Public investment spending and state economic growth in Mexico: Implications for a post-COVID-19 economic recovery

Gasto en inversión pública y crecimiento económico estatal en México: implicaciones para la recuperación económica post-COVID-19

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Abstract

In this paper we examine with a Keynesian approach the importance of public investment spending in promoting per capita GDP growth in Mexican states. The results of our estimations for the period 1989-2019 show the presence of a long-run relationship between public investment spending and GDP both per capita, which is reinforced by the result of the panel non-causality test employed that suggests that the direction of causality in the Granger sense between these variables goes from public investment spending per capita to GDP per capita, which ultimately can be interpreted as evidence that this type of public investment spending is a driver of growth by federative entity in Mexico. This result is relevant because it suggests the need not to postpone large public infrastructure projects undertaken by the federal government to promote economic growth mainly in the current recessionary conditions generated by the Covid-19 crisis in Mexico.

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Resumen

En este trabajo examinamos con un enfoque keynesiano la importancia del gasto de inversión pública para promover el crecimiento del PIB per cápita de las entidades federativas en México. Los resultados de nuestras estimaciones para el periodo 1989-2019 muestran la presencia de una relación de largo plazo entre el gasto de inversión pública y el PIB ambos per cápita, lo cual se refuerza por el resultado de la prueba de no causalidad en panel empleada que sugiere que la dirección de causalidad en el sentido de Granger entre estas variables va del gasto de inversión público per cápita al PIB per cápita, lo cual en última instancia puede ser interpretado como evidencia de que este tipo de gasto de inversión público es un motor del crecimiento por entidad federativa en México. Este resultado es relevante porque sugiere la necesidad de no postergar los grandes proyectos de infraestructura pública emprendidos por el gobierno.

Código JEL: C32, E62, C13, O23
Palabras clave: gasto de inversión; PIB per cápita; raíces unitarias en panel; cointegración en panel; estimadores para paneles cointegrados; México

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Introduction

The COVID-19 pandemic has caused severe damage, followed by various pathways to recovery worldwide. There have been successes and failures in the effort to contain the spread of the disease and mitigate its adverse effects on public health and the economy. Some economies have been able to quickly and successfully contain the spread of the virus, leading to a remarkable recovery, while others continue to struggle with rising infections. To restore steady growth, market forces are not sufficient to solve the multiple problems at hand. Governments must fill this gap and play a key role in recovery (Stiglitz, 2021).

There are still several challenges to be faced regarding the effective treatment of the disease, which generates uncertainty as little is known about the efficacy of the therapies used to combat this new disease. Although several vaccines are currently approved, their long-term efficacy remains to be determined, especially concerning the new highly transmissible variants recently identified in several countries (Stiglitz, 2021).

Depending on the type of health and economic policies deployed worldwide, there is still much uncertainty about the path to recovery. The possibility remains that COVID-19 could persist rather than abate as a temporary phenomenon. Although the rapid rollout of effective vaccines and the strong measures taken by some governments have given hope that the end of the disease is near, its continuing mutation and the large number of individuals who refuse to be vaccinated are continuing sources of concern (Stiglitz, 2021).

Several challenges remain in order to restore solid economic growth. According to Stiglitz (2021), economic policies should mitigate or minimize damage and lead economies to recover. In this

context, recovery will be easier if workers are not dismissed from companies, both in the short and long term, since in case of recovering success when economic activity resumes, entrepreneurs will not have lost their company-specific human capital. If small businesses are not supported, they will go bankrupt, and society will have the challenge of creating new businesses once the pandemic is over, which is more difficult than preserving existing ones.

Among the economic policy measures that have been discussed to address the recession triggered by the lockdown as a measure to deal with the spread of COVID-19 is the possibility of redirecting public resources to meet the needs represented by the health emergency. There is also the possibility of supporting companies with different programs to prevent bankruptcy and help workers who lose their jobs due to the massive closure of their sources of employment. On the health front, the need was raised for the government to allocate more resources for acquiring serological tests to identify and provide timely treatment to those infected. It was argued that this could be done by postponing some public investment projects, such as the construction of the new Santa Lucia airport and the Dos Bocas refinery in Tabasco. However, the federal government responded that it would not interrupt public investment in infrastructure so as not to halt the boost it represents for economic growth.

According to the Keynesian approach, government spending can be used as a powerful stimulus, especially in times of high unemployment. A large body of economic literature since the Great Recession has estimated fiscal multipliers by focusing on overall government spending and then disentangling some subcomponents, such as public investments, and in a few cases, public infrastructure investment. The effectiveness of fiscal stimulus packages occupies a prominent place in public debates surrounding the current COVID-19 crisis, as policymakers seek to understand whether boosting public or infrastructure investment helps increase economic growth and productivity and crowd out the private sector.

Other approaches analyze the link between government spending and economic growth. In Barro's (1990) endogenous growth model, government spending is a factor of production that affects output through two channels: i) the negative effect of taxation on the after-tax marginal product of capital and conversely, the positive effect of public services on this marginal product; and ii) at low levels of government spending, the positive effect of increased government spending on the marginal product of capital dominates so that growth increases. As government spending increases beyond this point, the adverse effect of distortionary taxes becomes more important, and growth peaks. For higher values of government spending, the effect of taxes dominates, and thus growth declines. On the first point, however, they recognize that there is an optimal tax rate that maximizes the growth rate.

This paper aims to provide evidence on the long-run relationship of public investment spending per capita to GDP per capita at the level of Mexican states. The issue is of interest not only because of the role that investment spending may play in economic growth but also because, as has been pointed out,

groups opposed to the ruling party have asked government authorities to postpone the main emblematic infrastructure projects of the current management and to allocate their resources to address other health needs related to the Covid-19 pandemic.

This article is divided as follows. The second section reviews the related empirical literature, while the third section explains the econometric tests employed and the data set of the study. The main empirical results of the study are presented and discussed in the fourth section, and finally, the conclusions are presented.

