OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

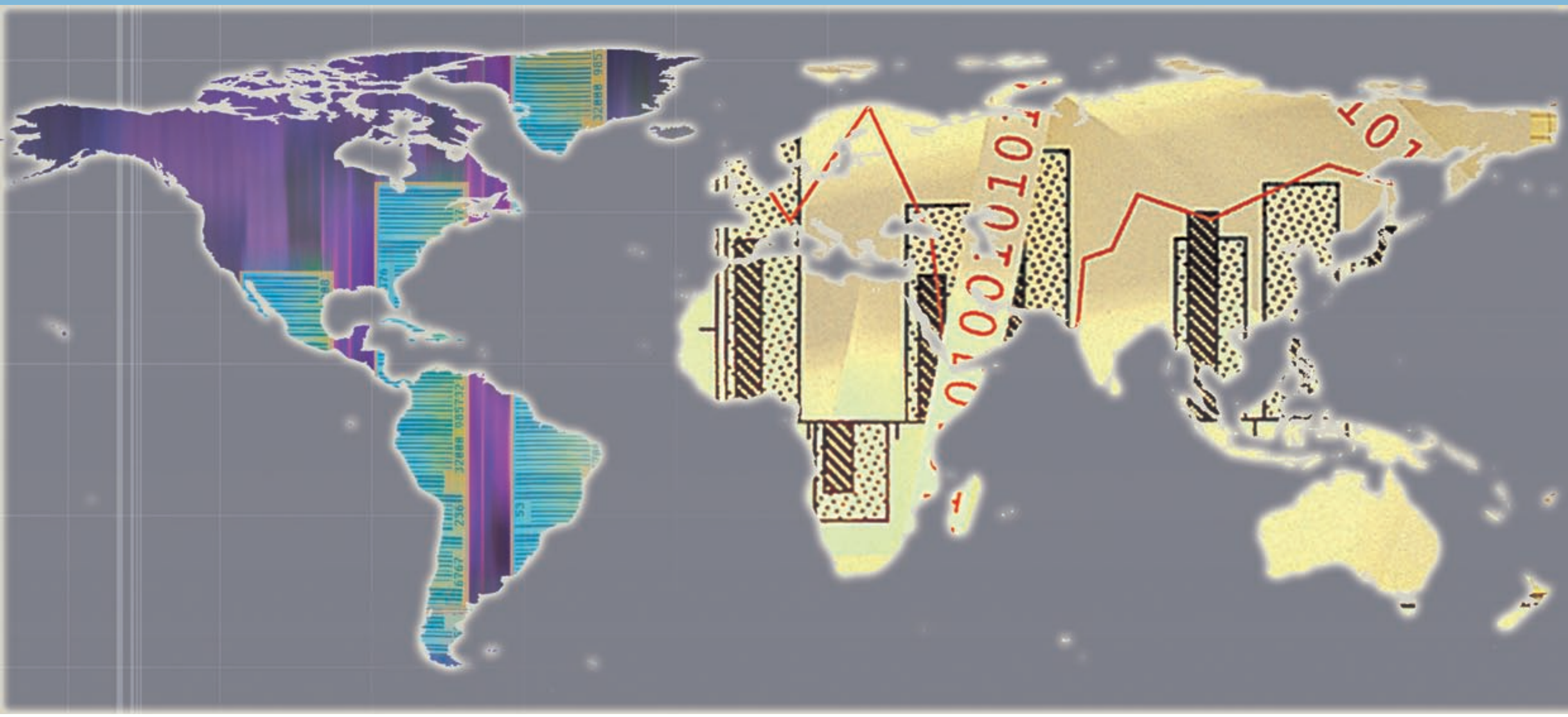
Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

RESEARCH AND STATISTICS BRANCH

WORKING PAPER 15/2009



Public Capital, Infrastructure and Industrial Development

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

RESEARCH AND STATISTICS BRANCH
WORKING PAPER 15/2009

Public Capital, Infrastructure and Industrial Development

Anders Isaksson
Research and Statistics Branch
Programme Coordination and Field Operations Division
UNIDO

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2010

TABLE OF CONTENTS

List of Figures

List of Tables

Abstract

This paper sheds light on how important public capital is for countries trying to industrialize and achieve faster economic growth. To this end, a small empirical model of industrial development is formulated and applied to manufacturing level and growth data for 57 advanced and developing countries for the time period of 1970 to 2000. In estimating the impact of public capital on industry special care is taken to deal with country-specific effects, reverse causality and endogeneity bias. The findings are clear: public capital has important explanatory power for why some countries have managed to industrialize, while others have not. Stages of development influence how strongly public capital matters, but there is evidence of impact at all income levels. Moreover, it seems that the returns to public investment are, largely, diminishing as income increases. A second key conclusion is that growth of public capital not only explains long-term levels of industry, but also how rapidly industry grows. Interestingly, the largest impact occurs for the fastest growing countries, i.e., the Asian tiger economies, and the High-income ones. Based on rates of return on public capital calculations, little support is found for the notion that public infrastructure is overprovided in developing countries. To the contrary, the rate of return on public capital is positive at all stages of development, although higher for the countries least endowed with such capital and those growing at the fastest rate.

Keywords: Public capital, infrastructure, manufacturing, industrial development, cross-country regression.

JEL Classification: C23; D24; H54; L60; N60; O14

1. Introduction

The dominant components in a country's public sector capital stock tend to be related to infrastructure such as roads, telecommunications and energy. Other items include military and structures such as hospitals and schools. Coupled with the network function, which enables interactions between geographically dispersed economic agents, this suggests that public investment and its attendant stock could have a sizeable impact on economic growth, productivity and an economy's ability to structurally transform. Nearly all sectors' production one way or another depends on infrastructure as an input. In short, a country's prosperity may be positively related to public capital.

In 1994, the World Bank in its World Development Report strongly argued for the role of infrastructure in development (World Bank, 1994), a message which was recently repeated in its Growth Commission Report (World Bank, 2008) and also taken up by UNCTAD's Least Developed Economies Report series (e.g., UNCTAD, 2006). For example, the Growth Commission Report states that countries that devote more of GDP to public investment - notably countries in Asia—also grow faster than those that invest a little.[1] Investment in public capital is believed to crowd in private investment. But where does this strong belief in public investment come from?

One argument is that public capital enhances the productivity of private capital, raising its rate of return and encouraging more investment. However, the theoretical impact of public capital to some extent depends on the setting. In a neoclassical growth model, increases in the stock of infrastructure will only have transitory effect, since long-run growth is driven by exogenous technological progress. In an endogenous growth model, on the other hand, steady-state income per capita can increase from investments in infrastructure.

Barro's (1990) seminal endogenous growth paper introduces government expenditure as a public good in the production function and accomplishes exactly this. One could, therefore, say that public capital is the foundation upon which the economy is built, that it is an enabling resource. It acts as a network that connects spatially separated economic agents. To measure its economic

[1] An example is Latin America, for which Calderón and Servén (2004b, a) show that the continent is lagging behind the international norm in terms of infrastructure quantity and quality and that infrastructure is an important determinant of GDP per capita growth.

contribution, one would need to account for the full set of interactions that the network enables. As a consequence, the contribution might be large.

Are these arguments supported by evidence? The serious empirical literature on the role of public capital in economic growth essentially started with Aschauer's (1989) work on the United States. He found the impact of public capital investment to be large, actually too large to be realistic.[2] Gramlich (1994) argued that if the return to such investment is as large as suggested by Aschauer's results, everyone should be in involved in such investments. Alas, this is not the case. While the critics probably were right, an often neglected side effect is that it awoke a largely dormant and critically important research area.

In the beginning, the renewed interest in public capital primarily identified shortcomings in Aschauer's econometric approach, which were thought to be behind his large estimate. The critique ranged from spurious correlation, stemming from the application of nonstationary data to reverse causality and endogeneity. Corrections along these lines tended to reduce the implied rate of return, although some researchers seemed to rather confirm the existence of large returns.[3] In particular damaging to Aschauer's results seemed to be to control for federal states and, more generally, fixed effects. Controlling for fixed effects tended to drive the return down to zero (e.g., Holz-Eakin, 1994).

On the other hand, in the case of developing countries Devarajan et al (1996) found that public capital expenditure had a negative effect on growth. A possible explanation was that expenditures that are normally considered productive could become unproductive if there is an excess amount of them.

It is not easy to empirically assess the impact of public investment and it is problematic to know what the rate of return "should" be. For example, it seems reasonable to assume that the marginal

[2] On the other hand, Estache (2006), based on others' empirical work, reports the following expected economic returns to investment in, in turn, electricity generation, telecommunications and roads: more than 40 per cent, 30-40 per cent and 200 per cent (or 80 per cent when outliers have been excluded). In a simple correlation graph, the World Bank (1994) finds that a one per cent increase in the stock of infrastructure is associated with a one per cent increase in gross domestic product.

[3] For example, Abdih and Joutz (2008) address several of the econometric shortcomings, but nevertheless repeats Aschauer's large coefficient. In addition, they find that private and public capitals are complements with equal-sized coefficients. One interpretation of their result is that the large coefficient must have some other source than endogeneity and nonstationarity.

quantities of public capital consumed by firms are "free of charge" and it, thus, becomes an unpaid production factor when maximizing profit. McDonald (2008) makes the important point that there is little agreement on what a reasonable rate of return from public investment is. The System of National Accounts (SNA) assumes it is only equal to its depreciation rate, which does not seem right. Since the main part of public capital is infrastructure—for example, roads, bridges, and water and sewage systems—and has no market price, its gross return actually cannot be calculated.

Also, it is unclear what the returns to scale of the production function should be. Including public capital in a production function can lead to increasing returns to scale across all inputs, while firms face constant returns to scale in private inputs. Moreover, public investment tends to be lumpy, which could give rise to non-linearities. One could imagine that at low incomes, infrastructure is complementary and has higher pay-offs, while at high incomes, substitutions effects dominate and pay-offs are lower. Beyond a certain optimal threshold, public capital investments may result in a negative net benefit to society as economic and social benefits are exceeded by related costs (Agénor, Bayraktar and El Aynaoui, 2008).

Furthermore, lumpiness breaks the link between capital stocks and capital services. Linking infrastructure and growth through constant coefficients is not sufficient from a policy perspective. The crowding-in effect argued in the Growth Commission Report may well turn out to be crowding-out effects and in other cases maintenance spending could raise budget deficits.

Measuring public capital itself can be problematic. For example, Haque and Kneller (2008) argue that corruption inflates the level of expenditure on public capital projects, while lowering the return to that capital, for example, because of low quality. Corruption implies that a unit spending on public investment does not buy a unit worth of service. Investment may be based on who offers the best kickbacks to officials rather than who offers the best price-quality combination. Public investment-GDP ratios are higher in highly corrupt countries compared to low corruption countries, which could produce large coefficients. Public capital constructed from investment series can be overvalued because of inefficient governments, leading to higher costs of implementation than technically possible. In many developing countries public capital has unproductive uses (Pritchett, 1996). This, too, can explain large coefficients.

Another source of large estimates may be the composition of public capital. For example, in a road network, the marginal productivity of one link depends on the capacity and configuration of all links in the network. The consequence could be that only the average effect, and not marginal effects, is estimated (Fernald, 1999). Another difficulty is whether capacity is built in advance or as reaction to needs. Investment in infrastructure is likely to lead to contemporaneous growth only if the country is poised for growth, otherwise it only prepares the country for growth, but the effects should show up with a lag.

