can have positive effects, such as eliminating bureaucratic barriers and streamlining government officials involved in corrupt activities.

Corruption affects property rights, constrains political institutions and makes it difficult to combat due to the secrecy involved (Hodge *et al.*, 2011). There are different positions on corruption's economic effects, with some studies indicating that this practice can facilitate GTW economic performance (Leff, 1964; Huntington, 1968), while others suggest STW (Mauro, 1995; Tanzi, 1998). Additionally, countries with increased dependence on exports, strict regulations and lack of inflation control are more likely to suffer from problems of corruption (Hodge *et al.*, 2011). A corruption transmission channel is uncertain since it decreases investment in physical and human capital (Hodge *et al.*, 2011). Aghion *et al.* (2016) suggest that analyzing this problem as a tax on businesses and consumers is inappropriate since taxes discourage entrepreneurs and high-tech companies. Furthermore, they conclude that the marginal effects of a tax on growth in countries with high levels of corruption are minimal.

Since 2000, empirical studies regarding the effects of corruption on economic performance have increased, using information from Transparency International, particularly the Corruption Perceptions Index (CPI). Although this index is the main one in these studies, there are also other indexes, such as the International Country Risk Guide (ICRG) Index or the World Governance Indicators (WGI), which have been used less in academic literature (Gründler and Potrafke, 2019). Mexico is located in the medium-high levels in the CPI, as it registers levels between 65 and 73%. According to this indicator, countries that receive more foreign direct investment are associated with lower levels of corruption in the CPI (Gründler and Potrafke, 2019).

It has been found in Latin America that, although progress has been made in the fight against corruption, no conclusive results have been obtained regarding improved competitiveness or growth in GDP (Useche and Reyes, 2020). It has also been found that inequality and corruption have an inverse relationship, so the policies applied to fight corruption may not be the most appropriate (Andres and Ramlogan, 2011). This inverse relationship could be due to the high participation of the informal sector in these economies (Dobson and Ramlogan, 2012).

Ramírez and Sanchez (2013) conducted a study in Mexico to test the STW hypothesis but did not find sufficient evidence due to the lack of available data. On the other hand, Ruiz and Garcia (2020) suggest that the perception of corruption positively affects economic growth when both the growth rate and the perception of corruption are low but negatively when both are high, which supports the existence of the two hypotheses, albeit at different points in time.

The effects of corruption on innovation

According to Iorio and Segnana (2022), although the relationship between corruption and innovation is well known, its exact nature has not yet been established. The increase in data availability allowed an increase in studies addressing this problem (Doan *et al.*, 2022). These studies can be divided into two levels of analysis: at the company level, where the effect of corruption on innovation in companies is analyzed, and at the country or regional level.

Corruption can negatively affect innovation. For example, businesses with high growth rates and profit margins may be associated with higher levels of innovation. In addition, businesses that make higher investments often require institutional certainty to carry out innovative activities (Karaman and Sylwester, 2020; Ross *et al.*, 2012; Riaz and Canter, 2020; Habiyaremye and Raymond, 2013).

These effects are observed both in MSMEs and at the large company level. Academic studies of these effects on companies such as Samsung, Siemens, and Wal-Mart, among others, are documented (Iorio and Segnana, 2022).

Macro-level studies also exist, which may refer to a country, a set of countries, or a set of states within a country. They have reached somewhat different findings from the company-level studies. Some of them are described in Table 2.

Table 1. References regarding the effects of corruption at the company level

Reference	*Summary*	*Effect*
Doan *et al.* (2022)	Bribes on tax payments have a positive effect on all innovation indicators.	Positive
Karaman and Sylwester (2020)	Bribes are significantly related to innovation, especially in businesses with many competitors. Competition drives innovation and corruption helps to avoid costly regulations.	Positive
Wellalage *et al.* (2020)	Female business owners give bribes more frequently than male owners, which supports the GTW hypothesis.	Positive
Karaman (2017)	Corruption positively affects the rate of innovation, regardless of how innovation and corruption are measured.	Positive
Nguyen *et al.* (2016)	Bribes drive innovation, such as product improvements or intellectual property, but their impact varies according to the effectiveness of local institutions. Multinational companies with corrupt practices can stifle innovation in the host country.	Positive
Huang and Yuan (2020)	Corruption negatively affects innovation, especially in companies with little influence over government officials. In such cases, corrupt practices replace innovation.	Negative
Ellis *et al.* (2020)	Corruption adversely affects innovation and its quality, as measured by patent citations.	Negative
De Soto (1987)	Corruption is often related to the informal economy, as entrepreneurs may be forced to pay bribes to avoid legal or regulatory problems.	Negative
Sena *et al.* (2018)	Independent boards of directors can insulate a business from the detrimental impact of corruption on its performance, as represented by innovation.	Negative
Iorio and Segnana (2022)	Both GTW and STW hypotheses can coexist and are not necessarily competing hypotheses.	Both
Riaz and Cantner (2020)	Small bribes stimulate process innovation but harm organizational innovations. Businesses involved in large-scale corruption tend to be innovative in products and processes.	Both
Habiyaremye and Raymond (2013)	Regarding multinationals, on the one hand, they increase corruption by using bribes to compete in host countries, which inhibits the innovation of other companies. On the other hand, increased public scrutiny and technology spillovers can decrease corruption and encourage innovation.	Both
Mahagaonkar (2010)	Corruption has a contradictory impact on innovation. While it facilitates innovation in marketing, it inhibits innovation in products, processes, and organizations. Four positive transmission mechanisms are identified: streamlining procedures, reducing uncertainty in incremental innovation, overcoming political obstacles, and protecting against crime and vandalism.	Both

Note: the effect column indicates whether the authors have found a positive or negative effect of corruption on innovation or both.
Source: compiled by the authors.

