# The impact of public investment on private investment in Mexican states

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## Abstract

The literature on economic growth has robustly demonstrated that gross fixed capital formation is a principal determinant of economic growth. What is more debatable, however, is the consensus regarding the interactions between public and private investment. The aim of this article is to contribute to this debate by focusing on the relationships between public and private investment in Mexico at the state level. In contrast to the conventional approaches which focus on investment “flows,” this article employs the variation in fixed capital stocks, adopting a panel econometric methodology. Findings indicate a positive relationship between both components –public and private– in terms of the variation of their stocks.

**Keywords:** public investment; private investment; panel data; substitution effect; complement effect; capital stocks.

## 1. INTRODUCTION

If the study of economic growth has yielded any conclusion that is both theoretically and empirically robust, it is that fixed capital investment is a significant determinant of the expansion rate of productive activity, i.e., of real gross domestic product (GDP).[1] Its incidence and transmission channels in this respect serve as short-term boosts to aggregate demand. More importantly, it has a long-term impact via the expansion and modernization of installed production capacity. In fact, by expanding and renovating physical infrastructure - by multiplying manufacturing plants with modern machinery and equipment - investment raises labor productivity and thereby pushes, so to speak, the production frontier.

For an economy like Mexico's, where the balance of payments is a crucial constraint to long-term growth, investment is vital for transforming the productive structure and removing this barrier. Without the expansion and modernization of capital, any attempts to remove the external constraint, to increase the income elasticity of exports, or to decrease the corresponding elasticity of imports are doomed to failure. Moreover, as economic growth is a key determinant of employment rates - and thus of the income and welfare of a large proportion of the Mexican population - the study of fixed capital formation becomes crucial for social development, not only economic development. Without the robust performance of public and private investment, this goal remains elusive for the vast majority of the population in emerging economies seeking to escape from poverty, such as in Mexico.

In light of this, the impact of public sector gross fixed capital formation on the private sector must be identified, to enhance the effects of both on short- and long-term economic growth. It is particularly important to understand when and why there may be a disharmonious relationship between the two, when - as some orthodox critics claim - public investment crowds out rather than crowds in private sector investment. As empirical research shows, neither the meaning nor the significance of the relationship between the public and private components of investment remain constant across geography, nor over time. Their interrelationship in a particular economy is subject to various contingent influences, to historical moments, and to institutional or regulatory frameworks such as property protection or rules on foreign direct investment (FDI) regarding activities in which it may engage. Furthermore, the political context is obviously an element that can influence this interrelationship, as is the stage of the business cycle in which the economy in question finds itself. In periods of high growth and pressure on productive or financial resources, an extraordinary rise in public investment may undermine the momentum of private investment, for example, in the absence of monetary policies to preserve the flow of credit for private business activities. In turn, during recessions or periods of declining growth, public investment could trigger a sharp rebound in private investment, including through institutional arrangements such as public-private partnership agreements that foster a favorable change in the overall business climate.

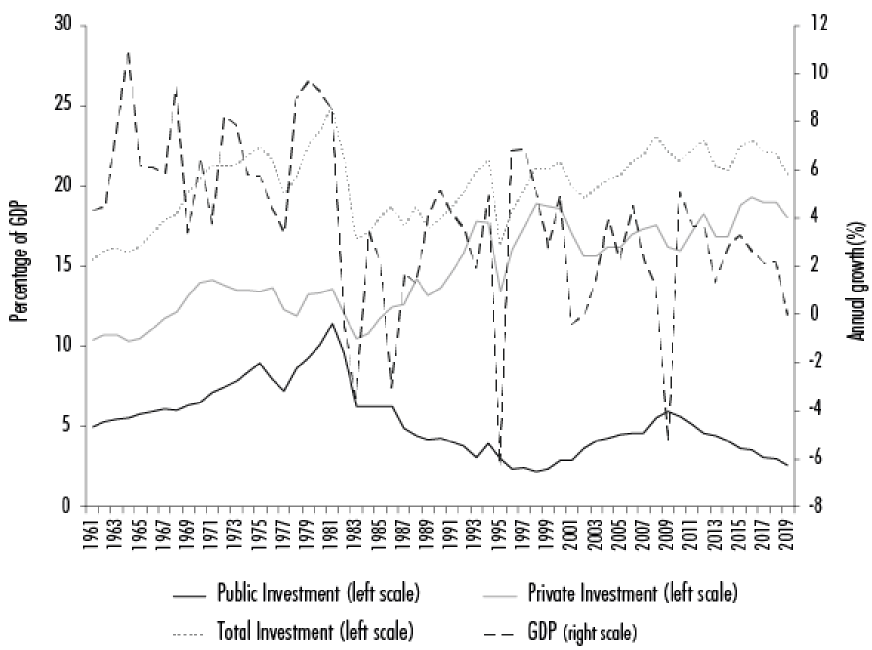
In the case of Mexico, it cannot be ruled out a priori that the relationship (crowding in or crowding out) between public and private investment differs across the various regions of such a large country. It has been the case, and continues to be the case, that public investment is strong and concentrated in some states and absent in other states at different historical moments. The current article sets out to analyze exactly this point: the interrelationship between private and public sector gross fixed capital formation at the state level, a subject that has received insufficient attention in the case of Mexico. This article also emphasizes empirical analysis based on fixed capital stock data, and not only on investment flows. As recent literature indicates, increases in capital strengthen productive capacity. It may well be the case that the welcome investment rebounds are not sufficiently dynamic to reverse the contraction of the net fixed capital stock. Thus, the analysis at the state level is based on data on the change in net capital stock, rather than focusing on rates of change in investment flows.[2]