However, Rodriguez (2006) makes the following cogent point. Suppose there is a link between infrastructure and performance, but that it has an uncertain and variable timing. It could take time for firms to learn how to take advantage of infrastructure improvements, and such timing may depend on the precise type of project and sectors that it affects. The implication is that the relation is complex and it could be too much to ask for a precise estimate given existing data. Level estimations could then be seen as average impacts and not marginal impact. If that is the case, one would indeed expect a large impact. Estimations based on first differences—a proposed solution to one of the critiques—will miss all this and yield insignificant estimates.

One cannot help but observe that nearly all of the empirical work concerns aggregate growth. But one may conjecture that sectors that more intensively are dependent on public investment will experience greater benefit, thus, so that a large estimate may be defended. Therefore, this paper contributes to the literature by analyzing the role of public capital in fostering industrial development. In doing so, several alleged econometric shortcomings are addressed; in particular, reverse causality, endogeneity bias and accounting for omitted state-dependent variables. Another contribution is to examine whether the estimated impact differ according to the stage of development. This notion is "borrowed" from Hulten and Isaksson (2007) and entails estimating the impact for country groups—so called meta-countries created based on income levels—and investigating how the impact changes across development stages.

This work is based on a panel of 57 developed and developing countries and spanning the time period 1970 to 2000. Two principal questions are asked: The first is whether the long-run level of industry is caused by the level of public capital, while the second—more short-term in nature—is whether countries investing more rapidly in public capital also experience faster industrial development. And as said, do these two impacts depend on countries' stage of development?

The results clearly indicate that public capital matters. Public capital has strong explanatory power for why some countries have managed to industrialize, while others have not. Public capital matters at all income levels, but largely the impact is diminishing with higher income. There is also evidence that countries that have managed to embark on a convergence path—the Asian tigers—have done so partly thanks to public capital. Another key conclusion is that growth of public capital not only explains levels of industry, but also how rapidly it grows. Interestingly, the largest impacts occur for the fastest growing countries, i.e., the Asian tiger economies, and the High-income ones.

Another important result is that for all meta-countries it seems worthwhile to invest in public infrastructure, since the returns on doing so is always positive. The rates of return seem to be connected to the rate of development—a conclusion drawn because the Asian fast-growers exhibits the greatest rates of return—as well as the initial level of development, as suggested by the high scores obtained for the countries with lowest income. In the latter case, investment in public infrastructure pays itself in terms of industrial development in about two years. In both cases, the rate of return on public investment exceeds that of private capital. For the other three country groups—all of which have already had their growth spurts and accumulated a sufficient stock of public capital—the rates of return on public capital is below that of private capital.

The paper proceeds as follows: it starts with a brief review of the empirical literature. This review is based on milestones rather than going through every paper written on this topic. Thereafter, in Section 3, an empirical model of industrial development is formulated. Section 4 discusses how some of the econometric issues alluded to above are addressed, while Section 5 discusses the data and provides some descriptive statistics. Section 6 goes through the results and the conclusions are contained in Section 7.

2. A selective review of the empirical literature[4]

The literature on public capital and economic growth is large, in fact too large to be reviewed thoroughly outside the context of a survey paper. Therefore, to put this paper in context a selective review is carried out. It is selective insofar as that the discussion will evolve around milestones achieved. Some of those milestones refer to papers addressing econometric issues,

[4] More extensive surveys of the literature are provided by Gramlich (1994), who summarizes the "old" literature, Romp and de Haan (2005), who critically discuss assumptions of different approaches and Straub (2008), who tries to derive policy recommendations out of different approaches at different aggregation levels as well as match theory with empirics.

while others indicate new approaches or areas, all of which have a bearing on economic growth. Because infrastructure is the largest component of public capital, works that analyze composite indices of all infrastructure are addressed as well. It seems reasonable to start with Aschauer's (1989) work and continue from there.

Aschauer's starting point is an attempt at explaining the productivity slowdown related to the first oil crisis 1973-74. He pointed out that U.S. investment in infrastructure had slowed down starting in the late 1960s and that this could have had something to do with slowing productivity growth. To this effect, using OLS he estimated an aggregate production function augmented with public capital on U.S. data. The obtained estimates of public capital effect ranged from 0.38 to 0.56, which implied a rate of return of at least 100 per cent per year.[5] The implication of this rate of return is that an investment pays for itself in terms of higher output within a year. Although this obviously must be regarded as too high, also Holtz-Eakin (1988), Munnell (1990)[6] and Lynde and Richmond (1992)[7] soon confirmed this result[8] However, it was soon to be argued that econometric problems could be behind these large estimates and in what follows below, studies dealing with such problems are presented.[9]

Holtz-Eakin (1994) takes charge with several of these econometric issues. Based on the private sector output of 48 states between 1969 and 1986, he estimates state production functions including public capital. Starting with OLS, he confirms Aschauer's results, but when moving to panel-data estimators such as fixed- and random effects, he does not find support for positive spillovers. Correcting for endogeneity of public capital does not change his conclusions.

[5] In Aschauer (2000), he estimates an output elasticity of 0.24 for a set of 46 low- and middle-income countries over the period 1970-1990.

[6] For example, Munnell's estimated marginal productivity of public capital was about 60 per cent, which (1992) seems to agree with this statement.

[7] Their estimated output elasticity with respect to public capital is on average 0.20, which about half of that is obtained by Aschauer (1989).

[8] What is too high an estimate? In the case of infrastructure capital this is a difficult question because, generally, its services are not sold on the market. Furthermore, since it has public goods character, the majority of its benefits refer to hard-to-measure items, such as improved health and security, time saving and cleaner environment (Gramlich, 1994).

[9] Hurlin (2007) investigates the importance of such biases as well as the implications of moving from estimating production functions in levels to first differences. His conclusion is that the production function approach does not generate reliable estimates of the genuine rate of return on public investment. Two biases are identified, namely, endogeneity bias and the presence of a common stochastic trend shared by all nonstationary inputs, both of which lead to an overestimation of the impact of public capital. First differencing, however, may lead to erroneous inferences as well by rejecting the hypothesis of a positive contribution of public capital.

However, he does not go as far as to claim that public capital does not provide any benefits at all, it is only benefits in excess of direct provision that find no empirical support.

Using in principle the same data and time period as Holtz-Eakin, Henderson and Ullah (2005) confirms Holtz-Eakin's results when based on parametric methods. However, the purpose of their paper is actually to introduce some new nonparametric estimation techniques and based on those the authors are able to establish a significant positive public capital elasticity amounting to 0.15. Although it is smaller than in the aggregate case, it is far from non-egligible. The authors' explanation provided is that the Cobb-Douglas production function fails to capture the non-linearity inherent in the relation between public capital and production (and the rest of the underlying technology) and by taking this into account a positive and statistically significant relation is re-established.

Another study that seriously addresses the issue of spurious regression is Everaert (2003). In a time series analysis of Belgian data for the period 1953 to 1996 he finds support for the notion that the decline in public capital investment has reduced steady-state real output. What is important is the fact that public capital appears to be integrated of second order, which means that first differencing would not be enough to render the series stationary. In any case, the author finds that the output elasticity is only approximately 0.14, which is much smaller than the early findings reported for the United States. Unfortunately it is difficult to generalize from this paper, as it is fairly uncommon for capital stock to be I(2).

Dessus and Herrera (2000) is a third paper that seeks to address the issue of spurious regression by using panel data and endogenize public and private capital in a three-stage least squares framework after carrying out a within transformation of the data. Furthermore, they define public capital stock based on a broad definition of state ownership. The sample consists of 28 developing countries observed from 1981 to 1991. The estimated impact ranges from 0.11 to 0.13 depending on whether or not constant returns to scale is imposed and gives a rate of return to public capital equal to 14.2 per cent, which is much lower than that obtained for the United States. Nevertheless, public capital is seen to be an important contributor to long-term economic growth.

Duggal, Saltzman and Klein (1999) instead incorporate infrastructure into the production function as part of the technological constraint, i.e., as a determinant of total factor productivity (TFP).

This is in line with the approach of Hulten and Schwab (2000). The estimation is carried out using two-stage least squares and infrastructure is measured as core infrastructure, which is dominated by highways and streets but also includes "other buildings" and "other structures". It turns out the estimated elasticity 0.27 is very close to Aschauer's 0.24 when the latter only included core infrastructure. The authors also demonstrate that the contribution of technological advances and of infrastructure are interactive rather than additive, further boosting the importance of infrastructure. Finally, it is also shown that the impact is non-constant over time. One conclusion is that improving on the theoretical underpinnings does not seem to help much in reducing the size of the elasticity.[10]

Kawaguchi, Ohtake and Tamada (2009) include public capital in a first differenced state production function, estimating the impact for 47 Japanese prefectures between 1994 and 1999. The authors find a rather innovative instrument in the directly elected number of members in the House of Representatives, arguing that the electoral reform in 1994 is a natural experiment leading to exogenous variation of public capital across regions.[11] Standard OLS estimates indicate that a 10 per cent increase in public capital is associated with a 0.4 per cent rise in output per labour hour. However, because of a perceived correlation between public capital and prefecture unobserved heterogeneity, the authors resort to first-difference estimation, leading to a statistically insignificant estimate of -0.16. Correcting for endogeneity bias reduces this estimate further to -0.38, although based on the test results regarding the endogeneity of public capital—the statistical test actually suggests that public capital is exogenous—their preferred result turns out to be -0.16. In other words, the authors find no support that public capital is productive. Munnell's (1992) criticism of U.S. studies that the use of first differences destroys any long-run relation between public capital and production or productivity applies here as well.[12]

Pineda and Rodriguez (2006) are also creative in finding exogenous instruments for public infrastructure, namely, one that is based on the interaction between changes in national tax collection and a rule regarding how much each state and local government receive of total

[10] In a later paper Duggal, Saltzman and Klein (2007), the same authors add information technology to the estimation, but the important role played by infrastructure in their 1999 paper remains.

[11] Perhaps the most difficult task involved in measuring the impact of public capital, as well as in many other econometric applications involving endogenous regressors, is that of identifying appropriate instruments. Their paper seems innovative in this respect.

[12] Her argument was that it is the long-term relation between economic performance and public capital that is of interest. By taking first differences, only short-term relations can be estimated. Furthermore, there are several reasons why estimated contemporaneous relations may turn out to be statistically insignificant.

national value added tax revenues. Both parts of the interaction are exogenous to state-level productivity and the variable serves as an indicator of exogenous changes in infrastructure investment. Another interesting aspect of their paper is that they actually focus on the manufacturing sector, albeit at the plant level, in Venezuela. Unfortunately, the authors do not provide any information on the time period or the number of firms, but the maximum total number of observations used in the estimations is 8,865. The results show that a 10 per cent increase in public investment leads to an increase in productivity of the manufacturing sector between two and 3.5 per cent. This turns out to imply that the government would recover 72 per cent of the initial investment every year, which seems excessively large.

In a study on South Africa, Fedderke and Bogetic (2009) investigate the impact of fixed capital stock of infrastructure, measured as public capital stock, on productivity growth. The data they use are aggregate and three-digit manufacturing sector data; however, only results for the manufacturing sector will be reported. For the latter, the authors employ a panel data set in the estimation with observations from 1970 to 1993. In terms of estimators, they estimate the relation with based on instrumental-variables as well as without control for the endogeneity of public capital. The authors distinguish between direct and indirect effects, where the former concerns labour productivity growth and the latter TFP growth based on value added production functions.