Table 2. References regarding the effects of corruption at the macro level

Reference	*Summary*	*Effect*
Mahagaonkar (2010)	Corruption may help market innovation but inhibits innovation in products, processes, and organizational structures. Bureaucracy discourages innovative projects involving significant uncertainties, especially if they are government-funded.	Positive
Tomaszewski (2018)	Corruption is a market transaction where corrupting agents meet corrupt agents and negotiate the price of the bribe.	Positive
Riaz et al. (2018)	Corruption causes innovation, while innovation does not cause corruption.	Positive
Anokhin and Schulze (2009)	Better control of corruption is associated with increasing levels of innovation and entrepreneurship. Corruption and the quality of institutions are important factors in explaining disparities in entrepreneurship and innovation rates.	Negative
Griffiths and Kickul (2008)	Corruption leads to misallocation of resources, lack of competitiveness and efficiency, lower public revenue, lower productivity and innovation rates, and lower growth and employment rates.	Negative
Habiyaremye and Raymond (2013)	Although multinationals can increase corruption by using bribes to compete in host countries, they also decrease corruption by being subject to greater public scrutiny and by generating technology spillovers that promote innovation.	Both
Wen *et al.* (2018)	Corruption impacts patents more than trademarks. There is a tolerable level of corruption beyond that which does not affect innovation. The temporary monopoly of patents can incentivize corrupt practices to maintain competitiveness.	Both

Note: The effect column indicates whether the authors have found a positive or negative effect of corruption on innovation or both.
Source: Compiled by the author.

Intellectual property as an innovation proxy variable

Knowledge comprises unobservable elements and can be measured using integrated, codified, tacit approaches. The first refers to software and computers, the second to patents and manuals, and the third to human capital (Aboites and Soria, 2008). Patents have been considered research and development factors in some knowledge production functions (Griliches, 1990).

Patents have been the most important measure for studies of codified knowledge and innovation (Aboites and Soria, 2008; Hall, 2007; Encaoua *et al.*, 2006; Foray, 2004; Cohen *et al.*, 2000; Granstrand, 1999; Griliches, 1990), although other measures exist such as utility models, industrial designs, industrial secrets, integrated circuits, copyrights, etc.

Some criticisms of quantitative indicators at the macro level, such as public spending on R&D, are that they say little about the observed linkages and impacts on performance. Moreover, they can only be evaluated long-term (Molas-Gallart and Davies, 2006). Quantitative indicators do not reveal the quality of research. For example, a research budget is an input rather than a measure of performance (Donovan, 2007). It has also been suggested that typical science and technology performance measures, such as patents, publications and citations, are final indicators that do not accurately account for research progress (Mote *et al.*, 2007).

3. DATABASES AND APPROXIMATION METHOD

A consensus exists regarding databases for economic and innovation variables provided by institutions such as the World Bank or the International Monetary Fund. In turn, the databases of Transparency International are used to study the corruption perception variable (Wen *et al.*, 2018; Riaz *et al.*, 2018; Griffiths and Kickul, 2008). Generally, panel data regression analysis (Wen *et al.*, 2018; Riaz *et al.*, 2018) or multivariate analysis (Griffiths and Kickul, 2008) are used.

The study focuses on the federal-state level in Mexico due to the availability of information. A multivariate analysis is carried out by applying a macro approach to the different states. For this purpose, two of its most popular techniques were used: on the one hand, principal component analysis to reduce variables and, on the other hand, structural equation analysis (SEM), with which the path followed by the STW and GTW hypotheses is analyzed. As shown in the literature review, no previous study has applied it to understand these phenomena.

Variables and sources of information

The variables were grouped by federal state and only those corresponding to 2015, 2017 and 2019 were analyzed due to data availability. The variables and their sources are described below.

- *Innovation variables.* These variables include the number of members of the National System of Investigators (NSI); applications and granting of patents, utility models and trademark registrations; budget variables, spending on science and technology. The amount allocated to the Ministry of Public Education (SEP) by each state as spending on education is also included.
- *Corruption variables.* These include variables from the National Survey on Government Quality and Impact (ENCIG). There are 21 variables for the perception of corruption. These perceptions range from 0 to 100, where zero is the least corrupt and 100 is the most corrupt.
- *Support variables.* Other variables that help in this analysis, such as population, Foreign Direct Investment (FDI), growth of the Gross Domestic Product (GDP) of the states, and finally, the total expenditure variable by federal state, are considered.

All these variables and their sources of information are summarized in Table A1 of the Annex.

Principal Component Analysis (PCA)

This analysis decomposes the total variance to evaluate the loss of information by eliminating components. The PCA technique is applied to reduce the number of variables associated with innovation and another number of components related to corruption. Table A1 shows 21 variables associated with corruption and nine for innovation, which can be reduced using this PCA technique.

In the PCA diagnosis, the KMO statistic (Kaiser Meyer) indicates the suitability of the matrix for the analysis. A KMO of less than 0.5 is discarded since the variables have a limited contribution. In addition, values greater than 1 or a contribution to variance greater than 70% are considered to determine the required number of principal components.

Using the principal components of variables related to innovation and corruption, descriptive tables are generated with the quartiles of each principal component, describing the relationships between corruption and innovation.

Structural Equation Model Analysis

SEM models combine the econometric perspective, which focuses on prediction, with the psychometric approach, which models latent variables inferred indirectly from multiple observed measures.

A proposed model includes two equations for the factors of Corruption and Innovation. The Innovation factor comprises variables with high non-repeated factor loadings, such as NSI members per million inhabitants, patent applications and utility models per million inhabitants, FDI per million inhabitants and the corruption factor. The equations