This article is structured as follows: following the introduction, the second section gives an overview of private and public investment rates in Mexico -as ratios of GDP- and the rate of economic expansion, from 1960 to 2019. Next, the third section outlines the theoretical perspective adopted in this article's empirical analysis, including a review of what we believe to be the most important studies on this issue for the case of Mexico. The fourth section then deals with the methodological aspects, particularly the construction of the capital stock series at the state level, expanding on contributions from one of the authors of the article. The fifth section shows the findings from the empirical analysis, starting with the introduction of the corresponding functional specification and its econometric estimation. These findings were obtained using panel data econometrics, with a rigorous model selection process. The article closes with conclusions and some suggestions for future research on this topic.

## 2. ECONOMIC GROWTH AND PUBLIC AND PRIVATE INVESTMENT IN MEXICO: LONG-TERM STYLIZED FACTS

The Mexican economy's growth dynamics and fixed capital accumulation rate, both private and public, warrant in-depth analysis. Figure 1 illustrates this using investment ratios as a proportion of output, together with the annual real GDP growth rate, from 1960 to 2019, the year prior to the COVID-19 pandemic crisis. The long-term expansion path of productive activity occurs in clearly recognizable phases. These phases are also related to changes in the pattern of fixed capital accumulation, both in aggregate and in its private and public components, and not always in the same direction. The first phase, from 1960 to 1981, was characterized by a development strategy of state-led industrialization and import substitution. In this period, the economy expanded at average annual rates of 6% or higher, and the investment ratio rose constantly, from 15.1% of GDP in 1960 to almost 25% in 1981, its highest ever level. This dynamism in the accumulation process occurred to an even greater extent in public investment, which rose from 5% of GDP in 1960 to 10.8% of GDP in 1981. Private investment, meanwhile, also increased, but to a lesser degree, across two periods with distinct drivers. In the 1960s private investment rose strongly before losing momentum and stagnating at levels below 15%. This a priori process seems to reveal a crowding-in phenomenon during the first decade, followed by a degree of displacement. By the end of this period, the public sector accounted for over 40% of fixed accumulation, with its share growing rapidly during the oil boom years (1978-1981). During this period, hydrocarbon resources, together with the extraordinary access to international financing for a state committed to an ambitious effort to industrialize the country, considerably increased public investment, particularly in the oil sector.

Figure 1. Growth and share of fixed, public, and private investment: Mexico, 1960-2020




*Note: Calculated from figures at constant 2013 prices.*
*The long-term series were elaborated by the authors with different processes of interpolation of official data with different base years.*

*Source: Compiled by the authors using official data from INEGI (2020)*

The industrialization project based on the oil boom initiated the second stage (1982-1987), which was characterized by a balance of payments and fiscal crisis, followed by a persistent recession and destabilization of key macroeconomic indicators in terms of inflation and the budget balance. The total investment ratio declined sharply, falling nine points, more severely than public investment fell. Private investment fell at the beginning of this phase, but then began to recover. This trend, which diverged from that of public investment, would become even more accentuated when market reforms were more fully implemented. The third phase began in 1998, with a recovery in economic activity, but at a slower pace than in the sixties and seventies, and a moderate rise in the total investment ratio. From then until 2008, private investment became more dominant in the process of capital accumulation than it had in previous years, while public investment declined in response to the new development model which was driven by market forces, rather than being state-directed. During these years, investment recovered significantly as a percentage of GDP. However, it was far from returning to its previous peak in 1981. In this divergent process, the ratio of private investment increased by almost 10% from its 1982-1983 low. Meanwhile, the declining public investment ratio fell to its lowest level in 1988, although it subsequently recovered some very limited momentum.