Generally, the instrumented elasticity of labour productivity with respect to different measures of infrastructure in this study is higher than in the non-instrumented case. This means that instrumentation tends to inflate the estimates, contrary to what the expectation might have been. The estimated elasticity of public capital is 0.19, suggesting a strong and economically important direct effect. In the case of TFP growth, the elasticity is no longer significant and is even negatively signed (-0.05). This might suggest that public capital works positively through factor accumulation, but has a negative effect on technological progress, at least in South Africa. However, it could also point to problems with the selected instruments. Unfortunately, there is no discussion of this in the text.

A paper with doubts on the production function approach is McDonald (2008), who uses a provincial panel for Canada, with data spanning the time period of 1981 to 2005. He starts by estimating a Cobb-Douglas production function with constant returns to scale, adding public capital to labour and private capital. This addition does not seem affect the elasticities of labour and private capital, but induces a small increase of TFP. He, then, goes on to argue that it is difficult to disentangle the impact of public capital from that of overall productivity growth. The reason is that public capital and TFP are found to be related and are capturing similar features of real GDP. To the extent that the impact of public capital is captured by TFP, no measurable impact is obtained. On the other hand, if element of TFP are instead captured, the impact of public capital will be overestimated. Econometric estimation, therefore, involves multicollinearity. The consequence is that accurate estimation of the rate of return to public capital is made impossible. The solution requires a different approach, for example a cost function, where the unpaid factor affects the level of the variable cost curve. Furthermore, he argues that cost functions tend to produce smaller effects of public capital than do production function and, thus, appears more reasonable. The author obtains an elasticity of between 0.10 and 0.15 and rate of return amounting to a mean of 17 per cent, however, ranging from 5 per cent to 29 per cent.

Another critic of the production function approach is Morrison and Schwartz (1996). They argue that the theoretical framework underlying the production function approach is too limited for a proper evaluation of the impact of public infrastructure. In particular, the treatment of public capital as a factor input like labour or private capital violates standard marginal productivity theory, since the per unit cost of it is not determined in the market. Instead they propose the use of a cost-function and apply that framework to 48 states' manufacturing productivity performance between 1970 and 1987. Their estimates suggest that the return to infrastructure is significant, although lower than those found by the aforementioned researchers. The range of estimated impact is 0.192 in Northern states to 0.622 in Southern states on average. Furthermore, the impact declines in all regions over time and the authors attribute that to slower growth of public capital.

Lynde and Richmond (1993) obtain similarly strong support for the aggregate economy using a translog cost function. They also find that private capital and public capital are complements rather than substitutes. Nadiri and Mamuenas (1994) employ industry-specific (2-digit) translog cost functions and obtain a significant elasticity for public capital in 11 out of 12 industries, albeit much smaller estimates than did Aschauer (1989).

Mamatzakis (2007) turn to a flexible cost function instead of the production function approach, suspecting such an approach is able to deal with some of the alleged problems associated with the former approach. An advantage of the study is that it directly addresses the role of public capital for Greek manufacturing industries at the ISIC 2 level. For the estimations, iterated three stage least squares is used, using lagged values of variables as instruments. It is found that public capital is cost-saving for most industries, with a one per cent increase in public capital reducing cost by between 0.039 to 0.4 per cent. Traditional labour intensive industries, such as Tobacco and Furniture seem unable to take advantage of public capital service provisions. The implication is that capital intensive sectors benefit more from such services.

A series of papers look at the relation between public capital and TFP. The work by Hulten and Isaksson (2007) suggests that determinants function differently at various stages of development. For example, in cases where there is road network, the construction of it could have a large effect on industry and overall economic development. But if there is also such a network, building another one or adding to an existing one is likely to have a much smaller effect. This is simply the law of diminishing returns at work. Hence, in addition to explaining industry differences and industrial development across countries, the paper tries to account for stages of development and implicit nonlinearities involved.

The authors estimate the relation between TFP and public capital using several estimators "ranging" from OLS to instrumental-variables versions of fixed- and random-effects. For the entire sample, while the fixed-effects estimator reduces the coefficient to 0.2, from the OLS one of 0.27, controlling for endogeneity bias increases the point estimate to 0.42. That is, a 10 per cent increase of public capital raises TFP by 4.2 per cent. Turning to meta-countries, the largest coefficient is obtained for Low incomers and then falls as income rises, with a statistically insignificant coefficient for High incomers. For the Asian tigers, the parameter is not statistically insignificant, but also negatively signed.

Destefanis and Sena (2005) investigate the role of public capital for regional TFP differences (1970-98). They essentially think of public capital in terms of infrastructure. The channels they are interested in are the following: 1) public capital can raise the productivity of private capital. The idea is that public investments allow for technical progress to be incorporated in the production, 2) investments in public capital may favour specialization in sectors/technologies with higher productivity, such as industry. They estimate elasticities of 0.17 and 0.12 for core and total infrastructures, respectively, with a larger impact in the laggard Southern regions of Italy. This is in contrast to many similar studies for the United States, which tend to find an insignificant impact. This could be due to better estimation techniques.

Bronzini and Piselli (2006) try to explain the level of TFP of Italian regions over the period 1980 to 2001 using, inter alia, public capital as a determinant. The issue of spurious regression is addressed by way of panel cointegration techniques, while also controlling for endogeneity bias. The authors find that public capital cointegrates with research and development (R&D) and human capital, with the latter exerting the strongest effect on TFP. They also find that public capital Granger-causes TFP and that the direction of causation is one-way only and, thus, public capital is exogenous. A 10 per cent increase in the public infrastructure of neighbouring regions leads to 1.1 per cent increase in TFP. Based on data for 2001, the authors move on to compute the average regional rate of return to public capital, which is 0.23.

Gu and McDonald (2009) start from the premise that public capital is not part of the TFP calculation. However, following the reasoning in McDonald (2008), it can effectively end up becoming part of TFP. Therefore, they first compute the contribution of TFP growth to GDP per hours worked to be 19 per cent annually on average from 1962 to 2006. Of this, 50 per cent is accounted for by public capital. From the perspective of TFP, this is a very large effect, but in terms of labour productivity the impact is only some 10 per cent, which seems more reasonable. In other words, technical change is only contributing a maximum of some 10 per cent to labour productivity growth.[13]

A different approach based on the New Economic Geography literature is adopted by Fingleton and Gómez-Antonio (2009), who test Aschauer's hypothesis for the Spanish economy at province level between 1985 and 2001. The authors estimate a wage equation, with wage proxying for productivity, using a spatial model with fixed time and province effects. The results indicate a positive impact of public capital on the level of productivity. A 10 per cent increase in public capital induces almost 1.8 per cent increase in productivity. This result is robust to several changes to the model specification. Another finding is that of negative spillovers to nearby provinces, which they interpret as a competition effect from neighbours.

Devarajan, Swaroop and Zou (1996) develop a growth model to show that the composition of public expenditures ought to matter for growth, with the expectation being that capital expenditures such that infrastructure should be positive correlated with growth, while current

[13] The term maximum is used because the residual is likely to also contain other components that are not technology per se. Isaksson (2007), however, suggests that many of those components are, nevertheless, related to changes in technology and the residual could, therefore, be seen as an item that is related to technology, though not necessarily technology itself.

expenditures may be negatively correlated. To this end, they use annual data on 43 developing countries from 1970 to 1990, estimated using OLS. By measuring the dependent variable, growth of real GDP per capita, with a five-year forward lag structure they hope to address the joint endogeneity of growth and public expenditures as well as reverse causality. They obtain the rather unexpected result that current expenditures increase the growth rate, while capital expenditures reduce the rate of growth. Similarly, using components of expenditures the coefficient on transport and communication is statistically significant and negative. Checking this result against a sample of 21 developed countries the conclusions are reversed and in line with a priori expectations. The same result sometimes applies to transport and communication, but seems to depend on the specification. The results, with the important exception of transport and communication, which is statistically insignificant, remain similar when using the fixed-effects estimator. The authors interpret the results to mean that governments in developing countries have been misallocating public expenditures in favour of capital resulting in an overprovision of such public capital and unproductive, at least at the margin.[14]

Finally two papers based on cross-country regressions. Easterly and Rebelo (1993) for some 100 developed and developing countries for the period 1970 to 1988 proxy public investment with such investment in transport and communication. After having collected and constructed new public investment data at aggregate and sectoral as well as different levels of government, and constructed decade-average public investment ratios, the authors regress decade-average per capita growth on this variable. The finding is that transport and communication investment is consistently positively correlated with a coefficient ranging from 0.59 to 0.66, which is large. The coefficient obtained for general government investment is, at 0.4, much smaller. By way of instrumentation to get at reverse causation, they find that the coefficient increases to 2, while the coefficient for general government investment is 0.7. Although the authors are disturbed by the size of the estimated coefficients and suggest that more work is needed, they conclude that causality runs from infrastructure to growth.

Based on principal components analysis, Calderón and Servén (2004) construct an infrastructure composite, consisting of information on telecommunications, electricity-generating capacity and

[14] Using more advanced estimation methods and explicitly accounting for heterogeneity in public spending across 15 developing countries, Gregoriou and Ghosh (2009) essentially replicate the results of Devarajan et al (1996) for the time period 1972 to 1999. Most importantly, however, they show that the point estimate for capital and current spending, respectively, range from -0.56 to -1.18 and 1.18 to 17.32, both quite substantial.

roads. Because these infrastructure components are fairly exhaustive, this is akin to including a stock of public capital in the regressions. In their analysis, the authors cover the time period 1960 to 2000 and 121 countries. In addition, they construct an indicator of infrastructure quality services based on waiting time for telephone main lines, percentage of transmission and distribution losses in the production of electricity and share of paved roads in total roads. They then regress growth of GDP per capita on a set of controls and the two infrastructure composites employing several estimators, including their preferred GMM-systems estimator of Blundell and Bond (1998). Independent of estimator, the stock of infrastructure enters significantly and with a positive signed coefficient, while the quality composite is only significant in one case but then with a clearly smaller parameter.[15]

To summarize, large estimates are generally obtained when regressing output or productivity on public capital, an estimate that tends to go towards zero when first differences are used instead of levels. It may be the case that cost functions deliver more reasonable estimates, but there are several econometric issues to deal with. Some of these include endogeneity bias, reverse causation and omitted state-dependent variables. Very few papers focus on industry or industrial development. Likewise, only a few consider stages of development concerns. It is there that this paper contributes to the literature.

3. Determinants of industrial development

The empirical literature of international income level comparisons and economic growth has evolved in two important directions. The first relates income and its change to so called deep determinants. These determinants essentially include measures of institutions (e.g., Acemoglu, Johnson and Robinson, 2005), geography (e.g., Sachs, 2003), human capital (e.g., Glaeser, LaPorta, López de Silanes and Schleifer, 2004) and international integration (e.g., Frankel and Romer, 1999). The second strand has focused more on proximate determinants, or a combination of deep and proximate determinants. The latter empirical literature has evolved into an industry. For example, more than 100 different determinants in various settings and have been shown to be statistically significant.

