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# *The Relationship Between Private and Public Investment in Developing Countries with Different Levels of Human Capital*

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**Abstract**

**Theoretical background:** Public capital goods can directly boost the productivity of private capital equipment, thus, increasing the profitability of private investment. In addition, in developing countries, public capital has an indirect effect on the rate of return on private capital because it facilitates the accumulation of human capital. Through these channels, the negative consequences of an increase in interest rates associated with fiscal expansion can be offset, and the crowding-out effect of public investment can be reversed.
**Purpose of the article:** The aim of this paper is to reassess the extent to which public investment crowds in or crowds out private fixed capital expenditure in developing economies.
**Research methods:** Panel data on 89 developing countries from the period 1970–2015 and several estimation methods are used. Care of the endogeneity problem was taken, slope heterogeneity assumption was relaxed and several measures of educational attainment were used.
**Main findings:** The crowding-in phenomenon is found to be stronger in countries with low levels of education and health. It seems that the positive productivity-enhancing effect of public investment on private investment is partially offset by the decrease in the income share of physical capital in countries that witness improvements in human capital. Public capital accumulation in countries which have achieved high human development is less effective, meaning that public investment should precede non-investment spending on education and health.

## Introduction

It has been well documented that the accumulation of physical capital contributes to economic growth. Khan and Reinhart (1990) were among the first to highlight the need to distinguish between public and private investment in empirical growth models. They showed that the private component of investment has a larger direct effect on growth than the public component. This article shows that public investment can affect economic growth indirectly by altering the incentives of private investors.

The debate on the relationship between public and private spending has continued for a long time. Few would argue with the idea that unproductive government expenses at least partially crowd out private expenditures in general and investment in particular. Views are more mixed when it comes to productive government spending, i.e. public investment. When investing, governments still compete with the private sector for scarce loanable funds; however, the larger stock of public capital increases the productivity of private sector capital, thus, encouraging business investment.

The aim of this paper is to reassess the extent to which public investment crowds in private fixed capital expenditure in developing economies. This issue is worth examining because the levels of public and private capital accumulation are comparable in developing countries. Average public investment in 1960–2015 equaled 5.6% of GDP and its private counterpart amounted to 12.1% of GDP. In 10 of 89 countries from the sample used in this paper, public spending exceeded private spending on capital accumulation.[1]

The persistent deficiencies in public capital in many developing countries imply that public investment spending should considerably increase the productivity of private capital. Productivity gains come from the direct effect of public investment and the indirect effect of the accumulation of human capital. The combined direct and indirect effects of public investment are expected to more than offset the adverse consequences of higher government spending on the availability of external financing. However, the accumulation of human capital alters the relationship between private and public investment because it can abate the positive effect of the latter on the return on private physical capital. Therefore, I hypothesize that, although the crowding-in effect prevails, its strength depends on the level of human capital.

This paper advances the existing research on the complementarity or substitutability of public and private investment. It addresses an important limitation of previous literature which ignored the role of human development in the relationship between public and private investment. Moreover, the empirical analysis is based on an exceptionally large sample covering more than 40 years' experience of 89 developing countries, thus, ensuring the reliability of results.

The plan for the rest of the paper is as follows: The review of the existing empirical research on the substitutability of public and private investment is conducted

[1] The list of countries is presented in the Appendix.

in the next section. The hypothesis of the paper is formulated in section 3. Section 4 contains a detailed description of the data and estimation methods used. The account of the main empirical results is given in section 5. Section 6 presents the results of robustness tests. Conclusions and policy recommendations are compiled in section 7.

## Crowding-in and crowding-out effects in the empirical literature

On theoretical grounds there is consensus that there are two channels through which public investment affects private capital accumulation: on the one hand, productive public spending raises the marginal product of private capital stock;[2] on the other hand, its financing in the form of taxes or borrowing can be distortionary. Since these two effects offset each other, the results of empirical research on the complementarity of public and private investment are mixed but tend to support the crowding-in effect in developing countries and the crowding-out effect in advanced economies.

Afonso and St. Aubyn (2009) found that public investment induced more private investment in 8 out of 17 investigated developed countries. As estimated by Dreger and Reimers (2016), the short-run effect of public investment on private investment in the euro area was zero; the cointegration analysis of private and public capital stocks proved the existence of the long-run crowding-in effect. The broader, macroeconomic impact of public investment in OECD countries was examined by Abiad et al. (2016), who studied the effects of shocks to unanticipated public investment and found that public investment forecast errors did not have a statistically significant effect on private investment as a share of GDP. This finding is indicative of crowding-in effects because public investment shocks were found to also increase output. The strength of the crowding-in effect depended on the efficiency of public investment and the method of financing of public investment.

The results of the Granger causality tests of the interaction between private and public investment made it possible for Atukeren (2005) to detect crowding-out and crowding-in effects in 11 and 8 countries in the group of 25 developing economies, respectively. The characteristics shared by countries where crowding-out effects occurred were the following: high share of government involvement in the economy, low trade openness, restrictions on the use of foreign currencies, and a stable, developed macro and monetary environments. The opinion that crowding-in and crowding-out effects vary across countries and regions depending on their inherent characteristics was shared by Munthali (2012), who used a sample of 10 Southern African Development Community members and found a statistically weak long-term crowding-in effect but a significant short-term crowding-out effect. Erden

[2] Public capital can enter the production function and thereby affect the marginal product of private capital in two ways: as an additional input, or as a factor which influences multifactor productivity. See Romp and de Haan (2007) for a review of the various approaches.

and Holcombe (2005) also considered institutional differences between developing and advanced economies and concluded that public investment complemented and crowded out private investment, respectively.

Individual country studies have revealed that structural changes in the economy impact the degree of complementarity between public and private investment (for India, see Bahal et al., 2015; for Fiji, see Narayan, 2004). When attention is not given to possible structural breaks in the relation between private and public capital accumulation, complementarity between them is a more typical result. This can be exemplified by the cases of Mexico (Ramirez, 1994) or Pakistan (Rashid, 2006); obviously, counterexamples such as Bolivia (Bojanic, 2015) also exist.

The impact of public capital accumulation on private investment seems to vary not only with time but also across the types of public investment. The estimates in Xu and Yan (2014) implied that government investment in public goods in China crowded in private investment significantly, contrary to government investment in industry and commerce, which significantly crowded out private investment.

The above literature review demonstrates that the degree of complementarity of public and private capital accumulation varies across countries and time. This paper certainly does not resolve the controversy concerning the crowding-out effect, but it enriches the analysis by considering human capital as an important moderator variable in the relationship between private and public investment.

## Theoretical background

Public capital goods can directly boost the productivity of private capital equipment, thus increasing the profitability of private investment. Furthermore, in developing countries, public capital has an indirect effect on the rate of return on private capital because it facilitates the accumulation of human capital. Through these channels, the negative consequences of tighter credit market conditions can be offset, and the crowding-out effect of public investment can be reversed.