Review of the literature

Public investment has several characteristics that make it appealing for spending cuts and for boosting economic recovery (Tandberg & Allen, 2020). It is largely discretionary and uneven, with most spending concentrated over a few years, and contributes substantially to economic activity, especially in low-income countries (IMF, 2020c). Decisions to cut, extend, or terminate public investment projects may also be motivated by political economy considerations. As the impacts of such investment are long-term, projects do not necessarily benefit from delays, and cost overruns are not always visible. Consequently, countries facing financial stress often resort to cutting or postponing public investment. In contrast, increased public investment is common in fiscal stimulus programs. These have the advantage of boosting long-term economic growth and supporting demand and employment in the short and medium term (IMF, 2020c).

According to Tandberg and Allen (2020), managing these two seemingly opposing responses to public investment requires two careful considerations: i) cuts in public investment must be designed with extreme caution to avoid an excessively negative impact on the economy, employment, and future costs. In some countries there may be legal and contractual impediments to reallocating funds from capital spending to current spending and to canceling or postponing projects; ii) for public investment resources to act as a fiscal stimulus, they must ensure that projects are well planned, selected, and executed to produce the expected benefits.

Evidence of the magnitude of fiscal multipliers

Fiscal multipliers are generally derived from the calibration of Neo Keynesian Dynamic Stochastic General Equilibrium (DSGE) models, structural macro-econometric models, and the so-called narrative methods, (Vagliasindi & Gorgulu, 2021). Starting from the work of Fatás and Mihov (2001) and the

seminal contribution of Blanchard and Perotti (2002), they are estimated from Vector autoregressions (VARs) and recently through some sophisticated identification methods to capture the possible endogeneity of fiscal shocks. Kraay (2012) highlights that different types of government spending may have different short-run effects on output; however, the identification of disaggregated multipliers is limited by imperfect data on the composition of spending. According to Vagliasindi and Gorgulu (2021), once subcomponents of government spending are taken into account, it is necessary to consider different types of instruments for different types of spending, which makes the problem extremely difficult.

Ramey (2019) shows that different definitions of the multiplier can lead to different estimates. To that end, the author estimates the effects of fiscal spending shocks using three different methods. The results show that the most plausible lower bound estimates of fiscal multipliers come from narrative and time-series-based methods, while the upper bounds result from more sophisticated calibrated models. However, calibration sometimes relies on strong assumptions in theoretical models or econometric analyses to identify the effect of fiscal policy.

The way the "multiplier" is defined in studies to capture the impact of fiscal stimulus packages is simply the relation between the expected change in output (GDP) and the proposed government spending (Vagliasindi & Gorgulu, 2021).

The meta-regression analysis of Gechert and Rannenberg (2018) sheds additional light on how the range of multipliers varies depending on the tax instrument used. Two facts stand out from their study. First, the averages of the multipliers corresponding to investment and government spending boosts are about twice as large as those for tax cuts and transfers. Among the government spending categories, the multipliers related to public investment show the highest value. Second, the minimum value of all financial instruments is negative, which means that the estimation range does not exclude that a fiscal stimulus would have an undesirable adverse impact on output.

The level of disaggregation of the data and its definition, the type of model used, the period, as well as the methodology employed may affect the estimates of fiscal multipliers (Capek & Crespo Cuaresma, 2020). Table 1 summarizes estimates of public spending and investment multipliers and methodologies for several countries, including the identification strategy to isolate structural shocks. The estimates are based on averages for a country or region over a given time, making comparisons difficult even among studies that calculate the multiplier for the same country.

Table 1
Public investment and spending multipliers reported by various studies

Country or region	Income Group	Author(s)	Period	Methodology	Multiplier Range	Type of spending
Peru	Upper middle income	Central Reserve Bank of Peru (2012)	1992-2012	VAR (output-expenditure elasticities for filtering automatic stabilizers)	0.24; 0.92 (short-term) 0.49; 1.42 (medium-term)	Current and capital spending
Peru	Upper middle income	Rossini et al. (2012)	2005-2011	SVAR	0.78; 1.36 (short-term) 0.52; 2.63 (medium-term)	Current and capital spending
Australia	High income	Hunt et al. (2009)		DSGE model (simulates impacts on the product)	1.22	Public investment
					1.12	Government consumption
Czech Republic	High income	Ambrisko et al. (2015)	1996-2011	DSGE model (simulates impacts on the product)	0.5 in the first year	Government investment
					0.6 in the second year	Government consumption
Germany	High income	Veld (2016)		Simulations of the European Commission's macro Quest model (simulations in different scenarios)	0.6	Public investment
Italy	High income	Acconcia et al. (2014)	1990-1999	OLS with VI to control endogeneity	1.5	Government spending
Japan	High income	Bruckner and Tuladhar (2014)	1990-2010	Prefecture-level VAR panel	0.26	Government spending
Japan	High income	Kanazawa (2018)	1980-2014	Local projections with the Instrumental Variables method (using the shock measure of excess returns as an instrumental variable)	1.64 (after one year)	Public Investment
Japan	High income	Kuttner and Posen (2002)	1990-1999	VAR (expenditure elasticities - product to filter out automatic stabilizers)	2 (cumulative multiplier for four years)	Government spending