The international financial crisis triggered in 2009 initiated the current phase, in which the economy, despite its rapid rebound in 2010, soon lost momentum and increasingly showed signs of being mired in a long-term slow-growth trap. For its part, the total investment ratio stagnated and began - with slight ups and downs - to decline starting from 2015. By 2019 it was barely above 20% of GDP. There is no immediately clear evidence regarding complementarity or competition between public and private investment during these long decades following the establishment of the neoliberal model; each shows a divergent trajectory in some years, pointing to crowding out, while in other years the opposite is true. In 2020, (not accounted for in Figure 1), faced with the effects of the pandemic and the international recession, Mexico's economy entered its largest recession. Investment, for its part, sharply accentuated the contractionary trend it had been experiencing for several years.

Having briefly analyzed here Mexico's macroeconomic performance, in terms the expansion rate of its productive activity and fixed capital accumulation, the next section offers a summary of some relevant empirical research.

## 3. INTERRELATIONSHIPS BETWEEN PRIVATE AND PUBLIC SECTOR INVESTMENT IN MEXICO: A REVIEW OF SELECTED EMPIRICAL STUDIES

The literature on the relationship between public and private investment reveals, from various analytical perspectives, that, a priori, it can be either a complementary relationship or one of displacement, without necessarily leaning towards one side or the other. Both possibilities are plausible and depend on a range of factors: historical context, monetary policy, financing and investment regulation, business climate, and rule of law, to name just a few. Given this complexity, the consensus is that solutions are contingent and are to be sought via the empirical study of specific cases in selected economies. In light of this, the current article works from a wide range of empirical studies from diverse economies on the subject of the interrelations between public and private investment, including some more focused on the problem of the accelerator. In the case of Mexico, some research analyzes the interaction between public and private investment variables, with contrasting results, depending on the data, the analysis periods covered, the functional specification to be estimated, and the econometric methodology followed. The most relevant of these studies will now be summarized.

Lachler and Aschauer (1998) tested the hypothesis that the slowdown of the Mexican economy (1981-1995) resulted from decreased public investment in infrastructure. The authors analyzed the impact of public investment on activity levels, considering the following three transmission channels: a) its impact on private investment; b) its effect on factor productivity; and c) its impact on the availability of financing. Additional variables they considered in their estimation were the public sector's current expenditure, its revenues, and total factor productivity. They found that public investment, on the other hand, exerts an adverse effect (substitution) on private investment, while simultaneously stimulating factor productivity and thus the expansion of economic activity. The authors also found that the effect on growth is contingent on the source of financing. If this occurs through the recomposition of government spending, its effect is positive, while financing obtained from debt or taxes has a negative effect.

Guerrero (1996) studied the hypothesis that the growth of private investment did not compensate for the fall in public investment, using the period 1980-1994 as a case study. He based his analysis on quarterly series for the period and cointegration techniques, using a range of additional variables such as private credit, the interest rate, GDP, the capital product ratio, the real and nominal exchange rate, as well as the index of prices and quotations of the Mexican Stock Exchange. He found a positive, significant accelerator effect of sales on private investment and also that the government deficit is associated with a crowding-in effect of public investment on private investment.

Ramírez (2004), meanwhile, studied the effects of public spending on Mexico's economic growth for the period 1955-1999, focusing on infrastructure. In addition to the usual variables, the author also included GDP and factor productivity. He concluded that both private investment and public spending on infrastructure have a positive and significant effect on growth rates, and also that the private component responds positively and significantly to public spending on infrastructure. Furthermore, he concluded that public infrastructure spending explains a significant percentage of the variation in private investment after 10 years. In a similar vein, Castillo and Herrera (2005) studied the effect of aggregate public spending on private spending in Mexico from 1980 to 2002. Following on from Johansen, the authors used cointegration techniques to identify long-term relationships, and the Vahid and Engle methodology of common cycles for the short-term relationships. Additionally, they included public and private consumption expenditure and GDP, as exogenous variables. The authors obtained evidence that increased public investment reduces private investment in the short term, possibly due to the pressure on financial resources. Regarding long-term relationships, they found that public investment significantly attracts private investment.

Fonseca (2009), on the other hand, used as variables gross fixed capital formation by type of good and buyer, GDP, and the real interest rate (approximated using the CETES rate adjusted for the rise in the national consumer price index and the public sector net domestic debt), all based on quarterly data for 1980-2007, and a range of econometric time series models. The author found that, in the short term, there is a partial displacement of private investment by public investment; in the long term, however, he reported a weak and marginal complementary effect. Hernández (2010), meanwhile, used a wide range of variables, including GDP, economically active population, and labor indicators to analyze the 1980-2008 period. He concluded that public investment can have a complementary effect as long as public investment is focused on generating favorable conditions (profitable and productive projects) to encourage private investment.