The mechanisms through which the productivity of private inputs is affected by public capital goods can be illustrated with the aid of the production function. Let us assume that the production function takes the Cobb–Douglas form:

$$Y = K_G^{\alpha} K_P^{\beta} L^{1-\alpha-\beta} \tag{1}$$

where $Y$ stands for output, $L$ represents labor, $K_G$ and $K_P$ are public and private capital stock, respectively. Parameters $\alpha$ and $\beta$ are equal to the public and private capital income shares, respectively, and their sum is less than 1.

The value of the marginal product of private capital, which is given by

$$MPK_P = \frac{\partial Y}{\partial K_P} = \beta K_G^{\alpha} K_P^{\beta-1} L^{1-\alpha-\beta} \tag{2}$$

is a positive function of the stock of public capital. More precisely, public investment which increases the stock of public capital by $\partial K_G$, has the following effect on the return on private capital:

$$\frac{\partial MPK_P}{\partial K_G} = \alpha\beta K_G^{\alpha-1} K_P^{\beta-1} L^{1-\alpha-\beta} > 0 \tag{3}$$

The impact of public capital growth on the productivity of private capital is unambiguously positive because $\alpha$ and $\beta$ are positive. So far, the interconnection of public investment, private investment, and human capital has been neglected. I argue that the degree of complementarity between private and public investment hinges on the level of human development. To demonstrate the role that human capital plays in boosting private investment, I replace the measure of raw labor input in the production function, $L$, by the stock of human capital $H$:

$$Y = K_G^{\gamma} K_P^{\delta} H^{1-\gamma-\delta} \tag{4}$$

The change in exponents in equation (4) is not accidental. Estimates of standard and human capital-augmented Solow growth models in Mankiw et al. (1992) showed that the share of physical capital in income falls by half if the quality of labor is accounted for. Similarly, using the dataset on public and private capital stocks that is the source of data for this article, An et al. (2019) found that after controlling for human capital, the physical (public and private) capital share parameter in the production function becomes smaller compared with estimates obtained when labor input is simply measured by employment. Interestingly, the magnitude of the reduction in the share of physical capital in income appeared to be stronger in richer countries. In more mathematical terms, it can be conjectured that an increase in skills leads to a reduction in the income share of physical capital, i.e. the following inequality holds:

$$\alpha + \beta > \gamma + \delta \tag{5}$$

The consequences of human capital accumulation for the relationship between public and private investment can be deduced from the value of the derivative of the marginal product of private capital with respect to public capital obtained from equation (4)

$$\frac{\partial MPK_P}{\partial K_G} = \gamma\delta K_G^{\gamma-1} K_P^{\delta-1} H^{1-\gamma-\delta} > 0 \tag{6}$$

Equation (6) reveals that an increase in human capital has a twofold effect on the relationship between public and private investment. On the one hand, the decrease in the share of physical capital in income reduces the value of $\gamma\delta K_G^{\gamma-1} K_P^{\delta-1}$ thereby reducing the positive impact of public investment on private physical capital accumulation. On the other hand, an increase in the stock of human capital leads to an increase in $H^{1-\gamma-\delta}$,

which magnifies the effect of public capital accumulation on the return on private physical capital.

It should be noted that public investment can promote private investment in health and education which leads to an increase in *H*. For instance, government outlay on infrastructure – roads, water supply systems, power grids, telecommunication networks – plays a critical role in the human capital accumulation process in developing countries. There is evidence that government programs aimed at providing access to safe water and sanitation improve educational outcomes and health. Sanitation programs led to a large increase in child height in India (Hammer & Spears, 2013; Augsburg & Rodríguez-Lesmes, 2018) and contributed to preventing anemia in Nepal (Coffey et al., 2018). Access to water, total road length, the number of students per classroom, and especially the share of households using electricity exerted a positive influence on life expectancy at birth in Indonesia (Kusharjanto & Kim, 2011). However, some infrastructural investment can be detrimental to health, as is exemplified by the negative impact of irrigation on life expectancy at birth in India (Mohanty et al., 2016).

A water treatment program improved the completed grades of education of rural youth in China (Zhang & Xu, 2016); the Total Sanitation Campaign in India increased the ability of six-year-olds to recognize letters and simple numbers (Spears & Lamba, 2016). Koolwal and Van de Walle (2013) found that in countries where substantial gender gaps in schooling existed in Sub-Saharan Africa, South Asia, North Africa, and the Middle East, better access to water was associated with higher enrollment rates. In contrast, the results of Nauges and Strand (2017) indicated a significant negative relationship between girls' school attendance and water carrying activity in Ghana.

Improvements in school infrastructure increased school enrolment rates and attendance, and children's health status in Georgia (Lokshin & Yemtsov, 2005). Public road investment had a positive effect on primary-age girls' school enrolment in Bangladesh (Khandker & Koolwal, 2011) and girls' school attendance in Brazil (Iimi et al., 2015). Besides the availability of schools, provision of telecommunication services and electrification were other infrastructure factors that turned out to be significant determinants of the combined index of adult literacy and school enrolment ratio in India (Mohanty et al., 2016); the long-run positive influence of electricity infrastructure on the aforementioned index was estimated by Kusharjanto and Kim (2011) to be larger in Indonesia by an order of magnitude than the impact of clean water, roads or the number of students per classroom.

From the above it follows that public capital can enhance human development. Healthier and more skilled workers provide an incentive to increase private investment because they use private physical capital more efficiently. Thus, public infrastructural investment stimulates private investment. In countries where major infrastructural bottlenecks to human development have already been eliminated, further increases in public capital can bring about smaller gains in labor productivity and private capital productivity, meaning that the crowding-in effect is weaker. It

suffices to realize that the derivative of the marginal product of private capital with respect to human capital, given by

$$\frac{\partial MPK_P}{\partial H} = (1-\gamma-\delta)\delta K_G^{\gamma} K_P^{\delta-1} H^{-\gamma-\delta} \tag{7}$$

is a negative function of $H$. It implies that the indirect effect of public investment on private investment, which operates through human capital accumulation, fades away as the stock of the latter increases.

In summary, human capital improvement has an ambiguous effect on the relationship between public and private investment. The return on private capital is directly positively affected by an increase in the stock of human capital (the expression in equation (7) is positive) and negatively affected by a decrease in the share of physical capital in income ($\beta$ and $\alpha$ in equation (2) are replaced with $\gamma$ and $\delta$ which are smaller). The former positive effect of human capital accumulation on the marginal product of private physical capital reinforces the crowding-in of private investment by public investment. On the contrary, the latter negative effect of human capital accumulation on the marginal product of private physical capital depresses the crowding-in of private investment by public investment. It has also been noted that public investment can facilitate human capital accumulation thereby magnifying the two opposing effects on crowding-in phenomenon.