$$vl.Corruption\ = StateGov + + FedGov\ + MunGov + Entrepreneurs \qquad (1)$$

$$vl.Innovation\ = NSI + SPatents + SUtModels + Corruption \qquad (2)$$

$$Expenditure\ = Total\ expenditure\ of\ the\ states \qquad (3)$$

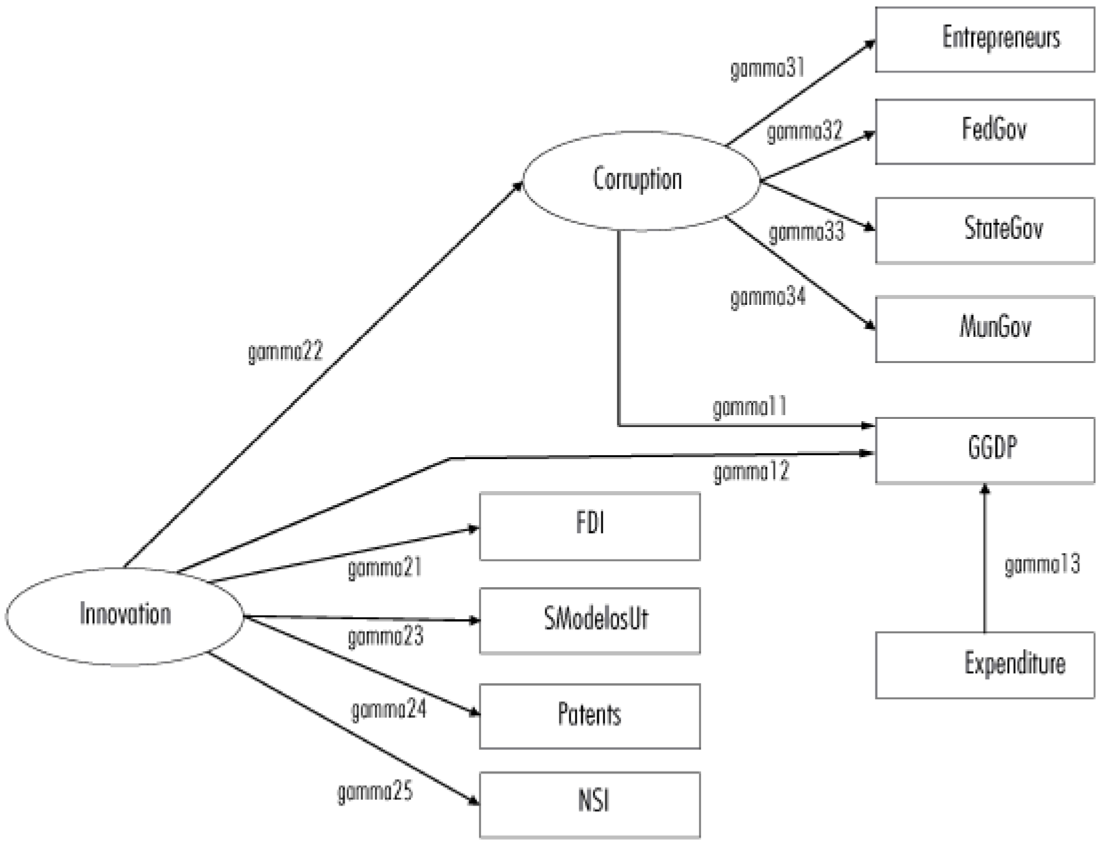
Where *vl.Corruption* and *vl.Innovation* are latent variables that determine the right-hand side variables. Once these factors are estimated, the parameters of the following regression model are calculated:

$$CGDP = Expenditure + Innovation + Corruption \quad (4)$$

where *GGDP* refers to growth in GDP. Equations 1-4 test the hypotheses that corruption can positively or negatively affect states' innovative capacity. The structural equation model is given in Figure 1.

Figure 1 shows the hypotheses to be compared. The arrows indicate the causality from one variable to another, while the gamma coefficients indicate the number of estimated parameters. This SEM model is applied in the years 2019, 2017 and 2015. The Chi-squared and SRMR statistics are used as tests of model adjustment.

Figure 1. SEM model for the STW and GTW hypotheses



Note: latent variables are enclosed in circles, and observable variables are in rectangles.
Source: compiled by the author using the Rstudio and DiagRamer package.