Interestingly, this literature has somewhat evolved with industrialization, and subsequent development into knowledge and services economies in the industrialized world. What is

[15] Calderón (2004) repeats the exercise for 93 countries for 1960-2005 for the composites of infrastructure stock and quality and essentially confirms the results of Calderón and Servén (2004).

sometimes left behind, then, is the important linkage between sectors, for example, that between manufacturing and agriculture. Therefore, to the deep determinants variables, agricultural labour productivity, which comes from the industry and structural change literature, is added (e.g., Lewis, 1954; Hirschman, 1958; Rostow, 1960; Chenery, 1986; Syrquin, 1986). By calculating the changes of these variables over time, also an industrial development model is obtained and those are the two empirical models to be estimated.[16]

The role of agriculture in furthering industry is interesting and statistical links between the two sectors seem to be the norm rather than the exception. On the one hand, improved agricultural productivity can be viewed as releasing resources, especially labour input, to manufacturing. Jorgenson (1961) and Sachs (2008) state that without technological progress in the agricultural sector, a modern sector might not even prove viable. The argument is that only when agricultural productivity is high—implying that a farm family can feed many urban citizens so that not each resident has to feed itself—can a significant share of the population become urbanized and engage in manufacturing production. Agriculture could then be seen as pushing industrial development. However, if the migration leads to shortage in food production (forward linkages) or the two sectors' marginal productivities converge agricultural growth can constrain manufacturing growth (Fei and Ranis, 1961).

A sectoral link can also develop because manufacturing productivity exceeds that of agriculture and, therefore, pulls labour out of the latter sector. This view holds that the marginal productivity of labour in the leading modern sector (i.e., manufacturing) much higher than in the laggard one (i.e., agriculture). In fact, because of unlimited supply of labour in agriculture, the marginal productivity there is extremely low, if not negligible. Labour, therefore, has a wage incentive to migrate from agriculture to manufacturing, allowing the modern sector to further grow and develop the economy (Lewis, 1954). Whichever effect—push or pull—that dominates, the link between the sectors has to be accounted for.

There are additional reasons linking the two sectors. The agricultural sector's exports provide foreign exchange, which can be used to import material and capital goods to industry. Furthermore, with a functioning banking sector, successful agricultural savings can be channelled to and invested by industry. Redistribution of agricultural surplus can be taxed and provided as

[16] Note that geography will not be explicitly accounted for, since it will be captured in the panel-data analysis by the country-specific effects.

support to manufacturing. Industrialization also raises demand for agricultural goods (Johnston and Mellor, 1961).

Agriculture is also a client of manufacturing. For example, fertilizers are important inputs in agricultural production so backward linkages are thus important. A slow-growing agricultural sector can, therefore, act as a drag on manufacturing. The expected estimated coefficient, hence, is not unequivocally positive.[17] That agricultural performance and industrial development are linked should be beyond doubt, but it is neither the purpose of this paper to sort out the causal direction of the link, nor whether that link is positive or negative.

Breisinger and Diao (2008) give an example where public investment in irrigation and infrastructure supported the introduction of modern technology in agriculture, which changed farmers' savings and investment behaviour: the Green Revolution. In the same vein, roads and distribution systems lower the costs of using technical inputs by geographically dispersed firms and households (Restuccia, Yang and Zhu, 2008). The public sector also supports technological development in different ways. It is, in particular, large projects characterized by indivisibilities, or lumpiness, which need support from the public sector. Murphy, Schleifer and Vishny (1989) even show that private investments might not occur unless the state can credibly demonstrate that is will undertake its investments.

There are several reasons to expect human capital to enter with a positively signed coefficient. For example, increased human capital leads to improved productivity, both in sectors and overall. It allows for operating more complicated tasks and producing outputs that are "high-skill". Human capital could also imply positive externalities along the lines of Lucas (1988). Foreign direct investments (FDI) tend to locate in human capital rich places. Benefiting from FDI knowledge externalities and technology transfer requires that domestic firms have sufficiently high human capital levels, i.e., absorptive capacity. Widespread human capital will also increase the scope that new technologies are, in the words of Basu and Weil (1998), appropriate. Industries

[17] Based on a multivariate causality framework in a panel setting, Awokuse (2009) is able to establish strong evidence supporting the notion that agriculture is an engine of economic growth, thus suggesting that agricultural labour productivity should be causing manufacturing performance. See also Pinstrup-Andersen and Shimokawa (2006) for reasons why agriculture could be a driver of growth. The same paper discusses how insufficient infrastructure is one of the key bottlenecks for utilization of agricultural research and technology by limiting farmers' options and agricultural output. With good rural infrastructure, economic returns to research and technology tend to be high. By contrast, Alvarez-Cuadrado and Poschke (2009) find evidence in support of manufacturing-led structural transformation.

unable to learn, adopt and adapt new techniques and technologies will be unable to move up value chains.

International integration is hypothesized to exert a positive impact on industrial development. Small domestic markets hold back industry in many developing countries. Opening up to trade and creating exports opportunities offers scale effects. This can, for example, come about by being able to lower unit costs of material by buying large amounts or producing at minimum efficient scale. Although the evidence is limited, there seems to be some scope for learning from exporting, at least for low-income countries (Bernard et al, 2007). Furthermore, competing with foreign producers may force domestic firms to become more efficient. Working with customers in industrialized countries may also give rise to knowledge externalities. Earning foreign exchange also means increased ability to import capital goods and materials from abroad at international prices that may be lower than those offered at home.

It is also clear from a massive amount of work that institutions and their quality play a role for development. Institutions reduce the uncertainty of economic interaction, increasing market efficiency and promoting long-term large investments (North, 1990). This also applies to the case for industry. For example, Rodrik et al (1994) discuss how institutions can create incentives that lead to innovation and new technologies. Much of such activities is intrinsic to manufacturing production and drives industrial development and, thus, increases the contribution of industry to aggregate productivity performance. Investments in transport infrastructure are large, lumpy and sunk. As such, and to the extent that such investments are carried out by private investors and unless ownership of property used as collateral can be secured, incentives to invest will be thwarted and investment held back. Institutional quality is, therefore, likely to have an impact on industrial development as well as on the amount of railway and roads.[18] To this end, impartiality of courts is crucial. The role of institutions for industrialization is highlighted in, for example, Botta's (2009) model on structural change and economic growth.

Jones (2008) discusses how corruption that leads to poor transport infrastructure reduce output in all affected sectors, including construction. Declining output in construction, in turn, reduce the output of transport infrastructure. Thus, there are important knock-on effects on further development of such capacity. Jones calls this a multiplier effect. This is true for other

[18] An example of this connection, and running over politics, is suggested by North and Weingast (1989) and finds empirical support in Bogart (2009).

complementary inputs as well, but not all of them are equally important to deal with in terms of their damaging effects on production. And the more sectors that are linked to the transport network, the more important it is for overall output and development. In developing countries many things at the same time tend to be fraught with problems, and transport infrastructure is often one of those.[19]

Finally, countries without a coastline or sea navigable rivers, and location in the tropics or in disease-stricken areas, find it relatively difficult to develop. The direct impact on industrial development is probably smaller than on agriculture. However, industry suffers indirectly through its linkages with agriculture and unfortunate geographical location may, therefore, hamper industrial development. Geography, through proximity to buyers, also affects exports in that the longer the distance, the smaller the export opportunity.[20]

4. Modelling strategy

The econometric model has to address a number of issues raised in the literature. These include spurious correlation due to nonstationary data, omitted state-dependent variables, endogeneity bias and reverse causality, of which the latter three may all cause overestimation and will, therefore, receive particular attention in this paper.

On the issue of spurious correlation, Hulten and Schwab (1991) estimate the relation between TFP and infrastructure using first differences. While applying first differences addresses non-stationarity in the data, it also removes the long-run relation between the variables of interest. More specifically, instead of estimating the impact of increasing the stock of infrastructure on, for example, manufacturing, it is the impact of increasing the growth rate of infrastructure on TFP growth that gets estimated. In other words, the analysis shifts from levels and long-term to one of growth and short-term. Unfortunately, there is no reason to believe that the short-term impact should be the same as that in the long-term. A better solution, which also preserves the long-run information of the data, is that of Canning and Pedroni (2004), who apply panel co-integration

[19] Other features of the state, such as democracy and budget balance, although important in themselves, are not the focus here. For example, work by Acemoglu (2005) and Alesina provide serious discussions to that end.

[20] Geography, measured as proximity in kilometres to nearest coast or sea navigable river, included in ordinary least squares and random-effects estimations was statistically significant with a positively signed coefficient. The implication is that good geographic conditions are conducive to industrial development.

techniques and establish a long-run relation between infrastructure and income per capita. Their finding of co-integration will be assumed to hold also for this paper.

To address omitted state-dependent variables, some researchers, for example Holtz-Eakin (1994), have used panel-data estimation techniques, such as the Fixed-effects (FE) estimator.[21] The country-specific effects can be interpreted as omitted initial conditions, for example the initial stock of infrastructure or, more generally, as a way to account for the initial development level. Furthermore, the country-specific effects capture omitted state variables, such as geography and cultural traits.

The advantage of the FE estimator is that it can handle the issue of omitted variables that may be correlated with infrastructure. Failing to do so will affect the estimated coefficient. To some extent, FE also helps mitigate the adverse consequences of endogeneity bias. For example, because public investment in transport infrastructure is likely to be tax-financed, richer countries tend to have bigger infrastructure stocks. An example is foreign aid used to finance public investment, which is allocated predominantly to the poorest developing countries.

But there is a problem with the FE estimator, namely, that it only accounts for the within country variation. As such, it ignores statistical variation between units, which, in some cases, may be the most relevant. Furthermore, it is not clear to what extent public capital varies over time within countries. This provides a rationale for the Random-effects (RE) estimator. However, it should be noted that the potentially implausible assumption of zero correlation between explanatory variables and the country-specific effects may render the estimate biased.

With these issues in mind, this paper attempts to account for both between and within variation by employing both the FE and RE estimators. Endogeneity bias and reverse causality are dealt with by application of instrumental variables (IV) versions of FE and RE. All estimation methods are applied to both levels and growth regressions.

[21] To some extent, this estimation method addresses nonstationarity as well, since, in the within form, deviations from the mean are used.

The regression analysis commences with an OLS benchmark estimation:

$$MVApc_{it} = \beta' X_{it} + \lambda' Z_{it} + \varepsilon_{it}, \tag{1}$$

where X is a vector including agricultural labour productivity, manufacturing exports per capita, human capital and institutions, and Z is a vector of transport infrastructure and ε is the standard i.i.d. residual. The FE and RE counterpart of (1) yields:

$$MVApc_{it} = \beta' X_{it} + \lambda' Z_{it} + \eta_i + \varepsilon_{it}, \tag{2}$$

where the additional parameters η_i represent unobserved country-specific effects, be they fixed or random.

In the IV versions of (2), the possibility that infrastructure Z_{it} is endogenous and causality running in the "wrong" direction are acknowledged and addressed. The instrumentation of infrastructure is meant to address these two issues. The vector Z_{it} is then replaced with the fitted counterpart $\tilde{z}_{it}$

$$MVApc_{it} = \beta' X_{it} + \delta' \tilde{z}_{it} + \eta_i + \varepsilon_{it}. \tag{3}$$

The instrument vector I_{it} includes external variables proposed and found reasonable by Canning (1998). The external instruments are lags 1-3 of population size and urban population density, and the growth of these variables. There are also internal instruments, namely, the other assumed exogenous explanatory variables X_{it}. Again, lags 1-3 are used. In addition, in the levels regression lags 1-3 of transport infrastructure growth is included, whereas in the growth regression, lags 1-3 of the transport infrastructure level replaces its growth counterpart. Admittedly, the choice of lag length is entirely arbitrary, but is kept low to preserve degrees of freedom.