The relationship between public and private investment is complex and includes not only the crowding-out effect of more restricted access to external financing, but also the crowding-in effect produced by an increase in the marginal product of private capital. The latter effect can be strengthened, weakened, or even overturned by the accumulation of human capital. Therefore, the hypothesis presented in this paper is as follows: Public investment crowds in private investment because the positive impact of an increase in the marginal product of private physical capital offsets the negative consequences of the tightening of credit market conditions. The level of human capital moderates the relationship between private and public investment.

This hypothesis implies that the impact of public investment on private investment is positive but smaller (or even negative) in countries where human capital is abundant. The unconditional influence of education and life expectancy on private investment is expected to be positive as they increase the productivity of physical capital. The validity of these predictions will be tested using a regression analysis of longitudinal data.

## Research methodology

Included in the sample are 89 developing countries (the Appendix contains the list) and the period covered is from 1970 to 2015; the panel is unbalanced and observations are annual. To control for GDP growth, public and private investment are expressed as shares of GDP. The data on investment and GDP are taken from

the *Investment and Capital Stock Database*, which was compiled by the International Monetary Fund (IMF, 2017). An important limitation of this study is that the theoretical arguments presented in the previous section are based on the assumption that public capital is one of the factors of production. Public investment used in this article is gross capital formation of the general government which includes not only expenditures on structures, land improvement, machinery and equipment, which can directly or indirectly affect the productivity of private capital, but also expenditures on transport equipment and weapons systems, which do not necessarily increase the country's productive capacity. Since some of the expenditures on fixed assets which are classified as gross capital formation of the general government are not productive, public investment variable used in this paper is an imperfect proxy for $K_G$ analyzed in the previous section.

Most governments have to rely on bank credit or bond financing of their expenditures, thereby draining external funds available to the private sector. In an econometric analysis of the relationship between private and public investment outlays, omitting a variable that measures private sector access to credit can lead to biased estimates. Financial development has also been shown in the literature to be an important determinant of corporate investment (see, e.g. Kasprzak-Czelej, 2013). The financial depth variable, labeled *credit*, is defined as the credit to the private sector in percent of GDP and is retrieved from the World Bank's *World Development Indicators* database. The log of this variable was taken to obtain a more normal distribution and reduce the gap between outliers and other observations.[3] It turned out that the log of the level of domestic credit was not a significant determinant of private investment contrary to its first difference (i.e. the rate of growth of credit to the private sector) which was therefore used as the independent variable.

Foreign capital inflows supplement domestic savings and can contribute to physical capital accumulation and be a source of development financing. This is particularly true if multinationals engage in productive activities and not just trade-related activities (see Amighini et al., 2017). Net inflows of foreign direct investment in percent of GDP will be used as the independent variable to assess the impact of capital inflows on domestic physical capital formation.

Two measurable aspects of human development are considered. The first is education (labeled *education*), proxied by the percentage of the population aged 15–64 with completed schooling and the average years of schooling attained, both measured at the primary, secondary, and tertiary levels. The data for 1960–2010 comes from the Barro and Lee database (2013) and projections for 2015 from Barro and Lee (2015). Both measures of educational attainment are available in 5-year intervals and were linearly interpolated to annual values. To capture the second dimension of

[3] The minimum and maximum value of credit to the private sector in percent of GDP is equal to .00082292 and 13956.763, respectively.

human development, i.e. health, I used the value of life expectancy at birth, labeled *life*, from the World Bank's *World Development Indicators* database.

To avoid spurious regression, the stationarity of all series has been tested by means of Augmented Dickey–Fuller unit-root test. This test has been selected because it can be implemented on unbalanced panels, does not assume that all panels share the same autoregressive parameters, and is flexible in terms of the required number of panels, $N$, and time periods, $T$ ($T$ is required to be large, and $N$ can be finite or infinite). As all variables for any country have nonzero means, the drift term was included in regressions. To mitigate the impact of cross-sectional dependence, the mean of the series across panels was computed for each time period and subtracted from the series. Following Choi's (2001) suggestion, the inverse normal $Z$ statistic was used to test the null hypothesis that all panels contain unit roots. In all cases, the null hypothesis was rejected, as shown in Table A1 in the Appendix.[4]

Private investment tends to be positively associated with its lagged value. Indeed, Eberly et al. (2012) confirmed that, due to the presence of investment adjustment costs, lagged investment is the best predictor of current investment. Moreover, the value of investment from the preceding year is a good proxy for the contemporaneous impact of all omitted variables which are nearly or completely time-invariant. The addition of the lagged value of the regressand to the set of regressors produces the following dynamic panel data model:

$$private\ investment_{it} = \alpha_t + \beta_0 private\ investment_{it-1} + \beta_1 x_{it} + d_i + e_{it}$$

where $i$ and $t$ are respectively the country and time index. The set of explanatory variables includes the period-specific effects, $\alpha_t$, the vector of covariates, $x_{it}$, and the unobserved country-specific effects, $d_i$, that may be correlated with $x_{it}$. The last term denotes the residual. The vector of explanatory variables contains public investment, the measure of human development and the interaction between them. The interaction terms *public investment* × *education* and *public investment* × *life* are intended to capture the moderating impact of human development on the relationship between public and private investment. Financial development (measured by the rate of growth of credit to the private sector) and foreign direct investment (net inflows in percent of GDP) are the control variable included in $x_{it}$.

The regression equation is a dynamic panel data model in which the minimum number of time series observations, $T$, is 16. This number can be considered to be large enough to attenuate the "small $T$" bias, i.e. the problem arising from a correlation between the lagged dependent variable and the residual in dynamic panel data models estimated by the fixed effects (FE) estimator. However, to ensure the robustness of the results, two solutions are adopted to deal with this potential problem.

[4] The values of inverse and modified inverse chi-squared, inverse logit statistics lead to the same conclusion.

The first method consists in correcting the FE estimator with the aid of an analytically derived expression for its inconsistency. Kiviet (1995) employed asymptotic expansion techniques to approximate the small sample bias of the FE estimator; he showed that the bias-corrected estimator (FEC) outperforms the instrumental variable and generalized method of moments estimators in samples with a small number of cross-sectional units.

Use of the bootstrap-corrected fixed-effects (BCFE) estimator of Everaert and Pozzi (2007) is the second way round the "small *T*" bias. To obtain the value of the bias, a bootstrap-based numerical method is applied instead of analytical approximations based on a strict set of assumptions which are often violated in practice. I used the algorithm proposed by De Vos et al. (2015) for unbalanced panels and generated bootstrap samples under the assumption that the error terms were from the normal distribution with cross-section specific variance.[5] This bootstrap error resampling scheme remains valid under cross-sectional heteroscedasticity. The number of observations is reduced because the procedure maintains only the largest block of uninterrupted observations for a country with gaps in the data.