Japan	High income	Miyamoto et al. (2017)	1980-1995 1996-2014	Local projection method (estimates the impulse-response functions of the disturbances, as well as the lags of the variables that usually enter into a vector autoregression)	0.6 1.5	Government spending
Republic of Korea	High income	Eskesen and Lueth (2009)		DGSE (simulates impacts on the product)	0.8	Government investment and consumption
The Netherlands	High income	Veld (2016)		Simulations of the European Commission's macro Quest model	0.5	Public investment
Gulf Cooperation Council	High income	Espinoza and Senhadji (2011)	1975-2009	VAR linking GDP, government spending, and non-oil GDP, all variables in real terms The VAR is estimated in growth rates	0.3 - 0.7 0.6 – 1.1	Current Spending Capital Spending
Spain	High income	Pereira and de Frutos (1999)	1970-1989	VAR without restrictions	0.65 after two years	Public capital accumulation
United States	High income	Coenen et al. (2012)		DGSE (simulates impacts on the product)	1	Government spending
United States	High income	Erickson et al. (2015)	2001-2012	OLS with VI to control endogeneity	1.5	Federal Government Spending
United States	High income	Ramey and Zubairy (2018)	1989-2015	Local projections (Based on sequential regressions of endogenous variables that change several steps ahead)	0.66 (after two years) 0.74 (after four years)	Government spending
102 Developing countries		Kray (2014)	1970-2010	Instrumental variables to control endogeneity (lags of eventual commitments and disbursements by	0.4	Spending

				official creditors to developing country governments)		
11 European countries	High income	Deleidi et al. (2020)	1970-2016	Local projections on a panel dataset considering different model specifications	0.96	Public investment
17 OECD economies	High Income	Abiad et al. (2015)	1985-2013	Local projections method (estimates impulse-response functions through the projection of the variable of interest on the disturbances, as well as the lags of variables that usually enter the VAR)	1.4 (Medium-term)	Public Investment

Source: Vagliasindi and Gorgulu (2021)

Other institutional factors affecting the fiscal multiplier

There is great interest in understanding the effect of the absence of efficiency on the size of the public investment multiplier due to cost overruns, implementation delays (leading to higher project costs or "wastage"), poor project selection or allocation across sectors, or simply due to corruption. Gurara et al. (2020) analyze the association between inflationary costs and public investment in a large sample of road construction projects in developing countries. They show a non-linear U-shaped relation between public investment and project costs.

Another strand of the literature identifies limited absorptive capacity among the reasons that may explain the weak association between accelerating public investment and output growth (Horvat, 1958; & Rosenstein-Rodan, 1961). One way to conceive absorptive capacity is in terms of diminishing marginal returns on public investment (Vagliasindi & Gorgulu, 2021).

Another important aspect for infrastructure spending to be considered an effective stimulus is deploying the funds and creating jobs when the economy is struggling. Mallet (2020) reviews the 2009 stimulus in the United States and notes that infrastructure projects move at a much slower pace than other types of stimulus, resulting in a delayed economic impact. This approach to the literature emphasizes implementing projects ready to be carried out to ensure fiscal stimulus.

On the other hand, temporary stimulus programs appear to be more successful in shifting resources within industries than in expanding the industry itself. There is also a risk that the firms

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accessing stimulus funds may not be the ones that suffer the most from the recession (Jones & Rothschild, 2020).

Additionally, increasing maintenance spending may be a promising option for stimulus spending, as it can create jobs (with corresponding effects on income) and maintain the capital stock. There is likely to be considerable room for this in many low-income countries, as maintenance spending tends to be under-budgeted (Jones & Rothschild, 2020). Maintenance spending is also one of the few areas of government consumption spending where increases can easily be temporary without risking increasing the long-term level of government spending (Schwartz et al., 2007).

Sectoral infrastructure multipliers

The literature on fiscal multipliers has focused mainly on the overall effects of investment and government spending on growth. At the same time, the composition of infrastructure investment and spending also determines the magnitude of the impact. However, the literature estimating the effects of investments in different types of infrastructure is in its infancy and limited (Vagliasindi & Gorgulu, 2021). Even concepts such as "multiplier" have a different connotation than when analyzing the impact of aggregate government spending.

Estimates of infrastructure multipliers have been made at the sectoral level but mostly for developed countries. The results suggest an inverse relationship between the level of wages and employment multipliers (International Energy Agency, 2020a).

Chi and Baek (2016) analyze the relation between transportation infrastructure and GDP for the period 1960-2012. They find that the expansion of transport infrastructure improves aggregate economic output and increases public investment in transport infrastructure; however, the impact of infrastructure in this sector is smaller than that of public investment in non-transport infrastructure. In this same category, Pereira (2000) shows that the long-run multiplier of US highway spending was 1.97 from 1956 to 1997, which is below the estimate for total public investment of 4.5. Similarly, Leduc and Wilson (2012) estimate the short- and medium-term multipliers to be 2.7 and 6.2, respectively, while Perotti (2004) estimates them to be around 1.47 in the short run and 0.37 in the long run for the period 1960-2001.

Regarding studies conducted for the energy sector, Blyth et al. (2014) conduct a review of works addressing the employment effects of certain policies and note that renewables have a higher job multiplier in the short term, while requiring less labor to operate and maintain in the long term. Comings et al. (2014) estimate the number of jobs that each megawatt of added renewable energy would generate as well as that of wind projects.

Several studies identified broadband infrastructure as an important area of public investment during an economic downturn. According to Qiang (2010), investment in broadband and next-generation networks as a countercyclical tool creates jobs and lays the foundation for economic recovery and long-term sustainable growth. Information technology (IT) infrastructure projects create more jobs than traditional infrastructure investments—partly due to the network multiplier—and also create better jobs in terms of higher skills and wages. Crandall et al. (2003) calculate the employment impact of an investment in broadband rollout and find that numerous jobs are created yearly for ten years.

According to Bivens (2003), communication jobs in the US economy have an employment multiplier of 2.52. Crandall et al. (2007) find that for every percentage point increase in broadband penetration, employment increases from 0.2 to 0.3 percent, or about 293,000 jobs for an economy that is not at full employment.

Strand and Toman (2010) analyze the short- and long-term effects of green stimulus measures. They find that most green stimulus programs with large short-term effects on employment and the environment are likely to have less significant positive effects on long-term growth and vice versa.