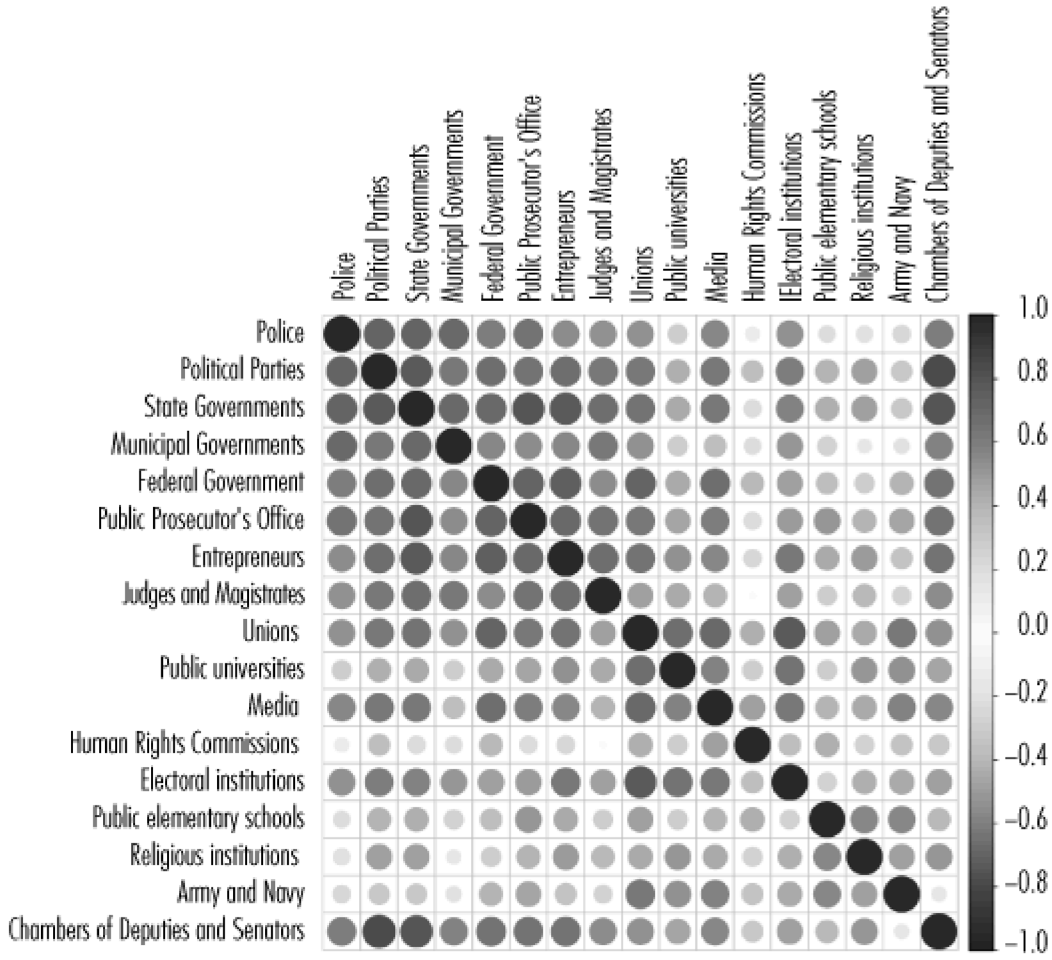
4. MODEL RESULTS

Principal component analysis

It is worth noting that, for practicality, the figures are only shown for 2019 since the statistics for 2015 and 2017 are similar.[1]

In Figure 2, the correlations between the variables are positive, suggesting a greater perception of corruption in highly correlated dimensions. KMO coefficients were calculated to assess the significance of the correlations and to perform a principal components analysis.

Figure 2. Correlation coefficients for corruption variables in 2019



Source: compiled by the author using data from ENCIG-INEGI (2019).

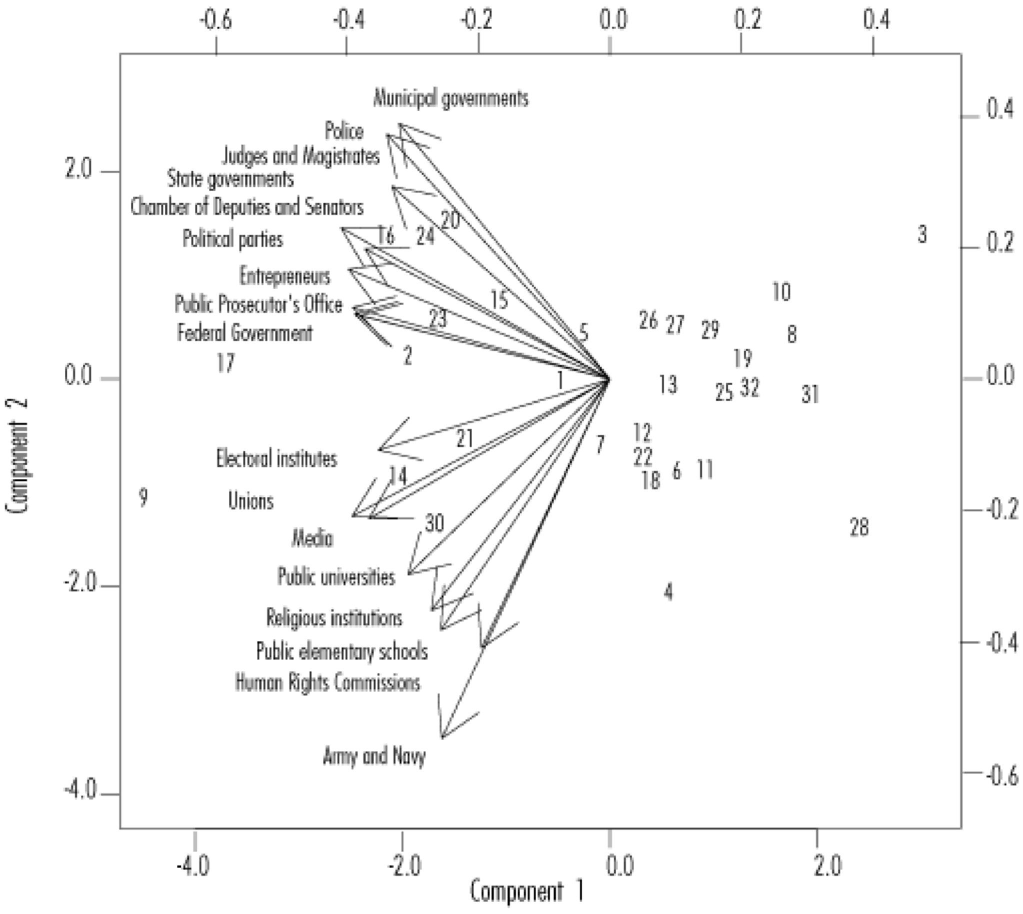
Table 3. KMO coefficients of corruption indicators for 2019

Variable	*KMO*
Global MSA	0.83
MSA for each variable	
Police	0.86
Political parties	0.85
State governments	0.89
Municipal governments	0.79
Federal Govemment	0.80
Public Prosecutor's Office	0.84
Entrepreneurs	0.85
Judges and Magistrates	0.82
Unions	0.86
Public universities	0.82
Media	0.88
Human Rights Commissions	0.74
Electoral institutes	0.83
Public schools	0.73
Religious institutions	0.81
Army and Navy	0.74
Chamber of Deputies and Senators	0.79

Source: compiled by the author using data from ENCIG-INEGI (2019).

According to Figure 3, the states follow two strategies in relation to corruption indicators. In one direction are "social" indicators, which include electoral institutes, public schools, human rights commissions, religious institutions and unions. In the other direction are "government" variables, such as state, federal and municipal governments, political parties, chambers of deputies and senators, entrepreneurs and public ministries.

Figure 3. Components 1 and 2 of the PCA for corruption indicators in 2019



Note: the numbers indicate federal states alphabetically;
the text provides indicator scores for principal components.
Source: compiled by the author using Rstudio.

Table 4 shows the PCA's factor loadings, which refer to the correlations between each principal component's score and the original variables.