Unfortunately, it is possible to argue that some of the external instruments chosen are correlated with manufacturing growth. For example, structural transformation often goes hand in hand with both manufacturing growth and urbanization. However, the level of urbanization or population should not present such a problem in the FE estimation, since the country-specific effects presumably accounts for that. Population growth and the rate of urbanization should also to a lesser extent be correlated with the level of manufacturing, although one may conceive of a situation where relatively rich countries have a slower growing population and high manufacturing per capita.

Easterly (2009) argues population size is not necessarily a bad instrument because there is a small-country bias in foreign aid such that smaller countries receive more aid on a per capita basis as well as higher aid as a ratio to their income. Because aid is often used to fund large infrastructure projects in developing countries, at least for IV-regressions involving such countries population size might actually work well. Furthermore, Easterly also claims that the literature has been unable to show that population has any scale effect for economic growth—for which manufacturing ought to be significantly important—which gives some additional support for using population as an instrument.

The final instrument vector is decided through a sequence of tests. In the first step, all instruments and their three lags are included in a regression. The error from this regression is then included in a second step regression to test for its statistical significance using a simple T-test. If the error term is statistically significant at conventional levels, infrastructure is deemed endogenous. To decide whether an instrument is valid, each variable in turn is tested, where statistical significance occurs at a T-value of at least 3.30. In addition, lags 1-3 of each variable are jointly tested—for example, lags 1-3 of population size—as is all lags of each variable, for example, the first lag of all instruments. In this case, the F-value needs to exceed 10 (Hill, Griffith and Lim, 2008). In each step the vector of instruments is tested using Sargan's over-identifying test, since too many instruments may overfit endogenous variables.

If, in the first step, the residual is statistically insignificant and none of the T- and F-test is statistically significant, the test process stops and infrastructure is deemed exogenous. However, to be sure no mistake has been made—after all there are strong priors that infrastructure is endogenous—a biased view against infrastructure being exogenous is introduced. This is done by continuing the test procedure with those variables that are statistically significant at conventional levels, but have T-values below 3.30. It turns there are only a few cases when the original test procedure erroneously leads to the conclusion of exogeneity, but when that occurs infrastructure is taken to be endogenous. Finally, it is ensured in the first stage regression that the instruments chosen indeed all are statistically significant.

Equations (1) to (3) are estimated in levels and first difference form to answer whether the level and growth of transport infrastructure help explain cross-country differences in manufacturing levels and rates of industrial development.[22]

5. Data

Data on manufacturing value added per capita are drawn from UNIDO's World Productivity Database (Isaksson, 2010). These cover between 57 advanced and developing countries annually from 1970 to 2000, with the number of countries actually used in the estimations being a function of the combined data availability of the right-hand side variables and instruments remaining in the final specification. The panel is unbalanced in the sense that some countries are observed for shorter time periods only. Table 1 shows the list of countries in the dataset.

Public capital is measured as using the perpetual-inventory method with a common across countries depreciation rate of three per cent and is taken from Hulten and Isaksson (2007).[23] Appendix III provides a more detailed discussion on its calculation and data sources. Human capital (H) is measured as the average attainment level for the population aged 15 and older (Barro and Lee, 2000). A measure for institutions (INST), proxied by economic freedom, is supplied by Gwartney, Lawson and Emerick (2003). Finally, agricultural labour productivity (AGR) and manufacturing exports (MEXP) are in constant US$ 2000 and are obtained from the World Development Indicators (2007).

In order to analyse whether countries' stage of development matters for the role of infrastructure, the countries are grouped according to their year 2000 income levels—High, Upper-Mid, Lower-Mid and Low—but with a special group consisting of fast-growing Asian countries, for simplicity called Tigers. These groups of countries are called meta-countries. The latter group of countries

[22] In the case of first differences, the issue of nonstationarity disappears unless the data have two roots. Although this could be the case for the fast-growers for *some* period of time, on average this does not seem to be a major issue.

[23] Pritchett (1996) argues that the (monetary) value of public investment may contain little information regarding the efficiency in implementing investment projects, especially in developing countries. According to his estimates, only about little more than half the investment makes a contribution to the stock of public capital. Consequently, public capital stocks are likely to be overestimated, which may affect the estimated impact of it. Furthermore, if the composition of the stock matters because the marginal productivity of one link depends on the capacity and configuration of all links in the network, it is not clear whether it is the average or marginal product of additional roads, telephone lines or electricity-generating capacity today that is being measured (Fernald, 1999). These issues may be useful to bear in mind during the analysis.

may be of particular interest for their ability to sustain good economic growth for an extended period of time. The question is, did investment in public capital have anything to do with that growth? For the level, or long-term, analysis annual data in logs are used. The industrial development part of the paper uses the first difference of those data and, hence, pertains to industrial growth or, short-term variations.

Table 2 contains a collection of summary statistics for the entire sample. It is readily seen that the range of manufacturing value added per capita across countries is large. This is also the case for public capital, agricultural labour productivity and manufacturing exports, while those of human capital and institutions appear to vary less. Although this does not necessarily imply a correlation between manufacturing and public capital, this is, indeed, the working hypothesis of this paper.

For all variables but human capital, the range of growth rates start from the negative territory and reaches fairly high levels. For example, average manufacturing growth per capita reaches as high as 9.9 per cent, which incidentally is quite close to the figures of public capital. The highest mean growth rate occurs for public capital (4.8 per cent), followed by agricultural labour productivity (2.7 per cent), manufacturing per capita and manufacturing export (both the latter at 2.3 per cent). The slowest growth, as expected, is registered for institutions, which only grows at an average speed of 0.7 per cent per annum.

Ratios between the stocks of public capital across meta-countries are large and add fuel to the notion of performance gaps between industrialized and non-industrialized countries (Table 3). Again a correlation between manufacturing performance and public capital is discernable. Tigers attain 6.33 per cent of High incomers' manufacturing levels, while their level of public capital is just over 12 per cent. Upper-mid Incomers attain as much as 31 per cent of High Incomers public capital, but only 19.79 per cent of the same group's manufacturing level. The other developing countries lag much behind in both categories. For example, Low incomers only attain 1.68 and 4.88 per cent, respectively, in terms of manufacturing value added and public capital. The corresponding ratios for Lower-mid Incomers are 7.12 and 11.42 per cent. Although this appears pessimistic, some comfort may be found in the work of Yepes, Pierce and Foster (2009), which suggests that convergence in infrastructure, may be underway.

The Annex contains two sets of two-way illustrations: the first for levels and the second for growth. A casual look at the levels illustrations suggests that the steepest slopes, i.e., largest parameters, will be found for public capital, agricultural productivity, manufacturing exports and human capital, but that the parameter of institutions will be positively sloped too. The growth illustrations are more difficult to decipher. However, accumulation of public capital, human capital and agricultural productivity growth and, possibly, institutions are positively related to industrial development, while change in manufacturing exports looks fairly flat. Multivariate regression analysis will sort out whether these two-way relations will continue to hold or whether they also capture other features shared by other relations.

6. Regression analysis

There are two sets of results to present. The first set concerns explanation of cross-country differences in manufacturing per capita levels. In other words, why do some countries have higher manufacturing levels than others? In the second set of results, the enquiry concerns why some countries' industries grow faster than others'. Both sets of results start by analyzing pooled datasets, an analysis that is immediately followed by results based on meta-countries.

6.1. Manufacturing levels per capita

6.1.1. All countries

Table 4 contains the results of five estimators: Ordinary Least Squares (OLS), Random-effects (RE), Fixed-effects (FE) and instrumental variables versions of the latter two (RE-IV and FE-IV). OLS, which is based on pooling the data across time and space, is the benchmark estimation, while RE and FE estimators, both panel-data estimators, are used to control for omitted country-specific effects (e.g., geographical features). The latter estimator also accounts for correlations between such effects and public capital as well as with other explanatory variables, while the former assumes away such correlations. In contrast to OLS and RE, the focus of the FE estimator is on the within-effects, that is, the impact within, in this case, countries. The rationale for employing the RE estimator in addition to FE, despite its obvious shortcomings regarding the assumption of zero correlation between country-specific effects and the explanatory variables, is that it weighs in between-country variation, which is ignored by FE. Although fixed effects can mitigate endogeneity bias, the obvious objection of public capital being endogenous is more properly addressed using RE-IV and FE-IV.

To the vector of control variables already discussed—AGR, MEXP, INST, and H—a trend variable (T) is added to account for technological change common to all countries.[24] Because public capital is expected to have profound long-term effects on technological change, the trend variable enters in interaction with public capital (TINT). A simple interpretation of TINT would be to understand it as an indication of how the impact of public capital has changed over time. A more interesting one is that public capital affects the influence of technological change on manufacturing. Yet alternatively, the incidence of technological change affects the impact of public capital on manufacturing. In all cases, the expected sign of the coefficient is positive.

Starting with the pooled estimator, the coefficient of PUB is positive and statistically significant. A 10 per cent increase in public capital is associated with a manufacturing per capita increase of 6.5 per cent. However, this impact is seen to decrease over time, as evidenced by the positively signed coefficient of TINT, leading to a total effect of 5.7 per cent. This is a very large impact. Large positive effects on manufacturing are also obtained for AGR, H and INST, which display elasticities of 0.44, 0.29 and 0.25, respectively. Contrary to expectations, at an elasticity of 0.1 the role of MEXP does not appear particularly economically significant. Global technological change has a (1.7 per cent) negative effect on industry. The sign of the coefficient might come as a surprise, but reflect the composition of the sample in that manufacturing is growing the fastest in mid- and upper-mid income economies; high- and low-income countries both have slower growing industries. Given that technological change is mainly fostered in the manufacturing sector, it is conceivable that if other sectors grow faster the overall association between global technological change and manufacturing could be negative.

Some of these results may confound the effects of country-specific effects and those of the explanatory variables and controlling for such effects dramatically change the impact of several of the determinants. This suggests that individual determinants are correlated with omitted state-dependent factors, such as geography, and initial conditions, such as high or low income. Interestingly, the RE and FE estimators produce very similar results, indicating that neither correlation between determinants and country effects, nor between effects, is a major issue.

[24] Clearly, the trend variable might, more generally, include the impact of macroeconomic environment or factors that affect trend changes in this environment. However, since technological change is interpreted to be one of the main factors behind such change, the interpretation of technological change will be maintained.

With a coefficient of almost 0.5, both RE and FE deliver a slightly smaller impact than does OLS. A 10 per cent increase is thus associated with a manufacturing increase of five per cent. This effect still seems excessively large, but is mitigated by the negative impact of the interaction with technological change. Accounting for the interaction effect, the total impact is down 4.5 per cent. It comes as a bit of surprise that accounting for country-specific effects does not reduce the point estimate further. This may be an indication that the OLS estimate does not exclusively capture omitted state dependent factors, such as geography.

Other important consequences of moving to panel-data estimators are registered. The coefficient of H has increased significantly and now a 10 per cent of human capital is associated with a 5.5 per cent increase of manufacturing value added per capita. Also the parameter of MEXP increases a little, to 0.14, while that of INST has decreased to about 0.17. The latter may indicate that omitted state-dependent variables are correlated with institutions, which is another variable that does not change very quickly over time.

So far, an economically meaningful impact of public capital on manufacturing has been recorded. But, how much of this effect reflects causality running from public capital to manufacturing? To address this issue, PUB is assumed to be endogenous. Two panel-data estimators are employed, namely, the instrumental-variables estimators of RE and FE. The last two columns of Table 4 contain the results of the IV estimators.