Similarly, capital-intensive investments such as digitization and 5G are more likely to show long-term economic benefits and are therefore much less likely to create strong short-term stimulus effects (Strand & Toman, 2010; & Hepburn et al., 2020).

Green building projects can also generate higher multipliers (Jacobs, 2012). In the European Union, every dollar of green investment boosted GDP by up to $1.50 across the region (Cambridge Econometrics, 2011). Additionally, there is evidence that boosting green technologies has effectively created jobs (IEA, 2020a; & Popp et al., 2020).

As can be seen, the estimates of fiscal multipliers are very sensitive to different modeling choices and methodologies, as well as to more innocuous ones, such as the period considered in the analysis.

Whereas public investments are characterized by having the highest multiplier, during recessions or times of unemployment, transfers may represent a more potent source of fiscal stimulus (Vagliasindi & Gorgulu, 2021). Nevertheless, not all crises are equal, and in some of the deepest crises, such as the Great Depression, spending and investment multipliers are still greater than one. The evidence on other macroeconomic "states" is not strong, with the most notable exception being a coordinated fiscal and monetary policy, especially under near-zero interest rates. Other institutional factors play a crucial role in determining the size of the public investment multiplier, particularly the country's absorptive capacity and the selection of high-quality projects ready for implementation.

In developing countries and emerging economies, however, estimates of the magnitude of public investment multipliers are scarce, mainly due to data limitations and reliability. In addition, knowledge about the specific impact of infrastructure investments is limited.

Green infrastructure investment appears to have higher multipliers and may have the potential to create jobs in the short term due to being labor intensive in the initial phase and may have higher long-term energy and climate security returns.

Impact assessment of COVID-19 and recent infrastructure programs

According to Vagliasindi and Gorgulu (2021), there are some reasons to expect that infrastructure spending may have lower multipliers in the recession caused by COVID-19. First, if uncertainty in the current crisis is deeper than in previous crises, individuals and firms may adopt a more cautious behavior in their spending. Second, if fear of COVID-19 causes people to avoid traveling and social activities, efforts to stimulate economic activity will be less effective. Third, it may be difficult to target government injections where there is a high marginal propensity to spend. Fourth, the impact on expectations may be more conditioned by emerging health risks than by financial responses (Stiglitz, 2020). In addition, employment impacts are very different across sectors.

The literature review by Vagliasindi and Gorgulu (2021) suggests that providing transfers may be more effective than committing new investments during a recession as severe as the one caused by COVID-19. The coexistence of extremely low-interest rates provides the monetary policy environment in which investment and spending are known to provide the largest multipliers. However, there is still no relevant empirical literature on these issues.

The particular characteristics of this COVID-19 crisis have implications for the prioritization of different types of infrastructure spending as part of any fiscal stimulus. It has also highlighted the lack of sanitation and public health infrastructure in various countries, especially in low-income ones (IEA, 2019a). Moreover, more than 860 million people worldwide lack access to electricity, which severely limits their ability to store medicines and food, access digital information, or maintain access to distance education (IEA, 2019b).

Digital technologies provide the main channel for governments, individuals, and businesses to cope with social distancing, ensuring business continuity while avoiding potential disruption. Even countries with adequate broadband connectivity are experiencing increased data and voice traffic congestion, compromising service quality. The shift toward remote working and distance learning only increases the urgency of achieving universal access to broadband connectivity (Vagliasindi & Gorgulu, 2021).

The COVID-19 outbreak has triggered supply chain disruptions and constraints resulting in delays and cancellations of infrastructure projects in several countries. In addition, macroeconomic uncertainties and negative economic outlooks have decreased the availability of private financing for infrastructure projects. Compared to the first half of 2019, investments involving private initiatives decreased by 56% in the first half of 2020, with East Asia and the Pacific being the most affected region, with a 79% decrease due to the redirection of funds to healthcare and social protection sectors (World Bank, 2020). Private investment commitments are mainly directed to a limited number of countries, which also points to the importance of public sector financing when private investment is discouraged.

In many countries, attention has begun to focus on long-term recovery plans. In the United States, a $1 trillion infrastructure plan was announced as part of the new stimulus package. The infrastructure plan would help boost the economy, focusing on roads, bridges, tunnels, 5G wireless infrastructure, and rural broadband. The UK has also announced a national infrastructure plan that involves heavy capital spending. The Malaysian government allocated a notable amount of resources to infrastructure projects such as road, bridge, and street lighting maintenance at federal, state, and local levels to protect small contractors and boost local economic activities (Vagliasindi & Gorgulu, 2021).

The measures adopted at the beginning of the COVID-19 crisis by various countries were very similar to those employed during the 2008-09 financial crisis and focused on immediate responses such as direct payments (stimulus checks). Nevertheless, historical experience reveals that, in the absence of other interventions, public investment also declines when there is a decline in economic growth (Abadie (2020).

Based on lessons from past crises, a promising fiscal stimulus is one that can bring immediate and lasting benefits, protect infrastructure investment and the existing infrastructure workforce, accelerate the adoption of clean energy, expand broadband networks, and develop digital skills. An alternative to regain the growth path for both developed and developing countries includes investment in green infrastructure, which requires high spending on short-term labor-intensive investments with high multipliers and various benefits. For these reasons, some authors propose that recovery packages consider and promote cleaner and environmentally friendly alternatives instead of focusing on traditional and polluting energy production (Mundaca & Damen, 2015; Jaeger, 2020; Kaufman, 2020; & Volz, 2020).

Econometric methodology and data

Panel unit root tests

To determine the order of integration of the GDP per capita and investment spending per capita series in real terms for the 31 states analyzed, panel unit root tests were used, following the methods of Levin, Lin, and Chu (2002), IPS (2003), Breitung (2000), Maddala and Wu (1999) (Fisher-type ADF), Choi (2001) (Fisher-type PP), and Hadri (2000). The advantage of the methods used by Maddala and Wu (1999) and IPS (2003) is that they relax the homogeneity assumption. Choi (2001) uses common factors to model cross-sectional dependence, considering a homogeneous AR (1) model.