Table 4. Factor loadings for corruption indicators in 2019

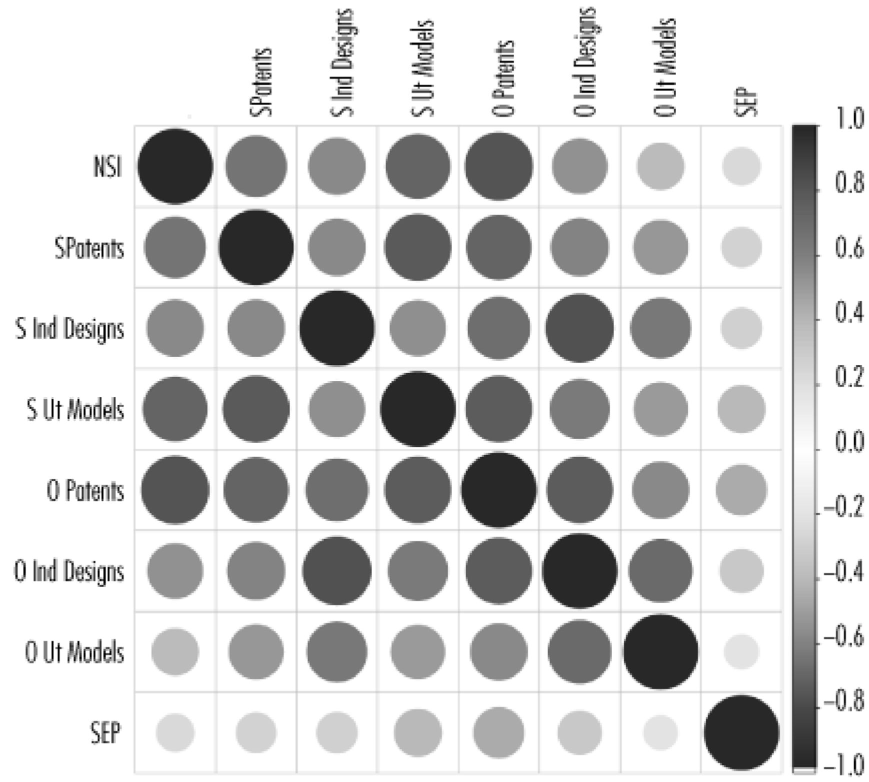
	CP1	*CP2*	*CP3*
Police	**-0.73**	0.43	-0.19
Political parties	**-0.85**	0.19	0.05
State governments	**-0.88**	0.26	0.14
Municipal governments	**-0.69**	0.44	-0.13
Federal Government	**-0.82**	0.11	-0.16
Public Prosecutor's Office	**-0.83**	0.11	0.15
Entrepreneurs	**-0.84**	0.12	0.14
Judges and Magistrates	**-0.71**	0.34	0.22
Unions	**-0.84**	-0.24	-0.26
Public universities	**-0.66**	-0.34	-0.12
Media	**-0.79**	-0.24	-0.25
Human Rights Commissions	-0.42	**-0.47**	-0.29
Electoral institutes	**-0.76**	-0.12	-0.33
Public schools	-0.55	-0.44	**0.44**
Religious institutions	-0.58	-0.40	**0.53**
Army and Navy	-0.55	**-0.62**	-0.04
Chamber of Deputies and Senators	**-0.80**	0.23	0.18

Note: figures in bold show more significant factor loadings.
Source: compiled by the author.

The first component, with the strongest factor loadings, contributes 54% of the total variance. The same procedure was applied to the innovation indicators, and a figure of correlation coefficients was presented.

In Figure 4, the SEP state expenditures variable is the only one that shows a negative relationship with other innovation indicators and weaker correlations. Before applying PCA to the innovation indicators as variable reduction, KMO coefficients were calculated to verify their feasibility.

Figure 4. Correlation coefficients for innovation variables in 2019



Source: compiled by the author using data from CONACYT (2019), SEP (2019) and IMPI (2019).

Table 5 shows that all variables are closely related and should be included together (overall MSA). A PCA was performed using the 2019 innovation indicators, where two significant principal components explain 74% of the total variation in the data (see Table 6).

Table 5. KMO coefficients of innovation indicators for 2019

Variable	*KMO*
Global MSA	0.81
MSA for each variable	
NSI	0.74
Patent application	0.86
Industrial design application	0.82
Utility model application	0.85
Granting of patent	0.79
Granting of industrial design	0.76
Granting of utility models	0.93
SEP	0.67

Source: compiled by the author using data from CONACYT (2019), SEP (2019) and IMPI (2019).

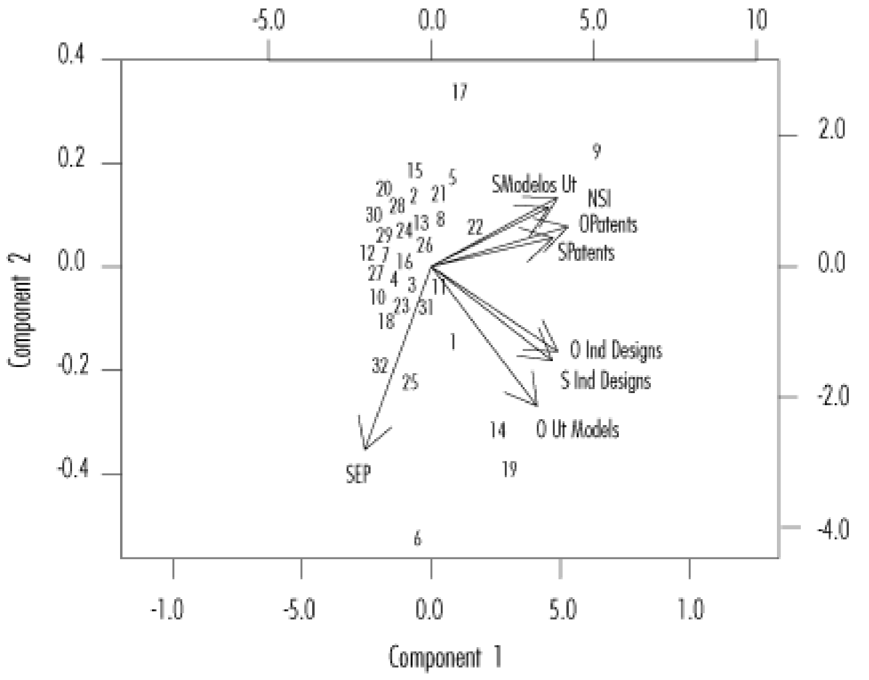
Table 6. Summary of the PCA for innovation indicators in 2019

	PC1	*PC2*
Standard deviation	2.247	0.9569
Proportion of variance	0.631	0.1145
Accumulated proportion	0.631	0.7455

Source: compiled by the author.