As is sometimes the case with IV estimators, the results can be sensitive to the instruments used. This is clearly the case here as well. While the estimated coefficients for PUB using RE-IV as expected shrinks further to 0.26, with FE-IV, contrary to predictions, the elasticity increases to 1.12. The respectively total impacts, at 0.25 and 0.98, are slightly lower, but the FE-IV result is any way difficult to accept. On the other hand, the problem with RE-IV is, as is well known, that the correlation between the country-specific effects and explanatory variables, or in this case, the institutions may not be zero. This may call into question the RE-IV results. Instead of trying to resolve this issue here, for now it seems safer to rather rely on RE-IV than FE-IV, given the latter estimator's unreliable coefficient and refer the issue to one of instruments.

The elasticities of AGR and MEXP do not change much, while that for H increases further to 0.69 and that for INST is now statistically insignificant. The FE-IV results are differently affected in that the coefficients of AGR, MEXP and H are considerably reduced to, respectively, 0.26, 0.09 and 0.12. Also in this case, the parameter of INST is statistically insignificant. Going with RE-IV, the conclusion is that ignoring endogeneity of public capital tends to upward bias the estimates. Nonetheless, there is no doubt that public capital has an appreciably important positive impact on industry.

6.1.2. Meta-countries

How do these "average" results hold up across different stages of development? Recall that the expectation is that the marginal effect of a public investment in a low-income country is higher than that in a high-income one. Table 5 provides the results for all the five different estimators discussed above. Due to space limitations, only the coefficients relevant for public capital are presented. There are two things to note before proceeding. The first is that for analyzing in which country group the impact is the largest, only the point estimate is needed. As statistical significance only indicates whether public capita explains variation in manufacturing value added growth, the analysis does not require parameter significance. Secondly, empty slots imply that endogeneity bias was not an issue.

Starting with OLS, it is striking to observe how the impact of public capital differs both in terms of sign and size across meta-countries. Clearly, the magnitudes are inflated for reasons already discussed. A positive effect of public capital on manufacturing is recorded for all country groups, with the highest total impact (0.87) occurring in the lowest income group—as expected—but followed, in turn, by High (0.78), Upper-mid (0.63), Tigers (0.58) and Lower-mid (0.12). It is interesting how much smaller the impact is for Lower-mid income countries compared with all the others.

Accounting for country-specific effects accentuates some of the results, while providing a much more sober picture. The FE estimator still ranks Low incomers the highest in terms of impact (0.68), but these are now followed by the fast-growing Asian tigers (0.55). In other words, the poorest and fastest-growing countries enjoy the greatest benefits of public capital. The two high-income groups share the third place with an impact just above 0.4, while for Lower-mid incomers the impact is actually negative, albeit just below zero. Whether this reflects causal effects is yet to be seen.

Perhaps the biggest surprise is the large relatively effect obtained for the High Incomers as well as the negative one for Lower-mid incomers. But public capital is a multifaceted item. Although the largest component is bound to be infrastructure, it is still possible that other components exert larger effects on industry. In other words, public capital in, say, France may not mean the same thing in Argentina, China and Zimbabwe. There are indications in Isaksson (2009a; 2009b; 2009c) that this is indeed the case, where estimated impacts differ substantially across types of infrastructure and meta-countries.

To be able to pronounce on causal directions, again IV-estimators were used. Somewhat surprisingly, the tendency is for the impacts to increase. This is especially the case for Tiger economies and Upper- and Lower-mid Incomers, whose respective FE-IV impacts climb to 0.78, 0.57 and 0.27. For the Low incomers, there is a slight decrease to 0.6, while for the High-income countries the total impact is 0.45. This gives the following ranking: Tigers, Low, Upper-mid, High and Lower-mid. Thus, the only surprise is that Lower-mid incomers occupy the last position and one can only speculate why this is the case; otherwise the ranking is largely according to expectations.

To summarize, there is little doubt that public capital has explanatory power for why some countries have managed to industrialize, and also for why others have not. There is also evidence that countries that have managed to embark on a convergence path—the Asian tigers— have done so partly thanks to public capital. Finally, public capital matters at all income levels, but the impact is differential; returns are largely diminishing as income and the stock of public capital increase.

6.2. Manufacturing Growth per capita

6.2.1. All countries

Table 6 presents the OLS, RE, FE, RE-IV and FE-IV results for industrial development and growth of public capital. It is clear that the rate of industrialization is positively and significantly related to the growth of public capital. Interestingly, the point estimates do not differ much across the estimators, except in the case of RE-IV, which produces a coefficient of 0.64. For the other estimators, the range is from 0.26 to 0.30, with the smallest being in the case of OLS. Accounting for the interaction term means that the RE-IV no longer appears as an outlier estimate. Now the total impacts range from 0.41 (FE) to 0.54 (OLS). This is more in line with prior expectations. Taking departure from the FE and FE-IV estimators, an impact of about 0.4 implies that an increase of the rate of public capital growth by one percentage point leads to a 0.4 percentage point increase of industrial growth. This translates into an increase of growth from 3.6 to 4.0 per cent annually. This is economically meaningful and within reason, especially if assuming that manufacturing accounts for about 20 per cent of GDP, which would imply an aggregate impact of 0.08 percentage points. Such reasoning, of course, ignores possible sectoral externalities and linkages, but still serves to put the estimate in context with previous empirical work.

Turning to the other determinants, the dominating determinant in OLS appears to be growth of human capital (ΔH), which has a parameter of 0.47. Also the change of institutional quality and growth of agricultural labour productivity score positively at 0.17 and 0.12, respectively, while the parameter of ΔMEXP is not statistically significant. The effect of moving to panel-data models is to increase the elasticity of ΔINST and lower that of ΔH. While in FE-IV the largest impact on industrial growth comes from growth of public capital, ΔINST and ΔH both deliver economically significant impact (0.24 and 0.28, respectively). Growth of labour productivity consistently carries an estimate of 0.12, while growth of manufacturing exports equally consistently is statistically insignificant.

6.2.2. Meta-countries

Like in the case of manufacturing levels, Table 7 presents results for industrial development and public capital in meta-countries. In the case of OLS, the largest total impact is obtained for the Tigers (0.65). Next follow the two high-income categories at 0.46, while a third group consists of the lowest income groups (0.31-0.39). It may be worth mentioning that the parameter for Low incomers is not statistically significant, although it is clearly economically significant. The effect of using panel-data methods, say, the FE estimator, is to increase the total impact for High incomers to the level of the Tigers—approximately 0.55 in both cases—of course also implying a decrease of parameter size in the latter case. Upper-mid and Lower-mid income economies form a new second group (0.35-0.38), while the impact for Low incomers is now down to 0.30 (still statistically insignificant). Finally, invoking the IV estimators only results in one change, namely, that the parameter for Upper-mid incomers is restored to its OLS value at 0.46 and, thus, there is no change in terms of rankings.

The conclusion is that growth of public capital not only explains levels of industry, but also how rapidly it grows. Interestingly, the largest impacts occur for the fastest growing countries, i.e., the Asian tiger economies, and the High-income ones. These two groups, arguably, also have the most advanced manufacturing sectors and a likely explanation could, therefore, be that public capital most positively impact in countries and sectors that most intensively use infrastructure and other public services. But such an explanation only partly fits with the level results. Therefore, it needs to be combined with the simple notion that marginal returns are relatively high when there is little public capital to begin with.

6.2.3. The rate of return of public capital

To further evaluate the extent to which public capital impacts differ across stages of development —and also whether the obtained estimates fall within reasonable margins—it is useful to calculate the (nominal) rate of return. Because what has been estimated is not a production function—at best a pseudo-production function without explicit account of capital and labour—it is not straightforward how to go beyond comparing output elasticities obtained here with those of other studies. Yet, an attempt will be made to go beyond such simple comparisons. The formula for such calculation emanates from the user cost of capital, which for the total economy can be solved for the implied rate of return[25]:

$$P_Y \frac{\partial Y}{\partial Z} = P_Z (r_Z + \delta_Z), \tag{4}$$

where P_Y and P_Z are the prices of gross domestic product (GDP) and a new unit of public capital, respectively, r_Z is the rate of return on public capital and δ_Z is the depreciation rate of public capital, in this paper assumed to be 3 per cent.

But it is not GDP that has been estimated in this paper and equation (4), therefore, needs to be couched in terms of manufacturing value added instead of GDP, leading to

$$P_{MVA} \frac{\partial MVA}{\partial Z} = P_Z (r_Z + \delta_Z), \tag{5}$$

where PMVA is the price of manufacturing value added.

This equation can be rearranged so that the rate of return on public capital can be calculated. To do this, the logarithmic partial derivative of manufacturing with respect to public capital can be

[25] The formula used here is based on McDonald (2008). Weiss (1999) discusses alternative approaches to economic rate of return calculations for different kinds of infrastructure projects as well as their respective pros and cons. To be sure, the calculations carried out in this paper, yet indicative, need to be viewed with a fair amount of caution.

re-written as $\frac{\partial MVA}{\partial Z} = \beta_Z \frac{MVA}{Z}$ and, therefore, equation (5) can be re-arranged and used for the purposes of calculating r_Z:

$$r_Z = \beta_Z \frac{P_{MVA} MVA}{P_Z Z} - \delta_Z, \tag{6}$$

where β_z is the elasticity of public capital, the numerator is nominal manufacturing value added and the denominator is the nominal public capital stock.[26]

Table 8a presents the results of this calculation for the sample as a whole as well as for the meta-countries, which are listed horizontally; estimation methods are listed vertically. The output elasticity chosen is the total impact, i.e., the combined effect of public capital and public capital in interaction with technological change. Because nearly all studies on the impact of public capital focuses on GDP rather than manufacturing—an adjustment to better justify the estimates will shortly be attempted—this first analysis is just a precursor to more realistic comparisons.

It is readily clear that the choice of estimation method has a strong bearing on the rate of return calculation, as does the country group. Generally, the rates of return tend to be greater than 100 per cent, suggesting that public investments pay for themselves within a year in terms of manufacturing growth. Going by the IV estimators, the greatest rate of return occurs for the poorest countries, followed by the fast-growing Asian countries. Third are countries belonging to the Upper-mid category, while the last place is shared by Lower-mid and High Incomers. The large rates of returns are reminiscent of those obtained by David Aschauer and others in the beginning of the 1990s and must be questionable.

Because the measure of public capital stock used here applies to the total economy and not only manufacturing, these rates of returns are likely to be overestimated. The reason is that they include the effects of other sectors through linkages as well as externalities from manufacturing to other sectors, both arising from public capital services. But the question is by how much these rates of return are overestimated. Since there is obvious way to purge these estimates of the unwanted components, for example, the effects from other sectors, while keeping those that

[26] In these calculations, the 1990 value of the ratio of nominal manufacturing value added in nominal public capital stock is used, since this is the base year.

directly relate to manufacturing, for example, externalities to other sectors, there is a need to use proxies. As a first proxy, a solution could be to adjust the output elasticity to the share of manufacturing in GDP.[27] To this end, the average share of manufacturing value added in GDP in 1980 and 2000 is used, leading to equation (7):

$$r_Z = (\alpha_{MVA}\beta_Z)\frac{P_{MVA}MVA}{P_Z Z} - \delta_Z, \tag{7}$$

where αMVA is the average share of manufacturing in GDP between 1980 and 2000.[28]

The results of these adjustments are presented in Table 8b. Continuing with the IV-estimators, RE-IV indicates a rate of return of 13 per cent, while that of the FE-IV is much larger at 61 per cent. On the assumption that the rate of return on private capital is 33 per cent, in the former case the rate of return on public investment is much below that of private capital, while in the latter case the opposite applies.