Finally, a potential problem of endogeneity, arising from a bidirectional relationship between physical and human capital, has to be addressed. A high level of private investment in equipment can increase the returns to education and health, thereby providing incentives to acquire it. To get around the reverse causality problem, the instrumental variables (IV) technique was employed. The values of educational attainment and fertility rate lagged by 20 years were used as instruments. The latter instrument is proxy for the number of children in the family which was shown to affect educational outcomes (see, e.g. Diebolt et al., 2017; Hanushek, 1992; Klemp & Weisdorf, 2019; Li et al., 2017) and health (see, e.g. Öberg, 2015; Rosenzweig & Zhang, 2009). Similarly, parental education, which the lagged value of educational attainment is intended to capture, was found to have positive and significant effects on children's schooling outcomes (see, e.g. Cheng, 2017; Dubow et al., 2009) and health (see, e.g. Aslam & Kingdon, 2012; Chou et al., 2010; Shariff & Ahn, 1995). The interactions terms between public investment and the lagged values of educational attainment and fertility rate were also included in the set of instruments.

The conventional two-stage least squares IV estimator is inefficient in the presence of heteroscedasticity. Moreover, the standard IV estimates of the standard errors are inconsistent and the diagnostic test for endogeneity and overidentifying restrictions are invalid. Therefore the two-step Generalized Method of Moments (GMM) was used which produces efficient estimates in the presence of heteroscedasticity of unknown form.

All estimations were performed using Stata software.

[5] Under assumption of cross-sectional heteroscedasticity; the error term was resampled over time within cross-sections.

**Research findings and discussion**

First, the consistent fixed effects and efficient random effects estimators were employed and the Hausman test was applied to evaluate the consistency of the latter. The results of the test, shown in the bottom part of Table 1 and in the notes to Table 2, clearly indicate that the fixed effects estimator is preferred.

The impact of the educational attainment of a population aged 15–64 and public investment on private investment is analyzed in Table 1. The crowding effect and a positive influence of human capital are found for all measures of education, except for the percentage of the population with completed primary schooling. The main hypothesis of the paper is validated because the coefficients of the interaction terms *public investment* × *education* are negative and statistically significant. The strength of the moderating effect of schooling increases with its level, i.e. the crowding-in effect is most likely to be reversed when tertiary education is widespread. It should also be noted that improvements in financial development and foreign direct investment encourage the accumulation of private physical capital because both variables are highly significant and their estimated coefficients are positive.

Private investment is an autoregressive process because the estimated value of $\beta_0$ is large and highly significant. This coefficient can be underestimated, and other coefficients can be seriously biased if the "small *T*" problem is non-negligible. To reinforce the reliability of the results, I adopted the two methods for the bias correction outlined in the previous section and show the results in Table A2 in the Appendix. Although the increase in the value of the estimated coefficient of the lagged dependent variable justifies the use of the bias-corrected estimators, the results discussed above remain intact. In particular, the crowding-in effect holds in developing countries, but its strength varies inversely with educational attainment.

**Table 1.** Education as a moderator in the relationship between public and private investment; fixed effects estimates

| Measure of educational attainment | Percentage of population with completed schooling | | | Average years of schooling | | | |
|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary |
| *lag of private investment* | 0.839*** | 0.817*** | 0.834*** | 0.834*** | 0.839*** | 0.827*** | 0.834*** |
| | (0.019) | (0.027) | (0.019) | (0.018) | (0.017) | (0.020) | (0.019) |
| *credit* | 0.010*** | 0.009*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment* | 0.004 | 0.118*** | 0.059* | 0.176*** | 0.120** | 0.132*** | 0.060* |
| | (0.058) | (0.043) | (0.034) | (0.063) | (0.054) | (0.050) | (0.034) |
| *education* | 0.004 | 0.000** | 0.001** | 0.004* | 0.004* | 0.006** | 0.027** |
| | (0.058) | (0.000) | (0.001) | (0.002) | (0.002) | (0.003) | (0.013) |
| *public investment* × *education* | 0.004 | -0.010*** | -0.024* | -0.032*** | -0.028** | -0.091*** | -0.452* |
| | (0.058) | (0.004) | (0.013) | (0.010) | (0.012) | (0.034) | (0.254) |

| Measure of educational attainment | Percentage of population with completed schooling | | | Average years of schooling | | | |
|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary |
| Observations | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 |
| R-squared | 0.738 | 0.744 | 0.739 | 0.740 | 0.739 | 0.742 | 0.739 |
| Hausman test $\chi^2$ | 151.41 | 233.25 | 169.20 | 187.67 | 163.12 | 210.79 | 167.12 |
| (*p*-value) | (0.0) | (0.0) | (0.0) | (0.0) | (0.0) | (0.0) | (0.0) |

Notes: Robust standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included.

Source: Author's own study.

Health condition is the second aspect of human development that potentially affects the strength of the crowding-in effect. The results for life expectancy at birth, obtained from all three estimators, are presented in Table 2. They evidence that good health attenuates the positive effect of public investment on private investment. The direct impact of the level of health is positive. These conclusions are robust to alternative estimation methods.

**Table 2.** Life expectancy as a moderator in the relationship between public and private investment

| Estimator | FE | LSDVC | BCFE |
|---|---|---|---|
| *lag of private investment* | 0.827*** | 0.861*** | 0.881*** |
| | (0.016) | (0.013) | (0.023) |
| *credit* | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) |
| *public investment* | 0.373** | 0.234** | 0.389** |
| | (0.154) | (0.116) | (0.152) |
| *life* | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) |
| *public investment × life* | -0.006** | -0.004** | -0.006*** |
| | (0.003) | (0.002) | (0.002) |
| Observations | 3,446 | 3,446 | 3,260 |

Notes: Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. $R^2 = 0.741$ and Hausman test $\chi^2 = 186.60$ for the model estimated by FE.

Source: Author's own study.

In order to ensure that reverse causality from private investment to human capital is not driving the results, all equations were estimated with the two-step GMM-IV estimators. As mentioned above, the instruments were the values of educational attainment and fertility rate lagged by 20 years, which were intended to capture the level of parental education and the size of the family. The results are presented in Table 3.