Panel unit root tests are theoretically based on a time-series approach. Both theory and the literature suggest that unit root tests of panel data have advantages over time series data, mainly because panel data combine cross-sectional data units and time series, which provides a larger number of degrees of freedom and improves statistical efficiency. In addition, this approach mitigates the bias caused by unobserved heterogeneity in the estimated regression.

Panel cointegration test with structural breaks by Westerlund and Edgerton (2008)

The panel cointegration test with structural breaks developed by Westerlund and Edgerton (2008) was used to test for cointegration in the given panel.

Westerlund and Edgerton (2008) propose two versions of the test, derived from the unit root LM test, for the null hypothesis of no cointegration. Both versions allow for heteroscedasticity and autocorrelated errors, individual- or unit-specific intercepts and trends, cross-sectional dependence, and unknown structural breaks in both the intercept and slope of the cointegrating regression, which can be located at different dates for different units (Lee 2013). They consider the following equation:

$$y_{i,t} = \alpha_i + \eta_i t + \delta_i D_{it} + X'_{it}\beta_i + (D_{it}X_{it})'\gamma_i + z_{it},$$

(1)

Where $x_{it} = x_{it}-1 + w_{it}$ is a vector of dimension k containing the regressors and follows a pure random walk process, and D_{it} is a scalar for the break dummy variable such that $D_{it} = 1$ if $t > T_i$ and zero otherwise, where z_{it} is a perturbation.

For a given N, to the extent that $T \to \infty$ then $N/T \to 0$, the normalized asymptotic value of the test statistic is defined as follows:

$$z_j(N) = \sqrt{N}\left[\overline{LM}_j(N) - E(B_j)\right] \rightarrow N\left[0, var(B_j)\right], \ \ j = \varphi, \tau.$$

(2)

Here, $\overline{LM}_j(N)$ is the average of $\overline{LM}_j(i)$, and B_j is the integration of a standard Brownian process.

Pedroni's PDOLS estimator

Pedroni's (1999, 2004) estimator is based on the following model:

$$yi, t = \alpha i + \beta i x i, t + \mu i, t$$

(3)

The PDOLS estimator is an extension of the individual dynamic ordinary least squares (DOLS) time series estimator, which, although efficient, is an individual estimator of the cointegrating equation that can be applied to non-stationary data (Neal, 2014). Pedroni (1999, 2004) extends this to time series panel data by performing a DOLS regression on each individual in the previous panel as follows:

$$y_{i,t} = \alpha_i + \beta_i x_{i,t} + \sum_{j=-P}^{P} \gamma_{i,j}\, \Delta x_{i,t-j} + \mu_{it}^*$$

(4)

Where $i=1,2,...,N$ is the number of units in the panel, $t=1,2,...,T$ is the number of periods, $p=1,2,...,P$ is the number of lags and leads in the DOLS regression, β_i is the slope coefficient, and $x_{i,t}$ is the explanatory variable. The coefficients β and their associated t-statistics are averaged over the whole panel through the group mean method of Pedroni (Neal, 2014).

$$\hat{\beta}_{GM}^* = \left[\frac{1}{n}\sum_{i=1}^{n}\left(\sum_{t=1}^{T} z_{i.t}z_{i,t}'\right)^{-1}\left\{\sum_{t=1}^{T} z_{i.t}\left(y_{i,t} - \bar{y}_i\right)\right\}\right]$$

(5)

$$t_{\hat{\beta}_i^*} = \left(\hat{\beta}_i^* - \beta_0\right)\left\{\hat{\sigma}_i^{-2}\sum_{t=1}^{T}\left(x_{i,t} - \bar{x}_i\right)^2\right\}^{\frac{1}{2}}$$

(6)

$$t_{\hat{\beta}_{GM}^*} = \frac{1}{\sqrt{N}}\sum_{i=1}^{N} t_{\hat{\beta}_i^*}$$

(7)

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Where $z_{i,t}$ is the $2(p + 1) \times 1$ vector of regressors, which includes the lags and leads of the differences in the explanatory variable, and σ^2_i is the long-run variance of the residuals μ^*_{it}. In contrast, Kao and Chiang (1997) and Mark and Sul (2003) compute panel statistics through the within dimension, with the statistic t designed to test H_0: $\beta_i = \beta_0$ against H_A: $\beta_i = \beta_A \neq \beta_0$. Pedroni's PDOLS estimator is averaged across the between dimension, i.e., the group mean. Accordingly, the test of the panel statistic is H_0: $\beta_i = \beta_0$, against H_A: $\beta_i \neq \beta_0$. In the alternative hypothesis, the regressors are not restricted to be a constant β_A. Pedroni (2001) states that this is an important advantage of time series panel estimators that rely on the between dimension, particularly when heterogeneity in slopes is expected.

The non-causality test in heterogeneous panel models by Dumitrescu and Hurlin (2012)

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$$y_{it} = \alpha_i + \sum_{k=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t}$$

(8)

With $K \in N^*$ and $\beta i = (\beta i\,(1)\,, \ldots\,, \beta i\,(K)\,)\,'$. For simplicity, the individual effects αi are assumed to be fixed over time. Similarly, the order of lags K is assumed to be identical for all units in the panel and is assumed to be balanced. Moreover, it allows the autoregressive parameters $\gamma i\,(k)$ and the coefficients of the regression slopes $\beta i\,(k)$ to differ across groups, but they are constant over time (Rodriguez, Mendoza, & Martinez, 2018). Thus the model posed in (8) is a panel model with individual fixed effects. The assumptions made for (8) are the following: (i) For each cross-sectional unit, the individual residuals it, ε are normally and independently distributed with $E(\varepsilon it) = 0$ and the finite heterogeneous variances $E(\varepsilon it\,2) = \sigma\varepsilon i\,2$; (ii) The residuals across individuals $\varepsilon i = (\varepsilon i,1, \ldots, \varepsilon i,T)$ are independently distributed between groups, i.e., $E(\varepsilon i,t\varepsilon j,s) = 0, \forall i \neq j$ and $\forall(t, s)$; and (iii) Both individual variables $xi = (xi,1, \ldots, xi,T)\,'$ and $yi = (yi,1, \ldots, yi,T)\,'$, are of stationary covariance with $E(yi,t\,2)$