Gutiérrez (2017a) related private investment to public investment based on cointegration techniques, but the data used did not satisfy the unit root tests, forcing him to use primary public expenditure, which includes public investment, as a proxy. Additionally, he used the exchange rate, interest rate, and GDP as exogenous variables, finding that primary public spending has a positive effect on private investment. It is beyond the scope of this literature review to offer a thorough examination of this topic; however, it is worth highlighting the challenge of incorporating a variable that measures the availability of financing which these studies faced.

## 4. METHODOLOGY: CALCULATING THE FIXED CAPITAL STOCK SERIES FOR MEXICO

The time series of fixed investment, calculated using national accounts, should capture the variation in the volume of fixed capital stock from one period to another. However, when using this variable to measure precisely the impact of capital accumulation on economic growth, it must be remembered that the extent to which the investment thus recorded corresponds to an increase in the stock of fixed capital - and disregarding the problem of its valuation at constant prices - depends on the depreciation rate of infrastructure, machinery, and equipment, not to mention their technological obsolescence. This presupposes the existence of plausible depreciation rates, following conventional practice. Depending on what these depreciation rates are, a pattern of gross investment could complement an increase in the capital stock or, conversely, a contraction of the capital stock to the extent that the addition to capital only partially offsets its measurable depreciation. This inference, needless to say, applies to both private and public investment.[3] In accordance with the orthodoxy on the subject, the perpetual inventory method was used to construct the series of capital stocks, both public and private, starting from a given depreciation rate. Put arithmetically, we start from the following:

$$SC_t = (1 - \delta) * SC_{t-1} + I_t$$

Where $SC_t$ denotes the fixed capital stock at the close of period $t$, $\delta$ is the depreciation rate and $I_t$ is the gross investment flow occurring in period $t$. A vital challenge to the perpetual inventory methodology is estimating the value of the capital stock in the initial year ($SC_0$), which can be addressed using a reliable series of investment flows. Several authors, such as Loría and de Jesús (2007) and Shiau *et al.* (2002), address this challenge using an adjustment factor, as proposed by Almon (1999).

### The Almon adjustment factor

Almon (1999) proposed this solution to the problem based on the following formula that calculates, in his words, a normalized series of fixed capital stocks:

$$Faj_t = (1 - \delta) * Faj_{t-1} + 1$$

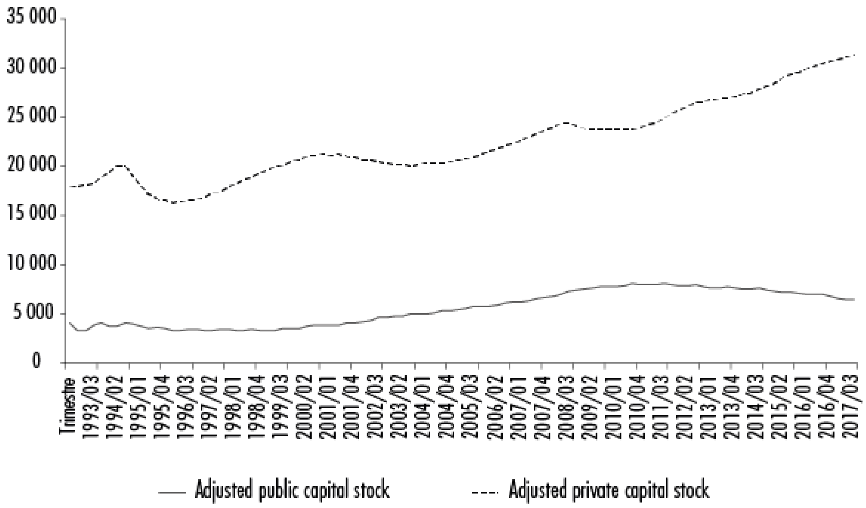
Where $Faj_t$ is the adjustment factor, $\delta$ is depreciation and $Faj_{t-1}$ is the adjustment factor for the previous period. For estimating the adjustment factor time series, it is assumed that the first data is equal to unity ($Faj_t$ = 1), and a "reasonable" depreciation rate is given. Based on the adjustment factor series thus calculated, the capital stock series is constructed, incorporating the corresponding adjustment factor in the calculation as follows:

$$SCA_t = \frac{(SC_t / Faj_t)}{\delta}$$

Where $SCA_t$ is the adjusted capital stock, $SC_t$ is capital stock, $Faj_t$ is the adjustment factor and $\delta$ represents depreciation. Essentially, what the adjustment factor allows for is the construction of, in Almon’s terminology, the "normalized" series of capital stocks in which the value of the first observation is not zero.