Some states prioritize higher expenditures on SEPs and grant models and applications for industrial designs (Figure 5, bottom), while others emphasize NSI members, patents and utility models (Figure 6, top).

Figure 5. Components 1 and 2 of the PCA for innovation indicators in 2019



Note: The numbers indicate federal states alphabetically; the text provides indicator scores in principal components.
Source: compiled by the author using Rstudio.

In addition to this graphical analysis, the innovation components' factor loadings were obtained and shown in Table 7.

Table 7. Factor loadings for innovation indicators in 2019

	CP1	*CP2*
NSI	**0.80**	0.20
Patent application	**0.83**	0.10
Industrial design application	**0.82**	-0.32
Utility model application	**0.86**	0.23
Granting of patents	**0.93**	0.14
Granting of industrial design	**0.86**	-0.29
Granting of utility models	**0.72**	-0.47
SEP	-0.45	**-0.62**

Notes: figures in bold show more significant factor loadings.
Source: compiled by the author.

In Table 7, the first component captures most of the factor loadings, accounting for 63% of the total variance. The second component is noted for its loadings on SEP expenditure and explains the strategies for developing innovation indicators in some states.

A table was prepared by crossing the first principal component of corruption indicators with the first of innovation indicators, which covers 54% and 63% of their respective variances. This is a ranking tool based on the states' performance in relation to these variables.

Table 8 shows the ranking of states according to their main components. Some, such as Mexico City, Jalisco, and Morelos, are in the top quartile of innovation but in the bottom quartile of corruption perception. Others, such as Nuevo León, have high levels of corruption perception despite being in the top quartile of innovation. This suggests that the GTW and STW hypotheses may apply in different states.

Table 8. Ranking of states according to the first component of each PCA and their quartiles

		First component of corruption			
		Q1	*Q1*	*Q3*	*Q4*
First innovation component	Q4	Mexico City, Jalisco, Morelos	Aguascalientes, Coahuila, Querétaro	Guanajuato	Nuevo León
	Q3		Mexico City, Puebla	Colima, Hidalgo, Sonora	Chihuahua, Sinaloa, Yucatán
	Q2	Baja California, Michoacán, Quintana Roo, San Luis Potosí, Veracruz		Campeche	Baja California Sur, Tamaulipas
	Q1		Chiapas, Guerrero, Oaxaca	Nayarit, Tabasco, Tlaxcala	Durango, Zacatecas

Source: compiled by the author based on PCA results.

Analysis of structural equations

The SEM results shown below are divided into tables (9, 10, 11 and 12) because the SEM generates a large quantity of information in the parameter estimation process. The results are shown for the three years of analysis and combined data.

Table 9 shows that the latent Corruption variable positively determines the variables of perception of corruption at the federal, state and municipal levels of government and the perception of corruption among entrepreneurs. The latent Innovation variable positively influences the number of NSI members, applications for patents and utility models, FDI, and the latent corruption variable. This last result is particularly important since it means that there is an endogenous relationship between innovation and corruption, i.e., corruption not only has an effect on innovation, but innovation has effects on corruption, as pointed out by several authors in Tables 1 and 2. In particular, it is indicated that innovative multinational companies, are corrupting local authorities to prevent local companies from being innovative (Habiyaremye and Raymond; 2013; Nguyen *et al.*, 2016). This type of relationship is also reported in markets where innovative businesses want to prevent competitors' innovation (Karaman and Sylwester, 2020; Riaz *et al.*, 2018; Wen *et al.*, 2018).

Table 9. Structures of latent variables or factors

	2019			*2017*			*2015*			*Combined*		
	Estimator	*Value Z*	*P(>|z|)*	*Estimator*	*Value Z*	*P(>|z|)*	*Estimator*	*Value Z*	*P(>|z|)*	*Estimator*	*Value Z*	*P(>|z|)*
	Latent variable: corruption											
State government	0.899			0.801			0.863			0.911		
Municipal government	0.7	4.649	0	0.877	5.837	0	0.907	7.208	0	0.92	15.143	0
Federal government	0.817	5.96	0	0.904	6.093	0	0.806	5.792	0	0.697	8.488	0
Entrepreneurs	0.871	6.618	0	0.925	6.287	0	0.937	7.638	0	0.954	16.634	0
	Latent variable: innovation											
NSI members	0.815			0.742			0.775			0.773		
Patent application	0.83	5.373	0	0.991	4.56	0	1.013	6.197	0	0.923	8.877	0
Utility model application	0.92	5.986	0	0.618	3.597	0	0.794	5.121	0	0.791	8.065	0
FDI	0.67	4.052	0	0.3	1.696	0.09	0.503	3.019	0.003	0.514	4.976	0
Corruption	0.37	1.944	0.052	0.367	1.954	0.051	0.409	2.283	0.022	0.182	1.656	0.098

Note: factor loadings of 1 in NSI members for innovation and in the perception of corruption in state governments for corruption.

Source: compiled by the author using Rstudio.

A noteworthy aspect is that all the variables are significant at the individual level. The following table shows the Chi-squared and SRMR statistics.

Table 10 shows that the sample variance and covariance matrices are only equal to the theoretical ones in 2015. This hypothesis is rejected in other periods and combined data, but the SRMR statistic indicates a good overall fit, especially in the combined data.

Table 10. Structural equation model fit statistics

	2019	*2017*	*2015*	*Combined*
Observations	32	32	32	96
Estimated parameters	21	21	21	21
Degrees of freedom	33	33	33	33
Test statistic	55.658	50.375	35.013	55.937
Chi-squared	0.008	0.027	0.373	0.008
SRMR	0.120	0.123	0.096	0.067

Note: Chi-squared and SRMR statistics evaluate the equality between variance and covariance matrices and overall significance.

Source: compiled by the author using Rstudio.