$< \infty$ and $E(xi,t\ 2\ ) < \infty$. Dumitrescu and Hurlin (2012) propose testing the hypothesis of non-causality between x and y:

$$H0: \beta i\ =\ 0\ \forall\ i\ =\ 1, \dots, N$$

(9)

Where $\beta_i = \left(\beta_i^{(1)}, ..., \beta_i^{(p)} \right)'$. Under the alternative hypothesis, there is causality from x to y in

at least one unit:

$$H1: \beta i\ =\ 0\ \forall\ i\ =\ 1, \dots, N1\ \beta i\ \neq\ 0\ \forall\ i\ =\ N1\ +\ 1, N1\ +\ 2, ..$$

(10)

Where N_1 is unknown and $N_1 < N$.

Their test for non-causality in the Granger sense is similar to the unit root test of Im *et al.* (2003). The Wald statistics for the test of non-causality in the Granger sense are calculated for each unit. The panel statistic is obtained as the average of the cross-sections of the individual Wald statistics (Herrerias *et al.*, 2013). Dumitrescu and Hurlin (2012) show that this statistic converges to a normal distribution under the hypothesis of non-causality when T tends to infinity first and then when N grows indefinitely. It is also possible to construct a standardized statistic, $Z_{N,T}^{HNC}$.

The unrestricted coefficients of the VAR model posed in (8) are heterogeneous under both the null and the alternative hypothesis. Therefore, if the null hypothesis of no causality is rejected, then the causality relations may be heterogeneous across regions (Herrerias *et al.*, 2013). Dumitrescu and Hurlin (2012) examine the small-sample properties of the statistic and find that the power of the test exceeds that of the Granger causality test in time series for small values of T, even in the presence of cross-sectional dependence.

Data

The data corresponding to government spending for the 31 states used in this paper come from INEGI's Economic Information Bank (BIE, Spanish: Banco de Información Económica), from which Mexico City is excluded because there is no historical information for that state. These data are presented in current pesos, so it was necessary to deflate them with the implicit price deflator of the aggregate GDP. On the other hand, GDP per capita data at 2013 prices come from the methodology proposed by Mendoza (2014), which employs structural-spatial interpolation methods with GDP series at 2003 prices, compatible with the structure of economic censuses, national accounts, the Quarterly Indicator of State Economic Activity (ITAEE, Spanish: Indicador Trimestral de la Actividad Económica Estatal) series, and population data

from INEGI censuses and estimates by CONAPO. It is necessary to specify that the population data estimated by Mendoza (2014) were used in the calculation of per capita public investment spending.

Results

Table 2 presents the results of applying various panel unit root tests to both public investment spending and the GDP of the states, both in per capita terms. Except for the Breitung (2000) test, all the unit root tests allow it to be inferred that GDP per capita has a unit root. Similarly, Hadri's (1999) stationarity test allows the null hypothesis of stationarity of GDP per capita in the period under study to be rejected.

In the case of per capita public investment spending, all tests except Fisher's Phillips-Perron test fail to reject the null hypothesis of the unit root. Likewise, the Hadri (1999) test rejects the stationarity hypothesis for this variable.

Table 2
Unit root tests

	GDP per capita		Public investment spending per capita	
	Statistic	P-value	Statistic	P-value
Levin, Lin, and Chu (t-statistic)	-0.9728	0.1653	1.6122	0.9465
Im, Pesaran, and Shin (W-statistic)	3.0638	0.9989	-0.9997	0.1587
ADF - Fisher ($\chi 2$)	-2.8403	0.9977	-0.3295	0.6291
PP - Fisher ($\chi 2$)	-1.7382	0.9589	7.9528	0.0000
Breitung (t-statistic)	-3.0746	0.0011	2.8744	0.9980
Hadri (Z-statistic)	18.4500	0.0000	5.4445	0.0000

Notes: All tests were performed with four lags. Fisher's ADF and PP tests were performed with intercept only.
Source: created by the authors

It can be concluded from these results that both variables have a unit root. Consequently, the next step is to find out if they are cointegrated, that is, if they have a long-run equilibrium relation.

The results of the panel cointegration tests with and without structural breaks of Westerlund and Edgerton (2008) applied to investment spending and GDP—both indicators in per capita terms—are shown in Table 3. As can be seen in this table, only the $Z\tau$ test (N) permits the rejection of the null hypothesis of no panel cointegration in the variables under consideration at the 10% significance level without considering any break (no shift), with level shift, and at 5% with regime shift. However, for the $Z\varphi$ test (N), it was not possible to reject the null hypothesis of no cointegration in any case. Concerning the break years, in both specifications with level shift and regime shift, most of the breaks occurred between 1994 and 2008, which correspond to the years in which two of the deepest shocks were recorded in the study period.