**Table 3.** Human development as a moderator in the relationship between public and private investment; IV estimates

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.840*** | 0.822*** | 0.837*** | 0.834*** | 0.837*** | 0.826*** | 0.835*** | 0.833*** |
| | (0.019) | (0.020) | (0.019) | (0.020) | (0.020) | (0.020) | (0.019) | (0.028) |
| *credit* | 0.009*** | 0.009*** | 0.009*** | 0.010*** | 0.009*** | 0.010*** | 0.009*** | 0.010*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment* | 0.027 | 0.112*** | 0.071** | 0.181*** | 0.128** | 0.141*** | 0.077*** | 0.488*** |
| | (0.055) | (0.031) | (0.028) | (0.050) | (0.063) | (0.032) | (0.029) | (0.178) |
| *education/life* | 0.000 | 0.001* | 0.001** | 0.001 | -0.000 | 0.005 | 0.027** | 0.001 |
| | (0.000) | (0.000) | (0.001) | (0.002) | (0.007) | (0.003) | (0.012) | (0.001) |
| *public investment* × *education/life* | 0.000 | -0.009*** | -0.025*** | -0.034*** | -0.033* | -0.099*** | -0.518*** | -0.008** |
| | (0.004) | (0.002) | (0.008) | (0.011) | (0.020) | (0.020) | (0.148) | (0.003) |
| Observations | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 |
| Endogeneity test $\chi^2$ | 0.166 | 0.502 | 2.379 | 4.069 | 4.963 | 1.416 | 3.668 | 2.998 |
| Endogeneity test *p*-value | 0.920 | 0.778 | 0.304 | 0.131 | 0.084 | 0.493 | 0.160 | 0.223 |
| Underidentification test $\chi^2$ | 81.469 | 166.251 | 192.999 | 189.748 | 41.786 | 216.810 | 241.287 | 12.388 |
| Underidentification test *p*-value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 |
| Sargan–Hansen test $\chi^2$ | 9.838 | 0.753 | 2.576 | 0.521 | 4.150 | 0.008 | 1.914 | 1.376 |
| Sargan–Hansen test *p*-value | 0.007 | 0.686 | 0.276 | 0.771 | 0.126 | 0.996 | 0.384 | 0.503 |
| Redundancy of interaction terms | 27.319 | 89.984 | 117.985 | 142.386 | 124.748 | 93.794 | 154.585 | 134.820 |
| Redundancy test *p*-value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Redundancy of lagged human capital | 125.020 | 192.851 | 240.084 | 333.312 | 270.088 | 273.603 | 317.655 | 180.017 |
| Redundancy test *p*-value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| *R*-squared | 0.737 | 0.743 | 0.739 | 0.740 | 0.737 | 0.742 | 0.739 | 0.740 |

Notes: 2-step GMM estimator is used. Standard errors shown in brackets are robust to heteroscedasticity and autocorrelation; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. The values of educational attainment and fertility rate lagged by 20 years are used as instruments.

Source: Author's own study.

Table 3 demonstrates that the issue of endogeneity does not put into question the results obtained so far. First, the significance and the value of estimated coefficient are virtually the same as in Tables 1 and 2. In particular, the crowding-in effect of public investment is confirmed and the interaction term between human capital and

public investment has a significantly negative effect on private investment. Second, the concerns about the endogeneity of human capital measures seem to be unwarranted. The endogeneity test statistic, defined as the difference between Sargan–Hansen statistic for the equation, where the suspect regressors are treated as endogenous, and Sargan–Hansen statistic for the equation, where the suspect regressors are treated as exogenous, is not statistically significant in all but two specifications shown in Table 3. It implies that the null hypothesis that the specified endogenous regressors can actually be treated as exogenous cannot be rejected in most cases.[6]

It should also be noted that the results of the Sargan–Hansen test of overidentifying restrictions do not cast doubts on the validity of instruments. Moreover, instruments are correlated with endogenous regressors because the results of the underidentification test prove that the estimated equations are identified. This conclusion is based on the LM version of the Kleibergen–Paap *rk* statistic, which is robust to heteroscedasticity and autocorrelation.

Dropping redundant instruments may lead to more reliable estimation because using several instruments can cause the estimator to have poor finite-sample performance. A test of whether a subset of excluded instruments is "redundant" was based on the value of partial correlations between the endogenous regressors and the instruments. If the correlations are zero, the specified instruments are redundant. The test statistic is an LM version of the Kleibergen–Paap *rk* statistic, which is robust to heteroscedasticity and autocorrelation. Under the null that the specified instruments are redundant, the statistic is distributed as $\chi^2$. The redundancy of two subsets of instruments was tested; the first subset contained the lagged values of educational attainment and fertility, and the second included the interaction terms between public investment and the lagged values of educational attainment and fertility. In all cases the null hypothesis that the specified subsets are redundant was rejected.

Critics of the inclusion of multiplicative terms in regression equations point to the unreliability of the results due to multicollinearity between the interaction term and its constituent variables. Although this multicollinearity does not seem to pose serious problems (Friedrich, 1982), I investigated the sensitivity of results to the method of modeling the moderating impact of human development. Instead of including an interaction term, I divided the observations on public investment into two groups corresponding to high and low levels of human development. The median values of the measures of educational attainment or life expectancy were the criteria used to classify human development as "high" and "low" in respective regression models. The public investment variable was split into two separate variables at the median level of the human development variable. In particular, *public investment* × *high* took the value of public investment for the above-median values of the respective human development variable, and 0 otherwise. Likewise, *public investment* × *low* took the value of public investment for the below-median

[6] It cannot be rejected in all cases at the 1% significance level.

values of the respective human development variable, and 0 otherwise. The median values of all measures of human development and the results obtained from this methodology are reported in Table 4.

**Table 4.** Human development as a moderator in the relationship between public and private investment; median values of school attainment and life expectancy were used as a criterion to classify high and low human development

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.820*** | 0.806*** | 0.824*** | 0.819*** | 0.821*** | 0.820*** | 0.825*** | 0.809*** |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| *credit* | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.011*** | 0.010*** | 0.010*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *education/life* | 0.000*** | -0.000 | 0.000 | 0.003*** | 0.003** | 0.002 | 0.006 | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.001) | (0.002) | (0.007) | (0.000) |
| *public investment × low* | 0.059*** | 0.052*** | 0.030* | 0.052*** | 0.035* | 0.044** | 0.024 | 0.034* |
| | (0.018) | (0.018) | (0.017) | (0.019) | (0.019) | (0.018) | (0.017) | (0.018) |
| *public investment × high* | -0.055*** | -0.077*** | -0.045* | -0.028 | -0.012 | -0.049** | -0.024 | -0.033 |
| | (0.021) | (0.023) | (0.023) | (0.020) | (0.021) | (0.022) | (0.023) | (0.023) |
| Observations | 3,357 | 3,357 | 3,357 | 3,357 | 3,357 | 3,357 | 3,357 | 3,357 |
| Median | 15.17 | 10.96 | 2.03 | 5.38 | 3.75 | 1.45 | 0.11 | 63.89 |
| *R*-squared | 0.711 | 0.707 | 0.712 | 0.708 | 0.709 | 0.711 | 0.712 | 0.707 |

Notes: FE estimator is used; the disturbance term is assumed to be first-order autoregressive. Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. The "high" and "low" variables are dummies that are coded 1 if the corresponding measures of human development are, respectively, above or below the median.