Table 11 shows that in 2015, the latent Corruption variable determined the latent Innovation variable to be 0.832. This latent Corruption variable has positive coefficients for all years and even in the analysis of combined years. This means that the impact of corruption on the variance of innovation is positive, demonstrating GTW effects.

Table 11. Estimators for the variances of the latent variables

	2015			*2017*			*2019*			*Combined*		
	Estimator	*z-value*	*P(>|z|)*	*Estimator*	*z-value*	*P(>|z|)*	*Estimator*	*z-value*	*P(>|z|)*	*Estimator*	*z-value*	*P(>|z|)*
StateGov	0.255	3.266	0.001	0.359	3.530	0.000	0.191	2.260	0.024	0.169	5.176	0.000
MunGov	0.177	2.774	0.006	0.231	3.100	0.002	0.510	3.624	0.000	0.153	4.910	0.000
FedGov	0.350	3.545	0.000	0.183	2.770	0.006	0.333	3.188	0.001	0.514	6.621	0.000
Entrepreneurs	0.122	2.171	0.030	0.144	2.384	0.017	0.241	2.675	0.007	0.089	3.387	0.001
NSI	0.399	3.667	0.000	0.449	3.215	0.001	0.336	3.160	0.002	0.402	5.538	0.000
SPatents	-0.026	-0.332	0.740	0.017	0.115	0.908	0.312	3.043	0.002	0.147	2.358	0.018
SModelsUt	0.370	3.580	0.000	0.618	3.740	0.000	0.154	1.794	0.073	0.375	5.324	0.000
IEDtotal	0.747	4.007	0.000	0.910	3.987	0.000	0.552	3.680	0.000	0.735	6.647	0.000
gGDP	0.880	3.999	0.000	0.813	3.977	0.000	0.974	3.997	0.000	0.826	6.879	0.000
Corruption	0.832	3.013	0.003	0.865	2.672	0.008	0.863	3.101	0.002	0.967	5.750	0.000
Innovation	1.000	2.575	0.010	1.000	2.313	0.021	1.000	2.716	0.007	1.000	4.297	0.000

Source: compiled by the author using Rstudio.

Table 12. Regression analysis of the structural equations model

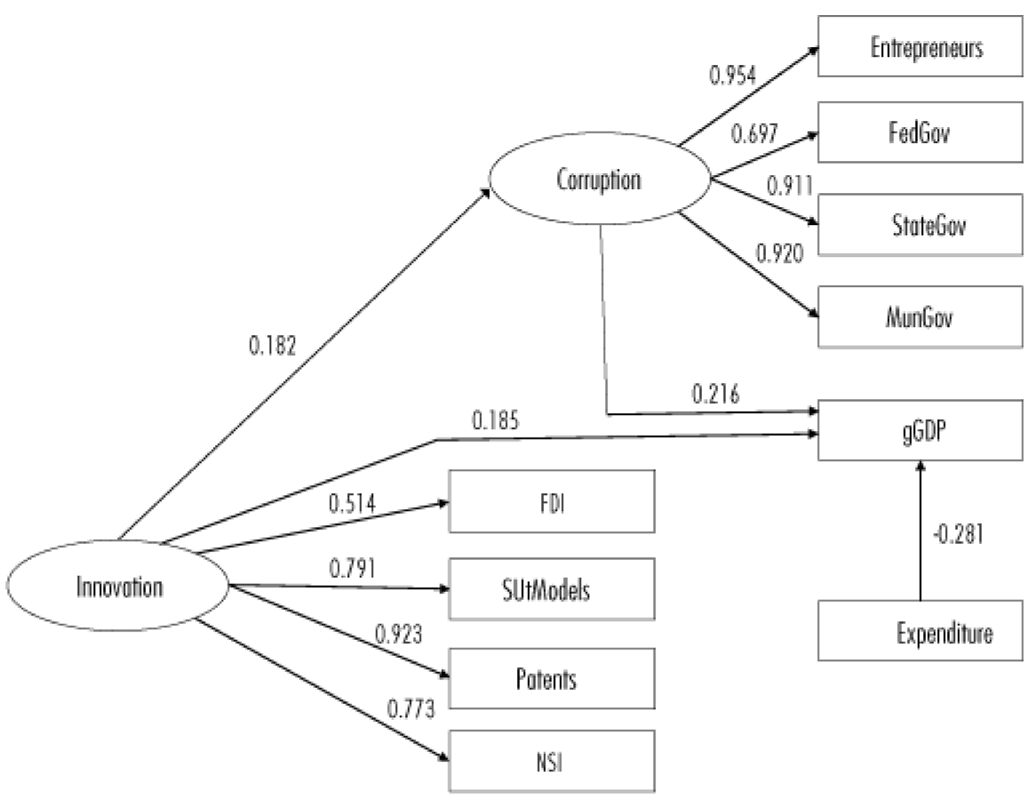
	Dependent variable: growth of GDP											
	2019			*2017*			*2015*			*Combined*		
Variables	*Estimator*	*Z-Value*	*P(>|z|)*	*Estimator*	*Z-Value*	*P(>|z|)*	*Estimator*	*Z-Value*	*P(>|z|)*	*Estimator*	*Z-Value*	*P(>|z|)*
Innovation	0.043	0.215	0.830	0.314	1.73	0.084	0.306	1.65	0.099	0.185	1.835	0.066
Corruption	0.075	0.377	0.706	0.131	0.729	0.466	-0.189	-0.998	0.318	0.216	2.211	0.027
Total expenditure	-0.128	-0.736	0.462	-0.203	-1.269	0.205	-0.195	-1.179	0.238	-0.281	-3.016	0.003

Source: compiled by the author using Rstudio.

It is observed that the corruption variable has a negative value for 2015 but is positive for 2019, 2017, and the combined years. This, on the one hand, reflects the inconsistency of the impact of corruption on economic growth and, on the other hand, when the data is analyzed as a whole for three years, the GTW hypothesis is reinforced since the perception of corruption shows positive and significant effects on economic growth.