Table 3
Results of panel cointegration tests with and without structural breaks by Westerlund and Edgerton (2008)

Statistic	k=1		
	No shift	Level shift	Regime shift
$Z_\tau(N)$	-1.360 [0.087]	-1.470 [0.071]	-1.872 [0.031]
$Z_\Phi(N)$	-0.777 [0.219]	-0.696 [0.243]	-0.709 [0.239]
		Breaks	Breaks
Aguascalientes		2008	2008
Baja California		2008	2008
Baja California Sur		2014	2008
Campeche		2016	2016
Coahuila de Zaragoza		2008	2008
Colima		2008	2000
Chiapas		2003	2003
Chihuahua		2008	2008
Durango		1997	1997
Guanajuato		2008	2008
Guerrero		1994	1994
Hidalgo		1994	1994
Jalisco		1994	2008
State of Mexico		1994	1994
Michoacán de Ocampo		1996	1996
Morelos		1994	1994
Nayarit		2003	2003
Nuevo León		1994	1994
Oaxaca		1994	2016
Puebla		1994	1994
Querétaro		1994	1994
Quintana Roo		2008	2008
San Luis Potosí		1994	1994
Sinaloa		2008	2008
Sonora		2008	2008
Tabasco		2004	2016
Tamaulipas		2008	2008
Tlaxcala		2004	2004
Veracruz de Ignacio de la Llave		2003	1997
Yucatán		1994	1994
Zacatecas		2009	2009

Notes: k is the number of common factors incorporated in the test; the numbers in square brackets correspond to the p-values of each test
Source: created by the authors

Once the existence of a long-run relation between the variables in question was verified, Granger causality tests were carried out in heterogeneous panels that allowed the evaluation of the direction of causality in the estimated equation with the variables under study. The results are presented in Tables 4 and 5. Table 4 presents the results with different lags of the test that per capita GDP does not cause per

capita public investment spending in the Granger sense, while Table 5 presents the results of the test that per capita public investment spending does not cause per capita GDP.

As can be seen in Table 4, although the test was performed with different lags, in no case is it possible to reject the null hypothesis that GDP per capita does not cause public investment spending in the Granger sense. On the contrary, in Table 5, where the null hypothesis that investment spending does not cause GDP per capita in the Granger sense is tested, it is possible to reject this null hypothesis with 5 lags at 10% and with 6 lags at 5% in one of the statistics of this test. This reinforces the previous result regarding the estimators for cointegrated panel variables that required a large number of lags and leads to reach significance in the estimated relation between both variables and suggests that there are medium-term effects between both variables. Thus, evidence was found that public investment spending causes Granger effects on GDP per capita in the 31 Mexican states considered in the analysis, which favors the Keynesian hypothesis that it is spending, in this case, public investment spending, that affects GDP per capita, i.e., economic development.

Table 4
Results of Granger causality tests in heterogeneous panel data models applied to per capita investment spending and per capita GDP of Mexican states: 1989-2019
(H_0 : Granger homogeneous non-causality of $\left(y/pob\right)_t \rightarrow \left(gp/pob\right)_t$)

	Wald statistic	P-value	Wald statistic	P-value	Wald statistic	P-value
	1 Lag		2 lags		3 lags	
$W_{N,T}^{Hnc}$	1.1326		2.2020		3.0810	
$\bar{Z}_{N,T}^{Hnc}$	0.5222	[0.6016]	0.5623	[0.5739]	0.1840	[0.8540]
$\tilde{Z}_{N,T}^{Hnc}$	0.1804	[0.8568]	0.0470	[0.9625]	-0.4245	[0.6712]
	4 lags		5 lags		6 lags	
$W_{N,T}^{Hnc}$	4.3012		5.1454		5.7900	
$\bar{Z}_{N,T}^{Hnc}$	0.5930	[0.5532]	0.2559	[0.7980]	-0.3375	[0.7358]
$\tilde{Z}_{N,T}^{Hnc}$	-0.2910	[0.7711]	-0.7442	[0.4568]	-1.3354	[0.1818]

Source: created by the authors

Table 5
Results of Granger causality tests in heterogeneous panels applied to per capita investment spending and per capita GDP of Mexican states: 1989-2019

(H_0: Granger homogeneous non-causality of $\left(gp/pob \right)_t \rightarrow \left(y/pob \right)_t$)

	Wald statistic	P-value	Wald statistic	P-value	Wald statistic	P-value
	1 Lag		2 lags		3 lags	
$W_{N,T}^{Hnc}$	1.2754		2.2325		3.1259	
$\bar{Z}_{N,T}^{Hnc}$	1.0884	[0.2782]	0.6471	[0.5176]	0.2861	[0.7748]
$\tilde{Z}_{N,T}^{Hnc}$	0.6700	[0.5028]	0.1180	[0.9061]	-0.3433	[0.7314]
	4 lags		5 lags		6 lags	
$W_{N,T}^{Hnc}$	4.2167		5.9673		8.8038	
$\bar{Z}_{N,T}^{Hnc}$	0.4266	[0.6696]	1.7031	[0.0886]	4.5066	[0.0000]
$\tilde{Z}_{N,T}^{Hnc}$	-0.4147	[0.6784]	0.2363	[0.8132]	1.5190	[0.1288]

Notes: Numbers in brackets indicate p-values
Source: created by the authors

Finally, a reduced version of the Keynesian model was estimated in which GDP per capita as a proxy for economic growth is a function of investment spending per capita, both in real terms, as shown in Equation (11):

$$\left(\frac{y}{pob} \right)_t = \delta + \eta \left(\frac{gp}{pob} \right)_t$$

(11)

Table 6 presents the results of the cointegration slope estimations both individually and as a panel. The estimations were carried out with and without common time dummies.

Table 6
Individual and panel cointegration slope estimates between each entity's GDP per capita with respect to
Investment Spending per capita through the PDOLS estimator for $(y/pob)_t = \delta + \eta(gp/pob)_t$.