Figure 2 presents the findings of this estimation and construction of the capital stock series for the Mexican economy as a whole for 1993-2017.

Figure 2. Public and private sector fixed capital stock:
Mexico, 1993-2017 (quarterly in billions of 2013 pesos)




*Source: Compiled by the authors using data from their own estimates of public and private capital stock*

## 5. PANEL DATA MODEL: ECONOMETRIC ESTIMATION

As is well known, there is a wide range of econometric estimation techniques. These can be broadly organized into two categories, depending on whether the data are cross-sectional or time series. In fact, panel data modeling methodology makes it possible to exploit databases with both types of information, and to generate better estimators, so to speak, given that such an approach makes full use of all data on the variables related to the various "individuals" with their observations over a period of time. The general equation for this type of model is as follows:

$$y_{it=} c_{it} + \beta 1X_{it} \ldots + \beta n Z_{it} + \varepsilon_{it}$$

Where:

$y_{it}$ = is the dependent variable in the observation of individual i at time *t*;

$c_{it}$ = is a vector of fixed or random effects, as the case may be;

$x_{it}$ = is an independent variable of individual *i* at time *t*;

$z_{it}$ = is the independent variable *Z* of individual *i* at time *t*;

$\beta n$ = are the estimated coefficients for the independent variables.

As this article sets out to estimate the effect of public sector fixed capital accumulation on that of the private sector, a panel data model was constructed and estimated at the state level. The following variables were considered: the private capital stock (*AKpriv*) as the dependent variable and, as explanatory variables, the public sector capital stock (*AKpub*), and the equilibrium interbank interest rate (TIIE). Likewise, to allow for the possibility of dynamic adjustment over time, we included some of these same variables lagged by one period denoted with an "underscore" and the number of the lag (e.g., _1), the private capital stock and real state GDP are lagged for the same period in the same way (_1). [4] Based on the specialized literature reviewed, the following functional specification was chosen for the estimation:

$$LnAKpriv_{=} \left(c_{ij}, \frac{LnAKPub}{LnPIB}, LnTIIE, \frac{LnAKPub}{LnPIB_{-1}}, LnTIIE_{\_1}, \frac{LnAKPriv}{LnPIB_{\_1}}, LnGDP_{\_1}\right) \qquad (1)$$

The estimated model was tested for correct specification.[5]

### Description of the database

As mentioned above, the econometric panels used fixed capital stock data series -private and public- and GDP at the level of Mexico's 32 states for the period 2003-2017,[6] in millions of constant pesos. We also used the TIIE series, derived as an average of the corresponding monthly data from the National Institute of Statistics and Geography (INEGI), 2016). The public fixed capital stock series were taken from Gutiérrez (2017b), and the private capital series were constructed during the current research, using both the perpetual inventories method and the adjustment factor proposed by Almon (1999), as outlined in the previous section and assuming an average annual depreciation rate of 9.7%. The state GDP series were taken from INEGI.[7]

### Econometric results[8]

In keeping with the orthodoxy on the subject, the first step was to estimate the pooled model using the ordinary least squares method, then using the random effects method to contrast them with each other. The result was that both models yielded estimates with similar coefficients (see Annex 1, models 1 and 2, respectively). The Breusch-Pagan test was used for formal comparison, which yielded a log Chi2 = 0.000 with a probability of Prob > Chi2 = 1.000. The p-value of the test indicates that the null hypothesis H0 cannot be rejected, thus allowing us to conclude that the random effects are not relevant.[9] The next step was to estimate the fixed-effect model (see Table 1).

**Table 1. Fixed effects model**

| *Variable* | *Fixed effects* | *No non-significant variables* |
|---|---|---|
| LnAKpub/LnGDP | **-2.394** | -1.894 |
| | [.765] | [.712] |
| LnTIIE | -0.005 | |
| | [.039] | |
| LnGDP_1 | 0.088 | |
| | [.075] | |
| LnAKpub_1/LnGDP_1 | **3.097** | 2.588 |
| | [.738] | [.647] |
| LnAKpriv_1/LnGDP_1 | **0.132** | 0.137 |
| | [.052] | [.052] |
| LnTIIE_1 | 0.050 | |
| | [.038] | |
| Constant | -1.234 | |
| | [.942] | |
| Within | 0.1581 | 0.150 |
| Between | 0.1882 | 0.065 |
| Overall | 0.1311 | 0.119 |
| Observations | 448 | 448 |
| Individuals | 32 | 32 |

Note: numbers in bold are statistically significant at 95%. The numbers in square brackets are the standard errors of the estimates.
Source: Compiled by the authors