Source: Author's own study.

The new modeling method provides evidence supporting the claim that human development is a moderator in the relationship between public and private investment. Public investment crowds in private investment only if the level of human capital is low. For the above-median values of human development, a negative influence of public investment is detected in 4 out of 8 model specifications. Contrary to the results shown in Table 1, higher education does not seem to have a particularly strong effect on the degree of complementarity between public and private investment. In fact, low levels of primary and secondary schooling are more conducive to the

crowding-in effect than the scarcity of tertiary education. Moreover, the estimated coefficients of human development are significant only in 4 specifications.

Since the data covers 89 developing countries that are likely to be quite diverse and heterogeneous, the robustness tests address the issue of slope parameter heterogeneity. The first approach consists of the estimation of a new model which assumes country-specific slopes on all explanatory variables. The Pesaran (2006) Common Correlated Effects Mean Group (CCEMG) estimator is the average of the coefficients estimated separately for each country in the sample. To mitigate the bias arising from cross-section dependence and time-variant unobservables, the set of regressors in the regression equation for each panel member (i.e. country) was extended to include the cross-section averages of the dependent and independent variables.[7] The CCEMG estimator produced consistent estimates of the parameters related to the observable variables that are presented in Table 5.

**Table 5.** Human development as a moderator in the relationship between public and private investment under assumption of parameter heterogeneity across countries

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.421*** | 0.373*** | 0.380*** | 0.388*** | 0.369*** | 0.392*** | 0.379*** | 0.381*** |
| | (0.030) | (0.033) | (0.030) | (0.033) | (0.031) | (0.031) | (0.029) | (0.027) |
| *credit* | 0.011*** | 0.009*** | 0.009*** | 0.007*** | 0.008*** | 0.007*** | 0.009*** | 0.009*** |
| | (0.003) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.002*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment* | 0.510* | 0.656*** | 0.590*** | 1.473*** | 1.929*** | 0.769*** | 0.716*** | 3.564*** |
| | (0.261) | (0.187) | (0.185) | (0.311) | (0.406) | (0.222) | (0.198) | (0.872) |
| *education/life* | 0.002** | 0.001 | 0.007 | 0.008 | 0.026*** | 0.013 | 0.095 | 0.004*** |
| | (0.001) | (0.001) | (0.005) | (0.005) | (0.007) | (0.009) | (0.083) | (0.001) |
| *public investment* | -0.036** | -0.050*** | -0.221*** | -0.257*** | -0.464*** | -0.433*** | -3.767*** | -0.059*** |
| *× education/life* | (0.018) | (0.013) | (0.076) | (0.061) | (0.099) | (0.114) | (1.354) | (0.014) |
| Observations | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 |
| Wald test $\chi^2$ | 0.711 | 0.707 | 0.712 | 0.708 | 0.709 | 0.711 | 0.712 | 0.707 |

Notes: CCEMG estimator is used. Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Cross-section averages of dependent and independent variables were included as additional regressors.

Source: Author's own study.

[7] The estimated coefficients on the cross-section averaged variables are not reported because they are not interpretable in a meaningful way.

The results obtained with the aid of the CCEMG estimator reveal that relaxing the assumption of parameter homogeneity across countries does not alter the main conclusions drawn in the previous section. The impact of public investment on private investment is positive and weaker in countries that are more abundant in human capital. It should be noted that the values of the coefficients on public capital and the interaction terms are larger and the coefficient on the lagged value of private investment is smaller when the CCEMG estimator is used. The significance and strength of the influence of credit growth and foreign direct investment inflows remained unchanged, and a significant positive relationship between private investment and human capital has been confirmed for primary education and life expectancy.

Endogenous growth theory teaches us that the quality of institutions and human capital interact in the process of economic development. The aim of the second robustness check is to test the stability of estimated coefficients with respect to differences in the levels of corruption and checks and balances between countries in the sample. The extent of corruption is measured by executive bribery and corrupt exchanges variable from the V-Dem dataset (Coppedge et al., 2021) which is based on experts' answers to the following question: How routinely do members of the executive, or their agents grant favors in exchange for bribes, kickbacks, or other material inducements, and how often do they steal, embezzle, or misappropriate public funds or other state resources for personal or family use? The version of the variable that was used was obtained from a Bayesian factor analysis model and runs from less corrupt to more corrupt.

I divided the observations on public investment into two groups corresponding to high and low levels of corruption. The public investment variable was split into two separate variables at the median level of corruption, which was 0.614. In particular, *public investment* × *high* took the value of public investment for the above-median values of corruption, and 0 otherwise. Likewise, *public investment* × *low* took the value of public investment for the below-median values of corruption, and 0 otherwise. Similarly, *public investment* × *life / education* × *high* and *public investment* × *life / education* × *low* were created as a product of public investment with human capital in more and less corrupt countries, respectively. The degree of corruption was found to be insignificant and is not included in the set of regressors.

The results obtained from the BCFE estimator that is robust to cross-sectional dependence (see Table 6) imply that the crowding-in effect is about two times stronger in less corrupt countries than in more corrupt countries. The positive influence of public investment on private investment is stronger in countries where human capital is scarce regardless of the severity of corruption. In summary, the strength of the crowding-in effect depends on the degree of corruption, contrary to the moderating effect of human capital.

**Table 6.** Human development as a moderator in the relationship between public and private investment in less and more corrupt countries; results obtained from the BCFE estimator

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.898*** | 0.861*** | 0.888*** | 0.884*** | 0.894*** | 0.876*** | 0.887*** | 0.876*** |
| | (0.026) | (0.025) | (0.026) | (0.025) | (0.026) | (0.025) | (0.026) | (0.027) |
| *credit* | 0.010*** | 0.009*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.004) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment × low* | 0.026 | 0.149*** | 0.082*** | 0.234*** | 0.173*** | 0.159*** | 0.083*** | 0.424** |
| | (0.033) | (0.025) | (0.020) | (0.051) | (0.060) | (0.027) | (0.020) | (0.167) |
| *public investment × high* | 0.006 | 0.079*** | 0.033 | 0.128*** | 0.081* | 0.109*** | 0.034 | 0.378*** |
| | (0.034) | (0.027) | (0.026) | (0.038) | (0.043) | (0.033) | (0.025) | (0.113) |
| *education/life* | 0.000 | 0.001*** | 0.001*** | 0.004*** | 0.005** | 0.007*** | 0.027*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) | (0.010) | (0.000) |
| *public investment × education / life × low* | 0.000 | -0.010*** | -0.028*** | -0.038*** | -0.036** | -0.098*** | -0.510*** | -0.007** |
| | (0.002) | (0.002) | (0.006) | (0.009) | (0.015) | (0.015) | (0.119) | (0.003) |
| *public investment × education / life × high* | -0.000 | -0.007*** | -0.018*** | -0.026*** | -0.023** | -0.082*** | -0.338** | -0.007*** |
| | (0.002) | (0.001) | (0.007) | (0.006) | (0.010) | (0.013) | (0.133) | (0.002) |
| Observations | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 |

Notes: Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. The "high" and "low" variables are dummies that are coded 1 if the degree of corruption is above or below the median, respectively.