	Without common temporary dummies			With common temporary dummies		
	Coefficient		*t* statistic	Coefficient		*t* statistic
Aguascalientes	0.195	6.024	***	0.177	4.162	***
Baja California	0.281	4.388	***	0.164	9.229	***
Baja California Sur	0.069	4.321	***	0.004	1.138	
Campeche	0.461	10.300	***	0.478	1.273	
Coahuila de Zaragoza	0.104	7.429	***	0.059	5.470	***
Colima	0.177	10.340	***	0.087	2.971	***
Chiapas	-0.167	-5.836	***	0.233	7.273	***
Chihuahua	0.073	2.018	**	-0.025	-0.782	
Durango	0.104	4.720	***	0.043	8.409	**
Guanajuato	0.358	4.571	***	-0.011	-2.101	**
Guerrero	0.052	2.120	**	-0.012	-0.643	
Hidalgo	0.018	2.025	**	-0.012	-0.999	
Jalisco	-0.648	-6.738	***	0.067	7.619	***
State of Mexico	0.205	7.597	***	0.111	12.040	***
Michoacán de Ocampo	0.206	9.457	***	0.120	6.561	***
Morelos	0.228	16.420	***	-0.001	-0.020	
Nayarit	0.086	8.203	***	0.047	4.194	***
Nuevo León	0.045	1.804	*	0.041	2.075	**
Oaxaca	0.065	4.793	***	-0.069	-8.578	***
Puebla	0.308	6.676	***	0.160	1.334	
Querétaro	0.683	6.951	***	-0.159	-19.060	***
Quintana Roo	0.017	1.090		1.119	2.444	***
San Luis Potosí	0.464	9.539	***	0.176	1.755	*
Sinaloa	0.156	15.690	***	0.050	11.860	***
Sonora	-0.104	-2.293	**	0.010	0.475	
Tabasco	-0.089	-8.891	***	0.014	5.557	***
Tamaulipas	0.317	11.080	***	0.048	1.038	
Tlaxcala	-0.166	-25.430	***	-0.276	-12.370	***
Veracruz	0.093	0.518	***	0.067	38.040	***
Yucatán	-0.077	-3.448	***	-0.059	-10.770	***
Zacatecas	0.878	9.329	***	-0.233	-1.201	
Panel	0.142	20.610	***	0.078	14.080	***

Notes: *, **, *** indicate rejection of the null hypothesis $H_0: \beta_i = 0$, at the 10%, 5% and 1% significance
levels, respectively. Source: created by the authors

As can be seen in Table 6, under the specification that does not include common time dummies,
almost all of the estimated coefficients were statistically significant at the 5% level. Whereas under the
specification that incorporates common time dummies, about two thirds of the estimated coefficients for
the individual slopes were significant at the 5% significance level. Similarly, the heterogeneity of the
estimated coefficients, both in magnitude and sign, suggests that they may depend on different factors,
such as the degree of development or the strength of institutions of the states in question.

Regarding the panel estimations in both specifications, the coefficient was positive and statistically significant, suggesting that per capita investment spending positively impacts per capita GDP at the level of Mexican states. However, it is much larger in the case of the specification that does not include common time dummies. These results suggest that investment spending per capita, as an exogenous variable in the Keynesian model, positively impacts economic growth. It should be mentioned that, in order to obtain statistically significant coefficients with these estimators, it was necessary to incorporate 5 lags and 5 leads in the model, which suggests medium and long-term effects between these variables.

Conclusions

The Keynesian approach can be used to understand that public investment spending is a powerful instrument to stimulate demand and thus, economic growth, especially in times of high unemployment, which has been widely debated since the Great Recession. Since then, several empirical papers have estimated fiscal multipliers. Most of the empirical literature on the impact of fiscal stimulus is almost exclusively focused on developed countries and only deals with broad categories of spending (transfers, tax cuts, government spending). The lack of reliable data in developing countries makes it difficult to appreciate the extent to which existing results would carry over to these very different economic environments. At the same time, the lack of disaggregated fiscal data, even for developed countries, limits what the literature can cover on the relative effectiveness of different types of spending in order to provide guidance on setting priorities (Vagliasindi & Gorgulu, 2021).

Moreover, there is no single recipe for fiscal stimulus to boost recovery or to find the conditions under which the multiplier is most effective. The empirical evidence on the subject is inconclusive on the assertion that multipliers are higher during different states of the economy and particularly during a recession. Also, in crises, transfers are sometimes more effective than spending multipliers. However, not all crises are the same: a deeper crisis may produce higher multipliers. The strongest evidence is that multipliers can be higher when there is coordination between fiscal and monetary policies, especially under the lower bound of the interest rate.

Vagliasindi and Gorgulu (2021) explored some policy recommendations on the effectiveness of countercyclical fiscal policies against the current COVID-19 crisis. There are several reasons why COVID-19 spending could have smaller multipliers, including more precautionary behavior, hoarding of cash, or people's fear of participating in traveling or social activities. So, efforts to stimulate economic activity will be less effective. At the same time, a countervailing consideration is that many countries also

face the kind of flexible monetary policy conditions that help increase the effectiveness of the fiscal stimulus.

Following a Keynesian approach, this paper provides evidence on the significance of per capita public investment spending in influencing economic growth through different panel unit root tests, cointegration tests, and estimators for this type of variables with panel data at the level of Mexican states from 1989 to 2019.

In general terms, the results of the panel unit root tests used conclude that the variables under study have a unit root. Similarly, one of the panel cointegration tests with breaks allows an equilibrium relationship between both variables to be inferred. Additionally, the estimators for panel cointegrated variables make it possible to deduce that the coefficient that measures the impact of public investment spending in per capita terms on the per capita GDP of Mexico's states is positive and statistically significant. Furthermore, the results of the Granger non-causality test employed favor the Keynesian hypothesis that investment spending per capita determines the GDP per capita of Mexico's states and not the other way around when a relatively large number of lags are incorporated, as postulated by Wagner's Law.

These results suggest that annual investment spending by the governments of the states is an engine of economic growth and development. So, reducing it in order to attend to other economic needs in Mexico could have adverse results on the economic growth of the economic entities, and therefore, on the country. Although not immediately, this could have adverse results in the medium and long term—4 or 5 years—which could worsen and deepen the difficult economic recession that the country is going through due to the COVID-19 pandemic. On the contrary, the increase in public investment spending in this category may stimulate economic growth in the coming years.

Acknowledgments

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