Turning to meta-countries, the highest rate of return is registered in the case of the Asian tigers (73 per cent for the RE-IV estimator and 66 per cent for the FE-IV), followed by the Low Incomers at 56 and 48 per cent, respectively. Upper-mid Incomers are third at about 24 per cent, while Lower-mid and High Incomers, again, share the last position with about 15 per cent rate of return. The results for the High Incomers can be compared with, for example, the 12 per cent rate of return obtained by Harchaoui and Tarkhani (2003) for Canada. And the obtained rate of return for High Incomers in this paper is much below those obtained by, for example, by Aschauer and Munnell for the United States mentioned in the beginning of the paper.

Incidentally, the estimated the rates of return for the United States are approximately at par with those obtained here for developing countries. However, infrastructure projects supported by the World Bank between 1974 and 1992 have an average rate of return of between 16 and 18 per cent, depending on time period chosen (World Bank, 1994), while in the case of FAO (IFAD) projects after 1985, the average economic rate of return is 24 per cent and ranging from 11 to 50 per cent (Weiss, 1999), both of which are lower than those estimated for developing countries in

[27] This is equivalent to adjusting the nominal manufacturing value added to nominal GDP ratio.
[28] Data for calculating the manufacturing share in GDP are from the World Development Indicators 2009 (World Bank, 2009).

this paper. It, thus, seems that rates of return on public capital fall below that of private capital once a development threshold has been crossed. Furthermore, the rates of return, in principle, decrease as incomes increase, but with the exceptions of the Upper-mid and Tiger country groups, suggesting the existence of plateaus and non-linearities.

A second proxy solution to account for the fact that it is the manufacturing sector, and not the entire economy, that is at focus. Equation (8) shows the calculation when the adjustment is carried out directly on the results based on equation (5):

$$r_Z = \left\{ \beta_Z \frac{P_{MVA} MVA}{P_Z Z} - \delta_Z \right\} \alpha_{MVA.} \tag{8}$$

Table 8c displays the corresponding rates of return. Since this calculation produces results very similar to that of Table 8b, there is no need to discuss these further. However, since no attempt was made to retain the externalities from manufacturing to other sectors, the resulting rates of returns may now instead be underestimated. With this in mind, Figure 1 summarizes Table 8b across estimation methods and meta-countries and allows for a direct comparison with the assumed 0.33 rate of return of private capital, in the graph depicted with a horizontal line.

In sum, for all country cases it seems worthwhile to invest in public infrastructure, since the returns on doing so is always positive. The rates of return seem to be connected to the rate of development—a conclusion drawn because the Asian fast-growers exhibits the greatest rates of return—as well as the initial level of development, as suggested by the high scores obtained for the poorest countries. In the latter case, investment in public infrastructure pays for itself in terms of industrial development in about two years. In both cases, the rate of return on public investment exceeds that of private capital. For the other three country groups—all of which have already had their growth spurts and accumulated a sufficient stock of public capital—the rates of return on public capital is below that of private capital. This seems to be largely in line with the expectations set out in the beginning of this paper.

7. Conclusions

This paper has sought to shed light on how important public capital is for countries trying to industrialize and achieve faster economic growth. To this end, a small empirical model of industrial development was formulated and applied to level and growth data for 57 advanced and developing countries for the time period of 1970 to 2000. In estimating the impact of public capital on industry, special care was taken to deal with omitted state-dependent variables, reverse causality and endogeneity bias. The motivation for this paper stems from the fact that there is little research focusing on the role of public capital for industry and that also analyzes how the impact of public capital changes across stages of development.

The findings are clear in that there is little doubt that public capital has important explanatory power for why some countries have managed to industrialize, as well as for why others have not. Stages of development influence how strongly public capital matters, but there is evidence of impact at all income levels and it seems that the returns to public investment are, largely, diminishing with income. Another long-term result is that countries that have managed to embark on a convergence path—the Asian tigers—have done so partly thanks to public capital.

A second key conclusion is that growth of public capital not only explains long-term levels of industry, but also how rapidly industry grows. Interestingly, the largest impacts occur for the fastest growing countries, i.e., the Asian tiger economies, and the High-income ones. These two groups, arguably, also have the most advanced manufacturing sectors and a likely explanation could, therefore, be that public capital most positively impact in countries and sectors which most intensively use infrastructure and other public services. But such an explanation only partly fits with the level results. Therefore, it needs to be combined with the simple notion that marginal returns are relatively high when there is little public capital to begin with.

In terms of more qualitative conclusions, for all country cases it seems worthwhile to invest in public infrastructure, since the returns of doing so is always positive. The notion that public capital may be overprovided in developing countries, see for example Devarajan, Swaroop and Zou (1996), finds no support in this paper. The rates of return seem to be connected to the rate of development—a conclusion drawn because the Asian fast-growers exhibits the greatest rates of return—as well as the initial level of development, as suggested by the high scores obtained for the poorest countries. In the latter case, investment in public infrastructure pays for itself in terms of industrial development in about two years. In both cases, the rate of return on public investment exceeds that of private capital. For the other three country groups—all of which have already had their growth spurts and accumulated a sufficient stock of public capital—the rates of return on public capital is below that of private capital.

This seems to be largely in line with the expectations set out in the beginning of this paper. In other words, little support for the notion that public infrastructure is overprovided in developing countries—as is sometimes voiced in the literature—is found in this paper. In terms of policy implications it seems clear that public investment is central to growth and development. Although this centrality seems to be a function of countries' stage of development, the returns to such investment at all income levels are positive.

From a policy making perspective, it is important to be aware that because investments in infrastructure are large and lumpy, the most likely candidate for providing it is the government. Although one could think of partnerships with the private sector, or to some extent even the private sector alone for smaller infrastructure projects, coordination costs might be overwhelmingly large. Furthermore, because infrastructure investment tends to be so large, this could also delay its financing. Both effects may result in slow implementation relative to infrastructure investments being carried out by the government alone.

Should policy makers expect that investment in public capital can drive growth by creating demand over and above its own investment? In other words, is public investment a necessary condition in the sense of triggering growth? An alternative view could be that it is only when countries are poised for growth, but are facing infrastructural bottlenecks, that governments should react by relieving the economy of such bottlenecks. If there is little demand, it probably will not help much to build another road or installing another power station and growth will not be driven by public investment. That is, the demand situation also matters. Although it seems easier to conceive of the second view, the regression results suggest that it is actually public capital that causes manufacturing growth. The bottom line is that policy makers need to inform itself of the demand situation before deciding on investing in infrastructures, especially in developing countries where resources are relatively scarce and trade offs are plentiful.

While a significant amount of ground has been covered in this paper, future research needs to look into at least some of the following areas. Firstly, when it comes to infrastructure, only the amount of it has been analyzed. However, it is likely that the quality of public capital stocks differ significantly across countries, which suggests that the public capital used here could be biased. Secondly, and related, the role of maintenance and repair has been ignored. But what does it mean to have a road that only exists on paper, but cannot be used? Hulten (1996) is one of few, if not the only one, who has addressed this empirically. According to his estimates, maintenance is at least as important as the infrastructure itself.

Thirdly, the dynamics of public investment has been neglected here. But does it mean anything that public investment occurs in spurts? Does it mean anything to analysis that the impact of public capital is felt over a long period of time and that it certainly is not contemporaneous with the time of investment? The answer to these questions is probably both yes, but the modelling of it will be much more complicated and it is uncertain how much more is learnt from it. Fourthly, the stages of development approach can be developed further. For example, in this paper countries have been grouped according to income levels, but in a rather ad hoc approach. An alternative would be to let the data decide on the grouping. The threshold analysis developed by Hansen (1999) and Caner and Hansen (2004) is a good example of how this could be done. More specifically, the impact of public capital should be the decisive factor and not income.

Finally, data quality across countries is likely to differ significantly, which means that the stages of development analysis may be biased.[29] Furthermore, although the income groups have been ranked according to their point estimates and rates of return, no formal statistical tests have been carried out that differences are actually statistically different. For both reasons, one needs to view the results with some humility and see them as indicative rather than sheer facts.

Nonetheless, this paper has contributed to the empirical literature by focusing on the role of public capital for industrial development. It has also estimated fairly reasonable rates of return on public investment—lower than many of those often encountered in the previous work— and it has evaluated such returns at different stages of development. Although there is a still lot of work to do, as has been identified above, the paper has hopefully helped in better understanding why and when policies stimulating public investment can be a source of industrial development and overall economic growth.

[29] That issues of data quality and accurate coverage not only apply to developing countries, although problems ought to be more severe in those countries, is exemplified by the proposal for a new architecture for the U.S. national accounts (Jorgenson and Landefeld, 2009).

References

Abdih, Yasser and Frederick Joutz (2008), "The Impact of Public Capital, Human Capital, and Knowledge on Aggregate Output," IMF Working Paper, WP/08/218, Washington, D.C.: International Monetary Fund.

Acemoglu, Daron, Simon Johnson and James A. Robinson (2005), "Institutions as the Fundamental Cause of Long-Run Growth," in Philippe Aghion and Stephen Durlauf (Eds.), *Handbook of Economic Growth*, Amsterdam: Elsevier, North-Holland.

Agénor, Pierre-Richard, Nihal Bayraktar and Karim El Aynaoui (2008), "Roads out of poverty? Assessing the links between aid, public investment, growth, and poverty reduction," *Journal of Development Economics*, Vol. 86(2), pp. 277-95.

Alvarez-Cuadrado, Francisco and Markus Poschke (2009), "Structural Change out of Agriculture: Labor Push versus Labor Pull," IZA Discussion Paper, No. 4247, Bonn: Institute for the Study of Labor.

Aschauer, David A. (1989), "Is Public Expenditure Productive?" *Journal of Monetary Economics*," Vol. 23(2), pp. 177-200.

Aschauer, David A. (2000), "Public Capital and Economic Growth: Issues of Quantity, Finance, and Efficiency," *Economic Development and Cultural Change*, Vol. 48(2), pp. 391-406.

Awokuse, Titus O. (2009), "Does Agriculture Really Matter for Economic Growth in Developing Countries?" mimeograph, Department of Food and Resource Economics, University of Delaware.

Barro, Robert J. (1990), "Government Spending in a Simple Model of Endogenous Growth," *Journal of Political Economy*, Vol. 98(5), pp. 103-25.

Basu, Susanto and David Weil (1998), Appropriate Technology and Growth, *The Quarterly Journal of Economics*, Vol. 113, no. 4 pp. 1025-1054

Breisinger, Clemens and Xinshen Diao (2008), "Economic Transformation in Theory and Practice: What are the Messages for Africa?" IFPRI Discussion Paper 0079, Washington, D.C.

Bronzini, Raffaello and Paolo Piselli (2006), "Determinants of Long-Run Regional Productivity: The Role of R&D, Human Capital and Public Infrastructure," *Temi di Discussione del Servizio Studi* No. 597, Rome: Banca d'Italia.

Calderón, César (2009), "Infrastructure and Growth in Africa," Policy Research Working Paper No. 4914, Washington, D.C.: World Bank.

Calderón, César and Luis Servén (2004a), "The Effects of Infrastructure Development on Growth and Income Distribution," Policy Research Working Paper No. 3400, Washington, D.C.: World Bank.