The F-test was used to measure the significance of the fixed effects, to allow comparison with the random-effects model. It resulted in an F-statistic of (31, 349) = 2.58 with a probability of Prob > F = 0.0000, which led to the rejection of H0; in other words, to a preference for the fixed-effects model. The Hausman test was then applied to these two models to decide whether the estimators were significantly different from each other. The result was a Chi2 statistic = 98.12 and a probability of Prob>Chi2 = 0.0000, which pointed to rejecting H0. That is, the difference between the fixed and random effects coefficients confirms the advantage of using the fixed effects model. The next step was to estimate this model, but with two-way fixed effects, in which temporal dichotomous variables are added to the original model to capture eventualities common to all states in the period analyzed. This process allows us to isolate the influence of these events in common (see Table 2).

Table 2. Two-step fixed-effects model

| *Variable* | *Fixed effects* | *No non-significant variables* |
|---|---|---|
| LnAKpub/LnGDP | **-2.876** | -2.841 |
| | [.810] | [.809] |
| LnTIIE | 0.053 | |
| | [.041] | |
| LnGDP_1 | 0.097 | |
| | [.095] | |
| LnAKpub_1/LnGDP_1 | **3.194** | 3.115 |
| | [.749] | [.745] |
| LnAKpriv_1/LnGDP_1 | **0.121** | 0.125 |
| | [.053] | [.053] |
| LnTIIE_1 | n.d. | |
| | n.d. | |
| Constant | -1.080 | |
| | [1.236] | |
| Within | | |
| Between | | |
| Overall | | |
| Observations | 448 | |
| Individuals | 32 | |

Note: numbers in bold are statistically significant at 95%. The numbers in square brackets are the standard errors of the estimates.
Source: Compiled by the authors.

The F-test on the significance of the model yielded an F-statistic of (10, 336) = 1.95 and a probability of Prob > F = 0.0383, which points to the rejection of H0. This, therefore, confirms that the dichotomous variables of the two-step model are significant and belong to the fixed-effects model. However, tests of the correct specification of the fixed effects model (i) autocorrelation, (ii) heteroscedasticity, and (iii) contemporaneous correlation, indicated the need to correct these three problems.

Tests of correct specification

*1)* Autocorrelation: Wooldridge F (1, 31) = 67.495 Prob > F = 0.0000

*2)* Heteroscedasticity: Wald Chi2 = 7199.81 Prob > Chi2 = 0.0000

*3)* Contemporaneous correlation: Pesaran 3.653, Pr = 0.0003 Mean absolute value of off-diagonal values = 0.271

The corrected estimates are presented in Table 3.

Table 3. Corrected fixed effects model (corrected for autocorrelation, heteroscedasticity, and contemporaneous correlation)

| *Variable* | *Fixed effects* | *No non-significant variables* |
|---|---|---|
| LnAKpub/LnGDP | **-3.121** | -3.160 |
| | [.766] | [.726] |
| LnTIIE | -0.463 | |
| | [.572] | |
| LnGDP_1 | 0.108 | |
| | [.090] | |
| LnAKpub_1/LnGDP_1 | **3.454** | 3.476 |
| | [.710] | [.659] |
| LnAKpriv_1/LnGDP_1 | 0.024 | |
| | [.156] | |
| LnTIIE_1 | n.a. | |
| | n.a. | |
| Constant | n.a. | |
| | n.a. | |
| Within | | |
| Between | | |
| Overall | | |
| Observations | 448 | |
| Individuals | 32 | |

Notes: n.a.: not available; numbers in bold are statistically significant at 95%. The numbers in square brackets are the standard errors of the estimates.
Source: Compiled by the authors.

In summary, after a rigorous process to determine the most appropriate model, including applying the correct specification tests corresponding to the panel methodology, the two-step fixed-effects model was chosen. Eliminating the coefficients that were not significant, the estimates -based on the panel information collected from the 32 states for the period under study- indicate that the evolution of the public sector's fixed capital stock, coincident and lagged in a period, are significant determinants of the evolution of the private sector's fixed capital stock.