Source: Author's own study.

Checks and balances are the second measure of institutional quality that was used to assess the degree of heterogeneity of slope coefficients. This variable comes from the *Database of Political Institutions* compiled by Cruz et al. (2021) and its higher values indicate stronger checks and balances. The median value of this variable in the sample is 2, and it was used to split the public investment variable into two separate variables containing observations of public investment in countries with strong or weak checks and balances systems. Each interaction term between public investment and human capital was also divided into two variables corresponding to high or low checks and balances values. The measure of checks and balances itself was found to be an insignificant determinant of private investment and is not included in the model.

According to the results obtained from the BCFE which are presented in Table 7, in countries with more checks and balances, the crowding-in effect and the moderating effect of human capital are stronger. The net effect of public investment on private investment, calculated as the sum of the coefficients on public investment and its interaction term with human capital, is positive and greater in countries with strong systems of checks and balances.

**Table 7.** Human development as a moderator in the relationship between public and private investment in countries with weak and strong checks and balances; results obtained from the BCFE estimator

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.895*** | 0.865*** | 0.891*** | 0.889*** | 0.899*** | 0.877*** | 0.890*** | 0.880*** |
| | (0.026) | (0.025) | (0.026) | (0.026) | (0.026) | (0.026) | (0.026) | (0.027) |
| *credit* | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.004) | (0.004) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment × low* | 0.056 | 0.087*** | 0.043 | 0.108** | 0.073 | 0.096*** | 0.044 | 0.261* |
| | (0.041) | (0.030) | (0.027) | (0.049) | (0.053) | (0.035) | (0.027) | (0.151) |
| *public investment × high* | -0.009 | 0.127*** | 0.062*** | 0.216*** | 0.138*** | 0.154*** | 0.063*** | 0.492*** |
| | (0.032) | (0.022) | (0.019) | (0.040) | (0.049) | (0.024) | (0.019) | (0.130) |
| *education/life* | 0.000 | 0.001*** | 0.001*** | 0.004*** | 0.004* | 0.007*** | 0.028*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) | (0.010) | (0.000) |
| *public investment × education / life × low* | -0.003 | -0.007*** | -0.018*** | -0.020** | -0.017 | -0.064*** | -0.331*** | -0.004* |
| | (0.002) | (0.002) | (0.006) | (0.009) | (0.015) | (0.018) | (0.127) | (0.003) |
| *public investment × education / life × high* | 0.002 | -0.010*** | -0.026*** | -0.038*** | -0.032*** | -0.103*** | -0.488*** | -0.008*** |
| | (0.002) | (0.001) | (0.006) | (0.007) | (0.012) | (0.011) | (0.124) | (0.002) |
| Observations | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 |

Notes: Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. The "high" and "low" variables are dummies that are coded 1 if the degree of checks and balances is above or below the median, respectively.

Source: Author's own study.

The last test of parameter heterogeneity assumes that the strength of the crowding-in effect depends not only on human capital but also on the level of development. I divided the observations on public investment into two groups corresponding to prosperity or poverty measured by the level of per capita income relative to the US. The variables *public investment × low* and *public investment × life / education × low* are equal to *public investment* and *investment × life/education*, respectively, if per capita income is equal or smaller than 0.05 (i.e. 5% of US per capita income) and 0 otherwise. The variables *public investment × high* and *public investment × life / education × high* are equal to *public investment* and *investment × life/education*, respectively, if per capita income is greater than 0.05 and 0 otherwise.

It turned out (see Table 8) that the level of income is the most powerful criterion for assessing the strength of the crowding-in effect, although itself it is not a factor that significantly affects the accumulation of private physical capital. In poor countries, the crowding-in effect is significant in only 2 model specifications, and the interaction term of public investment with human capital is significant in 5 specifications. In contrast, the crowding-in effect in high-income countries is not significant in only

1 specification. Furthermore, the moderating impact of human capital is significant in rich and poor countries, but it is about twice stronger in the former.

**Table 8.** Human development as a moderator in the relationship between public and private investment in rich and poor countries; results obtained from the BCFE estimator

| Measure of human development | Percentage of population with completed schooling | | | Average years of schooling | | | | Life expectancy |
|---|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary | |
| *lag of private investment* | 0.890*** | 0.854*** | 0.872*** | 0.869*** | 0.883*** | 0.859*** | 0.870*** | 0.862*** |
| | (0.026) | (0.025) | (0.026) | (0.026) | (0.026) | (0.025) | (0.026) | (0.025) |
| *credit* | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.004) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment × low* | -0.002 | 0.037 | -0.022 | 0.078* | 0.066 | 0.039 | -0.022 | 0.388*** |
| | (0.033) | (0.032) | (0.030) | (0.043) | (0.049) | (0.033) | (0.029) | (0.148) |
| *public investment × high* | 0.036 | 0.159*** | 0.110*** | 0.310*** | 0.226*** | 0.210*** | 0.116*** | 0.725*** |
| | (0.036) | (0.024) | (0.020) | (0.052) | (0.064) | (0.029) | (0.019) | (0.218) |
| *education/life* | 0.000 | 0.001*** | 0.002*** | 0.005*** | 0.006** | 0.008*** | 0.033*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) | (0.010) | (0.000) |
| *public investment × education / life × low* | -0.002 | -0.006*** | -0.009 | -0.024*** | -0.031** | -0.058*** | -0.161 | -0.008*** |
| | (0.003) | (0.002) | (0.007) | (0.008) | (0.015) | (0.013) | (0.136) | (0.002) |
| *public investment × education / life × high* | 0.001 | -0.011*** | -0.032*** | -0.048*** | -0.045*** | -0.118*** | -0.622*** | -0.011*** |
| | (0.002) | (0.002) | (0.005) | (0.008) | (0.015) | (0.015) | (0.118) | (0.003) |
| Observations | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 |

Notes: Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included. The "high" and "low" variables are dummies that are coded 1 if the level of per capita income (relative to the US per capita income) is above or below the median, respectively.

Source: Author's own study.