Figure 6 shows that the perception of corruption in entrepreneurs has a greater influence on the latent corruption variable than the perception of government authorities. At the municipal level, corruption contributes significantly to this latent variable (after excluding entrepreneurs). The explanatory weight of the number of applications for patents and utility models stands out for the latent Innovation variable.

Figure 6. Causalities and coefficients of the structural equation model using combined data



Note: Latent variables are enclosed in circles, and observable variables are in rectangles.

Source: compiled by the author using Rstudio.

Concerning the effects of innovation on growth, positive impacts are observed in the analyzed years, indicating a consistent direction to this effect. Regarding expenditure, it also shows consistency in signs and significance, especially in the combined data for the three years.

5. CONCLUSIONS

A positive effect of corruption on innovative activity and economic growth is found. The PCA shows heterogeneity among regions because although Mexico City, Jalisco, and Morelos have low levels of corruption perception and Nuevo Leon has a high level, both groups of states have the highest levels of innovation. This indicates that the GTW and STW hypotheses may only hold true for some states.

The SEM can corroborate that corruption positively affects the latent variable of innovation and economic growth, which points to the GTW hypothesis. This could be for various reasons, such as avoiding bureaucratic barriers when obtaining patents and permits, the need for specialized resources or permits that sometimes can only be obtained through corruption, the discouraging of innovation through competitive bribes, and the search for protection or certainty by corrupting local authorities, which provides confidence for long-term innovative projects, among other factors.

Structural equation modeling provides evidence in favor of the GTW hypothesis regarding innovation and economic growth. This has implications for public policy since, in order to foster innovation, vices such as illegal payments and bribes, which generate financial losses and distort markets, eroding the trust and reputation of the parties involved, need to be addressed. Corruption has legal costs and negative social effects, such as inequality and institutional weakness, and diverts resources from legitimate projects. This fight would lead to lower transaction costs and possibly higher levels of innovation without necessarily engaging in corruption, which could become an alternative science and technology policy from a more ethical viewpoint to boost this area, highlighting the importance of finding a balance between the need to reduce transaction costs to foster innovation and the pressing need to address corruption effectively to ensure an ethical and equitable business environment.

Reflection is needed on why some people sacrifice public morality for personal gain, even in pursuing innovation and competitiveness. In addition, consideration should be given to the long-term consequences of corruption, which go beyond economic costs and include the erosion of trust in institutions and inequality. Corruption is not just a price to pay for public morale; it is a significant cost that society bears when it fails to uphold its fundamental ethical values.

Future research needs to analyze in detail the mechanisms that allow corruption to positively impact innovation, as this study only provides an overview at the level of federal states. However, the scarcity of business-level surveys and the lack of studies in Mexico represent significant challenges to building a solid state-of-the-art around these hypotheses.

ANNEX

Table A1. Variables and sources of information

Variable	*Description*	*Source*	*Measure*
State	Federal State		
Police	Perception of corruption "Widespread" in Police	ENCIG-INEGI	Percentage
Political parties	Perception of corruption "Widespread" in Political Parties	ENCIG-INEGI	Percentage
State governments	Perception of corruption "Widespread" in State Governments	ENCIG-INEGI	Percentage
Federal Government	Perception of corruption "Widespread" in the Federal Government	ENCIG-INEGI	Percentage
Deputies and Senators	Perception of corruption "Widespread" in Deputies and Senators	ENCIG-INEGI	Percentage
Public Prosecutor's Office	Perception of corruption in Public Prosecutor's Office	ENCIG-INEGI	Percentage
Municipal governments	Perception of corruption "Widespread" in Municipal governments	ENCIG-INEGI	Percentage
Entrepreneurs	Perception of corruption "Widespread" in Entrepreneurs	ENCIG-INEGI	Percentage
Media	Perception of corruption "Widespread" in the Media	ENCIG-INEGI	Percentage
Electoral institutions	Perception of corruption "Widespread" in Electoral Institutions	ENCIG-INEGI	Percentage
Judges and Magistrates	Perception of corruption "Widespread" in Judges and Magistrates	ENCIG-INEGI	Percentage
Unions	Widespread" perception of corruption in Unions	ENCIG-INEGI	Percentage
Public hospitals	Perception of corruption "Widespread" in Public Hospitals	ENCIG-INEGI	Percentage
Public universities	Widespread" perception of corruption in Public Universities	ENCIG-INEGI	Percentage
Public schools	Perception of corruption "Widespread" in Public Schools	ENCIG-INEGI	Percentage
Religious institutions	Perception of corruption "Widespread" in Religious Institutions	ENCIG-INEGI	Percentage
Human Rights Commissions	Perception of "Widespread" corruption in Human Rights Commissions	ENCIG-INEGI	Percentage
Army and Navy	Perception of corruption "Widespread" in the Army and Navy	ENCIG-INEGI	Percentage
Co-workers	Perception of corruption "Widespread" in coworkers	ENCIG-INEGI	Percentage
Neighbors	Perception of corruption "Widespread" in Neighbors	ENCIG-INEGI	Percentage
Relatives	Perception of corruption "Widespread" in Family members	ENCIG-INEGI	Percentage
Total Expenditure	Total expenditure by states	Public Accounts and State Official Journals	Expenditure per 100 thousand inhabitants
CTI	State Science and Technology expenditure	Public Accounts and State Official Journals	Expenditure per 100 thousand inhabitants
FDI	Foreign Direct Investment	Ministry of Economy	FDI per 100 thousand inhabitants
GDP	Annual Growth in Gross Domestic Product	INEGI	Percentage
Population	Total population at mid-year	CONAPO	Level
Spatents	Patent applications	IMPI	Record per million inhabitants
Opatents	Patents granted	IMPI	Registration per million inhabitants
Sdesigns	Industrial design applications	IMPI	Registration per million inhabitants
Odesigns	Industrial designs granted	IMPI	Registration per million inhabitants
Smodelout	Utility model applications	IMPI	Registry per million inhabitants
Omodelout	Utility models granted	IMPI	Registration per million inhabitants
SEP	SEP expenditure by federal state	Federal public account	Expenditure per 100 thousand inhabitants

Source: compiled by the author.

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