The estimates of such a correctly specified fixed effects model, correcting for the problems identified above, resulted in the following equation:

$$\underset{[\text{Standard Error}]}{LnAKPriv/LnGDP} = \underset{[0.766]}{-3.121} * LnAKPub/LnGDP + \underset{[0.710]}{3.454} * LnAKPub\_1/LnGDP\_1 + \varepsilon_{it} \quad (2)$$

As this equation shows, the public sector's fixed capital stock - once lagged and a coincident effect added - has a significant positive net effect on the private sector's fixed capital stock. Note, however, that the coincident and lagged effects are of different signs. The first is negative, suggesting a crowding-out relationship, perhaps a simultaneous one; the second, lagged effect indicates the opposite: a positive crowding-in effect, more significant and slightly stronger than the first. Furthermore, the estimates indicate that every 1% increase in the public sector's fixed capital stock generates a positive crowding-in effect one year later, of a little more than three percentage points (+3.454) on the private sector's fixed capital stock. Likewise, it can also be seen that an increase in the public sector's fixed capital stock induces a contractionary effect on private investment that tends to be reflected in a reduction of its fixed capital stock, of slightly lesser magnitude (-3.121). The result, taking the coefficient estimates by their value in equation (2), suggests a net favorable impact of public investment on private investment in the order of an increase of 0.331 tenths of a percentage point in its corresponding stock.

## 6. CONCLUSIONS

This article’s primary objective was to identify the interrelationship between public and private sector fixed capital formation in Mexico, for approximately the first two decades of the 21st century, before the onset of the recessionary phase inaugurated in the Mexican economy in 2018, confirmed in 2019 and exacerbated in 2020 with the COVID-19 pandemic. Through econometric exercises, and based on the most widely used analytical model - associated with the accelerator theory- we estimated the existence of a significant relationship between both components of fixed capital formation: public and private. Unfortunately, the conclusions, rather than resolving the current debate on the results of previous research for the Mexican case, are more likely to complicate the debate. Indeed, while a lagged crowding-in effect and a concomitant crowding-out effect were detected, the discussion is still open. From a simplistic perspective, the results of the estimates do not provide clear policy recommendations for boosting economic growth. Rather, findings will need to be carefully analyzed in accordance with policy objectives over time; specifically, findings will depend on the importance attributed to the impact -during the same period and the subsequent period- of the increase in public investment over private investment.

This article's findings should be expanded on in future research. On the one hand, it is crucial to distinguish between the different types of fixed capital. The impacts on private investment may well differ if communications infrastructure is expanded and modernized or clean energies are developed, from a situation involving, for example, "white elephants." On the other hand, the respective impacts on private investment could differ greatly regarding residential construction or the opening of new plants and the importation of state-of-the-art machinery. All of this remains an increasingly relevant topic for future research on the Mexican economy and the relationship between public and private investment.

## ANNEX

**Table A1. Estimated panel data models**

| | *Model 1* | | *Model 2* | | *Model 3* | |
|---|---|---|---|---|---|---|
| *Variable* | *POOLED* | *No non-significant variables* | *Random effects* | *No non-significant variables* | *Fixed effects* | *No non-significant variables* |
| LnAKpub/LnGDP | **-2.398** | -2.233 | **-2.398** | -2.233 | **-2.394** | -1.894 |
| | [0.702] | [0.641] | [0.702] | [.641] | [.765] | [.712] |
| LnTIIE | -0.041 | | -0.041 | | -0.005 | |
| | [.0710] | | [0.035] | | [.039] | |
| LnGDP_1 | **0.015** | 0.015 | **0.015** | 0.015 | 0.088 | |
| | [0.007] | [0.007] | [0.007] | [.007] | [.075] | |
| LnAKpub_1/LnGDP_1 | **2.487** | 2.331 | **2.487** | 2.331 | **3.097** | 2.588 |
| | [.710] | [0.631] | [0.710] | [.631] | [.738] | [.647] |
| LnAKpriv_1/LnGDP_1 | **0.372** | 0.375 | **0.372** | 0.375 | **0.132** | 0.137 |
| | [.046] | [0.046] | [0.046] | [.046] | [.052] | [.052] |
| LnTIIE_1 | 0.052 | | 0.052 | | 0.050 | |
| | [.039] | | [0.039] | | [.038] | |
| Constant | 0.071 | | 0.071 | | -1.234 | |
| | [.151] | | [0.151] | | [.942] | |
| Within | | | 0.1195 | 0.1149 | 0.1581 | 0.150 |
| Between | | | 0.8077 | 0.81 | 0.1882 | 0.065 |
| Overall | | | 0.2615 | 0.2581 | 0.1311 | 0.119 |
| Observations | 448 | | 448 | 448 | 448 | 448 |
| Individuals | 32 | | 32 | 32 | 32 | 32 |