The results presented in this section revealed that the crowding-in effect is stronger in less corrupt, rich countries with more checks and balances. The hypothesis that the relationship between public and private investment depends on the level of human capital has been supported. A high level of education and health reduces the crowding-in effect, mainly in rich countries with stronger checks and balances systems. Despite the fact that the countries included in the sample differ in terms of development level, corruption control, and checks and balances, the results of empirical analyses allow a few firm conclusions to be drawn.

## Conclusions

This paper contributes to our understanding of the crowding-in phenomenon in developing countries by highlighting the influence of human development on the sign of the relationship between private and public investment. In developing countries, a high level of education and good health of the workforce are some of the benefits of public infrastructural investment; if these are already in place, the likely productivity gains from the accumulation of public capital are modest and the crowding-out effect is more likely to occur. This prediction was tested using data on 89 developing countries covering the period 1970–2015 and taking care of the endogeneity problem. It was shown to hold true regardless of the measure of educational attainment, estimation method, slope heterogeneity assumption and methodology used to model the moderating effect of human development.

The impact of education and health on private investment is positive except for the percentage of the population with completed primary schooling. The rate of growth of credit to the private sector and foreign direct investment were found to be positively associated with private investment, suggesting that bank loans and foreign savings are an important source of external financing in developing countries.

The main message of the paper can be summarized as follows: public investment is complementary to private investment, but the strength of the crowding-in effect depends on human development. More precisely, the crowding-in effect is associated with inadequate educational attainment and health conditions. In countries where human capital is plentiful, the impact of public investment on private investment is weaker. The policy recommendation concerns the prioritization of government spending. In countries with a shortage of human capital, accumulation of public physical capital is preeminent because it encourages private investment and accelerates the removal of deficits in machinery and equipment. Giving priority to non-investment spending on education and health systems would reduce the efficiency of subsequent public infrastructural investment due to a weakening of the crowding-in effect.

Due to data limitations, a broad concept of physical capital was used, which includes machinery structures, information, and communication capital. It would be interesting to analyze in future research the existence of crowding-in or crowding-out effects using disaggregated data on investment spending that are not yet available for developing countries. Another limitation of this paper is that the empirical analysis was confined to developing countries. The conclusions of this study may not apply to developed countries. Finally, the list of control variables could be extended at the expense of the number of countries included in the sample.

It is also important to note that the analysis was based on the assumption of exogeneity of public investment. Although this assumption has a long tradition in the literature about the crowding in and crowding out effects in developing countries (see, e.g. Sundararayan & Thakur, 1980), a future research could allow for relaxing this assumption.

## Disclosure statement

The author declares that he has no relevant or material financial interests that relate to the research described in this paper.

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## Appendix

### List of 89 countries included in the sample

Albania, Algeria, Argentina, Armenia, Bahrain, Bangladesh, Barbados, Belize, Benin, Bolivia, Botswana, Brazil, Burundi, Cambodia, Cameroon, Central African Republic, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cote d'Ivoire, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Eswatini, Fiji, Gabon, Gambia, Ghana, Guatemala, Haiti, Honduras, India, Indonesia, Iran, Islamic Rep., Iraq, Jordan, Kazakhstan, Kenya, Kyrgyz Republic, Lao PDR, Lesotho, Liberia, Malawi, Malaysia, Maldives, Mali, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, Uruguay, Venezuela, RB, Vietnam, Yemen, Rep., Zambia, Zimbabwe.

**Table A1.** Results of Augmented Dickey–Fuller unit root tests

| Variable | Inverse normal *Z* statistic | *p*-value |
|---|---|---|
| private investment | -15.8476 | 0.0 |
| public investment | -16.2381 | 0.0 |
| growth of credit-to-GDP ratio (Δlog *credit-to-GDP*) | -10.0176 | 0.0 |
| foreign direct investment (percent of GDP) | -17.1573 | 0.0 |
| percentage of population with primary schooling | -11.1648 | 0.0 |
| percentage of population with secondary schooling | -9.2120 | 0.0 |
| percentage of population with tertiary schooling | -4.0883 | 0.0 |
| average years of schooling (all grades) | -11.6961 | 0.0 |
| average years of primary schooling | -7.0203 | 0.0 |
| average years of secondary schooling | -7.7713 | 0.0 |
| average years of tertiary schooling | -4.4208 | 0.0 |
| life expectancy at birth | -10.0176 | 0.0 |

Source: Authors' own study.

**Table A2.** Education as a moderator in the relationship between public and private investment; sensitivity to estimation method

| Measure of educational attainment | Percentage of population with completed schooling | | | Average years of schooling | | | |
|---|---|---|---|---|---|---|---|
| Level of education | primary | secondary | tertiary | all grades | primary | secondary | tertiary |
| Estimator | | | | FEC | | | |
| *lag of private investment* | 0.876*** | 0.855*** | 0.877*** | 0.867*** | 0.872*** | 0.864*** | 0.877*** |
| | (0.014) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) |
| *credit* | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment* | -0.026 | 0.100*** | 0.053** | 0.124*** | 0.064 | 0.105*** | 0.053** |
| | (0.040) | (0.024) | (0.022) | (0.045) | (0.048) | (0.028) | (0.022) |
| *education* | -0.000 | 0.000*** | 0.001*** | 0.004*** | 0.004* | 0.006*** | 0.026*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) | (0.009) |
| *public investment* × *education* | 0.003 | -0.008*** | -0.022*** | -0.024*** | -0.015 | -0.078*** | -0.395*** |
| | (0.002) | (0.001) | (0.006) | (0.008) | (0.011) | (0.017) | (0.120) |
| Observations | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 | 3,446 |
| Estimator | | | | BCFE | | | |
| *lag of private investment* | 0.899*** | 0.867*** | 0.890*** | 0.890*** | 0.899*** | 0.879*** | 0.890*** |
| | (0.026) | (0.025) | (0.026) | (0.026) | (0.026) | (0.025) | (0.026) |
| *credit* | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** | 0.010*** |
| | (0.003) | (0.004) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| *foreign direct investment* | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| *public investment* | 0.009 | 0.116*** | 0.058*** | 0.166*** | 0.106** | 0.136*** | 0.059*** |
| | (0.028) | (0.022) | (0.019) | (0.036) | (0.042) | (0.024) | (0.018) |
| *education* | 0.000 | 0.000*** | 0.001*** | 0.004*** | 0.004* | 0.007*** | 0.027*** |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.002) | (0.001) | (0.010) |
| *public investment* × *education* | 0.001 | -0.009*** | -0.024*** | -0.030*** | -0.025** | -0.092*** | -0.438*** |
| | (0.002) | (0.001) | (0.005) | (0.006) | (0.010) | (0.011) | (0.112) |
| Observations | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 | 3,260 |

Notes: Standard errors are shown in brackets; asterisks indicate significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Dummies for each year are included.

Source: Author's own study.