| | *Model 4* | | *Model 5* | | *Model 6* | |
|---|---|---|---|---|---|---|
| *Variable* | *Fixed effects two-stage* | *No non-significant variables* | *Fixed effects AR1* | *No non-significant variables* | *FGLS Heterocedasticity* | *No non-significant variables* |
| LnAKpub/LnGDP | **-2.876** | -2.841 | **-2.751** | -2.567 | **-1.310** | -1.013 |
| | [.810] | [.809] | [.835] | [.814] | [.437] | [.408] |
| LnTIIE | 0.053 | | -0.016 | | 0.005 | |
| | [.041] | | [.039] | | [.021] | |
| LnGDP_1 | 0.097 | | 0.057 | | **0.015** | 0.015 |
| | [.095] | | [.124] | | [.003] | [.003] |
| LnAKpub_1/LnGDP_1 | **3.194** | 3.115 | **3.494** | 3.256 | **1.428** | 1.091 |
| | [.749] | [.745] | [.804] | [.691] | [.441] | [.404] |
| LnAKpriv_1/LnGDP_1 | **0.121** | 0.125 | **-0.240** | -0.229 | **0.525** | 0.519 |
| | [.053] | [.053] | [.053] | [.053] | [.042] | [.041] |
| LnTIIE_1 | n.d. | | 0.043 | | 0.017 | |
| | n.d. | | [.037] | | [.024] | |
| Constant | -1.080 | | -0.649 | | -0.052 | |
| | [1.236] | | [1.055] | | [.089] | |
| Within | | | 0.1179 | | | |
| Between | | | 0.0033 | | | |
| Overall | | | 0.0053 | | | |
| Observations | 448 | | 416 | | 448 | |
| Individuals | 32 | | 32 | | 32 | |

| | *Model 7* | | *Model 8* | | *Model 9* | |
|---|---|---|---|---|---|---|
| *Variable* | *PCSE Heterocedasticity* | *No significant variables* | *PCSE Heteroscedasticity and correlation correlation* | *No non-significant variables* | *PCSE HHeteroscedasticity, Contemporaneous correlation, and serial correlation* | *No non-significant variables* |
| LnAKpub/LnGDP | **-2.398** | -2.233 | **-2.398** | -2.233 | **-3.121** | -3.160 |
| | [.621] | [.607] | [.681] | [.680] | [.766] | [.726] |
| LnTIIE | -0.041 | | -0.041 | | -0.463 | |
| | [.037] | | [.043] | | [.572] | |
| LnGDP_1 | **0.015** | 0.015 | **0.015** | 0.015 | 0.108 | |
| | [.006] | [.006] | [.006] | [.006] | [.090] | |
| LnAKpub_1/LnGDP_1 | **2.487** | 2.331 | **2.487** | 2.331 | **3.454** | 3.476 |
| | [.628] | [.621] | [.698] | [.711] | [.710] | [.659] |
| LnAKpriv_1/LnGDP_1 | **0.372** | 0.375 | **0.372** | 0.375 | 0.024 | |
| | [.115] | [.112] | [.135] | [.132] | [.156] | |
| LnTIIE_1 | 0.052 | | 0.052 | | n.d. | |
| | [.039] | | [.048] | | n.d. | |
| Constant | 0.071 | | 0.071 | | n.d. | |
| | [.124] | | [.124] | | n.d. | |
| Within | | | | | | |
| Between | | | | | | |
| Overall | | | | | | |
| Observations | 448 | | 448 | | 448 | |
| Individuals | 32 | | 32 | | 32 | |

Notes: n.a.: not available due to collinearity; numbers in bold are statistically significant at 95%. The numbers in square brackets are the standard errors of the estimates.

Source: Compiled by the authors.

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[1] For detailed reviews of the topic see, inter alia, Nurkse (1953), Ros (2013a), Blecker and Setterfield (2019), and UNCTAD (2016 and 2003) from a heterodox perspective, as well as Aghion and Howitt (2008), Hofman (2000), and Sala-i-Martin (1997).

[2] See Arslanalp *et al*. (2010 and 2011) on the theoretical limitations on studying the commensurability of the interrelations between investment and real GDP growth when the focus is on the dynamics of investment flows rather than the dynamics of capital stocks. These are closely related, but different, concepts. One is a stock, the other is a flow; it is the net magnitude of a stock that measures the availability of a crucial factor of production, i.e. capital.

[3] See Arslanalp *et al*. (2010).

[4] This article's methodology goes from the general to the particular, and thus presents both the findings showing the complete model and those with the non-significant variables omitted. State GDP was integrated into the model because of its importance given the analytical basis adopted and to address the problem of possible omitted variables. The interest rate was included, as in the vast majority of studies reviewed, as a proxy for the cost of financing, a determinant of investment decisions.

[5] In this case, autocorrelation, heteroscedasticity and contemporaneous correlation tests.

[6] Data from 2003 onwards were used due to their availability at INEGI.

[7] All variables are expressed in logarithms, meaning that the coefficients reflect elasticities.

[8] Aparicio and Márquez (2005).

[9] As usual, the null hypothesis (H0) is rejected when the p-value is $< 0.05$.