Calderón, César and Luis Servén (2004b), "Trends in Infrastructure in Latin America, 1980-2001," Policy Research Working Paper No. 3401, Washington, D.C.: World Bank. Chenery, Hollis B. (1986)

Destefanis, Sergio and Vania Sena (2005), "Public Capital and Total Factor Productivity: New Evidence from the Italian Regions, 1970-98," *Regional Studies*, Vol. 39(5), pp. 603-17.

Devarajan, S., V. Swaroop, and H. Zhou (1996), "The Composition of Public Expenditure and Economic Growth," *Journal of Monetary Economics*, Vol. 37, pp. 313-44.

Duggal, Vijaya G., Cynthia Saltzman and Lawrence R. Klein (2007), "Infrastructure and Productivity: An Extension to Private Infrastructure and Its Productivity," *Journal of Econometrics*, Vol. 140, pp. 485-502.

Duggal, Vijaya G., Cynthia Saltzman and Lawrence R. Klein (1999), "Infrastructure and Productivity: A Nonlinear Approach," *Journal of Econometrics*, Vol. 92, pp. 47-74.

Easterly, William (2009), "Can the West Save Africa?" *Journal of Economic Literature*, Vol, XLVII(2), pp. 373-447

Easterly, William and Sergio Rebelo (1993), "Fiscal Policy and Economic Growth: An Empirical Investigation," NBER Working Paper No. 4499, Cambridge, MA: NBER.

Estache, Antonio (2006), "Infrastructure: A survey of recent and upcoming issues," paper presented at the Annual Bank Conference on Development Economics, Tokyo, Japan, May 29-30, 2006.

Everaert, Gerdie (2003), "Balanced Growth and Public Capital: An Empirical Analysis with I(2) Trends in Capital Stock Data," *Economic Modelling*, Vol. 20, pp. 741-63.

Fedderke, J.W. and Z. Bogetic (2009), "Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of 19 Infrastructure Measures," *World Development*, Vol. 37(9), pp. 1522- 39.

Fei, J.C. and Gustavo Ranis (1961), "A Theory of Economic Development," *American Economic Review*, Vol. 51, no.4, pp. 533-65.

Fernald, John. G. (1999), "Roads to Prosperity? Assessing the Link Between Public Capital and Productivity," *American Economic Review*, Vol. 89, pp. 619-38.

Fingleton, Bernard and Miguel Gómez-Antonio (2009), Analyzing the Impact of Public Capital Stock Using the NEG Wage Equation: A Panel Data Approach," Strathclyde Discussion Papers in Economics, No. 09-12, Department of Economics, University of Strathclyde, Glasgow.

Frankel, Jeffrey and David Romer (1999), "Does Trade Cause Growth?" *American Economic Review*, Vol. 89(3), pp. 379-99.

Glaeser, Edward L., Rafael LaPorta, Florencio López de Silanes and Andrei Schleifer (2004), "Do Institutions Cause Growth?" *Journal of Economic Growth*, Vol. 9(3), pp. 271-303.

Gramlich, Edward M. (1994), "Infrastructure Investment: A Review Essay," *Journal of Economic Literature*, Vol. 32 (September), pp. 1176-96.

Gregoriou, Andros and Sugata Ghosh (2009), "On the Heterogenous Impact of Public Capital and Current Spending on Growth Across Nations," *Economics Letters*, Vol. 105, pp. 32-35.

Gu, Wulong and Ryan McDonald (2009), "The Impact of Public Infrastructure on Canadian Multifactor Productivity Estimates," Economic Analysis (EA) Research Paper Series No. 021, Statistics Canada.

Gwartney, James and Robert Lawson, with Neil Emerick (2003), Economic Freedom of the World: 2003 Annual Report, Vancouver: The Fraser Institute. Data retrieved from www.freetheworld.com.

Harchaoui, Tarek M. and Faouzi Tarkhani (2003), "Public Capital and Its Contribution to the Productivity Performance of the Canadian Business Sector," Economic Analysis (EA) Research Paper Series No. 050, Ottawa: Statistics Canada.

Haque, M. Emranul and Richard Kneller (2008), "Public Investment and Growth: The Role of Corruption," Centre for Growth & Business Cycle Research Discussion Paper No. 098, University of Manchester.

Henderson, Daniel J. and Aman Ullah (2005), "Nonparametric Estimation in a One-Way Error Component Model: A Monte Carlo Analysis," mimeograph, Department of Economics, State University of New York, Binghamton.

Hirschman, Albert O. (1958), The Strategy of Economic Development, New Haven, CT: Yale University Press.

Holtz-Eakin, Douglas (1988), "Private Output, Government Capital, and the Infrastructure Crisis," Discussion Paper No. 394, Columbia University.

Holtz-Eakin, Douglas (1994), "Public Sector Capital and the Productivity Puzzle," *Review of Economics and Statistics*, Vol. 76(1), pp. 12-21.

Hurlin, Christophe (2007), "*How to Estimate Public Capital Productivity*?" mimeograph, University of Orléans.

Isaksson, Anders (2009a), "Telecommunications and Industrial Development,“ RST Staff Working Paper, 14/2009, Vienna: UNIDO.

Isaksson, Anders (2009b), "Energy Infrastructure and Industrial Development,“ RST Staff Working Paper, 12/2009, Vienna: UNIDO.

Isaksson, Anders (2009c), "On Track for Industrial Development,“ RST Staff Working Paper, 13/2009, Vienna: UNIDO.

Johnston, B. and J.W. Mellor (1961), "The Role of Agriculture in Economic Development," *American Economic Review*, Vol. 51(4) pp. 566-93.

Jorgenson, Dale W. and J. Steven Landefeld (2009), "Implementation of a New Architecture for the U.S. National Accounts," *American Economic Review*: Papers and Proceedings, Vol. 99(2), pp. 64-68.

Jorgenson, Dale W. (1961), "The Development of a Dual Economy," *Economic Journal*, Vol. 71, no. 282, pp. 309-34.

Kawaguchi, Daiji, Fumio Ohtake and Keiko Tamada (2009), "The Productivity of Public Capital: Evidence from Japan's 1994 Electoral Reform," *Journal of The Japanese and International Economies*, Vol. 23, pp. 332-43.

Lewis, W. Arthur (1954), "Economic Development with Unlimited Supplies of Labour," The Manchester School, Vol. 47(3), pp. 211-29.

Lynde, Catherine and James Richmond (1993), "Public Capital and Total Factor Productivity," *International Economic Review*, Vol. 34(2), pp. 401-14.

Lynde, Catherine and James Richmond (1992), "The Role of Public Capital in Production," *Review of Economics and Statistics,* Vol. 74(1), pp. 37-44.

Mamtzakis, Emmanouel C. (2007), "EU Infrastructure Investment and Productivity in Greek Manufacturing," *Journal of Policy Modeling*, Vol. 29, pp. 335-44.

McDonald, Ryan (2008), "An Examination of Public Capital's Role in Production," Economic Analysis (EA) Research Paper Series No. 050, Ottawa: Statistics Canada.

Morrision, Catherine J. and Amy Ellen Schwartz (1996), "State Infrastructure and Productive Performance," *American Economic Review*, Vol. 86(5), pp. 1095-1111.

Munnell, Alicia H. (1990), "Why Has Productivity Growth Declined? Productivity and Public Investment," *New England Economic Review*, Federal Reserve Bank of Boston, January/February, pp. 3-22.

Munnell, Alicia H. (1992), "Policy Watch: Infrastructure Investment and Economic Growth," Journal of Economic Perspectives, Vol. 6(4), pp. 189-98.

Murphy, Kevin M., Andrei Schleifer and Robert Vishny (1989), "Industrialization and the Big Push," *Journal of Political Economy*, Vol. 97(5), pp. 1003-26.

North, Douglass C. (1990), Institutions, Institutional Change, and Economic Performance, Cambridge: Cambridge University Press.

Pineda, José and Francisco Rodriguez (2006), "Public Investment in Infrastructure and Productivity Growth: Evidence from the Venezuelan Manufacturing Sector," Wesleyan Economics Working Paper, No. 2006-010, Department of Economics, Wesleyan University.

Pinstrup-Andersen, Per and Satoru Shimokawa (2006), "Rural Infrastructure and Agricultural Development," paper presented at the 'Annual Bank Conference on Development Economics', Tokyo, Japan May 29-30, 2009.

Pritchett, Lant (1996), "Mind your P's and Q's," World Bank Policy Research Paper, No. 1660, Washington, D.C.: World Bank.

Restuccia, Diego, Dennis Yao Tang and Xiaodong Zhu (2008), "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis," *Journal of Monetary Economics*, Vol. 55(2), pp. 234-50.

Rodriguez, Francisco (2006), "Have Collapses in Infrastructure Spending led to Cross-Country Divergence in per Capita GDP?," background note for the 2006 World Economic and Social Survey of the United Nations Department of Economic and Social Affairs.

Rodrik, Dani, Arvind Subramanian and Francesco Trebbi (2004), "Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development," *Journal of Economic Growth*, Vol. 9(2), pp. 131-65.

Romp, Ward and Jakob de Haan (2005), "Public Capital and Economic Growth: A Critical Survey," European Investment Bank Paper, Vol. 10(1), pp.41-70.

Rostow, W. W. (1960), *The Stages of Economic Growth: A Non-Communist Manifesto*. Cambridge University Press.

Sachs, Jeffrey D. (2008), *Common Wealth: Economics for a Crowded Planet*, New York: Penguin Group.

Sachs, Jeffrey D. (2003), "Institutions Don't Rule: Direct Effects of Geography on Per Capita Income," NBER Working Paper No. 9490, Cambridge, MA: NBER.

Schultz, Theodore W. (1964), *Transforming Traditional Agriculture*, London: Yale University Press.

Straub, Stéphane (2008), "Infrastructure and Growth in Developing Countries: Recent Advances and Research Challenges," Policy Research Working Paper No. 4460, Washington, DC: World Bank.

Syrquin, Moshe and Hollis B. Chenery (1986), *Patterns of Development: 1950 to 1983,* Washington, D.C., World Bank.

UNCTAD (2006), *The Least Developed Countries Report*, 2006, New York and Geneva: United Nations.

Weiss, John (1999), "Infrastructure and Economic Development," Economic Research Papers, No. 50, Background paper prepared for the African Development Report 1999, African Development Bank.

World Bank (2009), *World Development Indicators 2009*, CD-Rom, Washington, D.C., World Bank.

World Bank (2008), *The Growth Report: Strategies for Sustained Growth and Inclusive Development*, Washington, D.C., World Bank.

World Bank (1994), *World Development Report 1994: Infrastructure for Development*, New York: Oxford University Press.

Yepes, Tito, Justin Pierce and Vivien Foster (2009), "Making Sense of Africa's Infrastructure Endowment: A Benchmarking Approach," Policy Research Working Paper, No. 4912, Washington, D.C., World Bank.

Table 1. List of countries

HIGH INCOME	UPPER-MID *Income per capita = 6,001 and above in year 2000, excluding OECD + Israel*	LOW-MID *Income per capita = 3,001-6,000 in year 2000*	LOW INCOME *Income per capita = up to 3,000 in year 2000*	TIGERS
Australia	Argentina	Colombia	Bangladesh	China
Austria	Barbados	Costa Rica	Benin	India
Belgium	Chile	Dominican Republic	Bolivia	Indonesia
Canada	Mauritius	Ecuador	Guinea Bissau	Korea, Republic of
Denmark	Mexico	Egypt	Kenya	Malaysia
Finland	Panama	El Salvador	Malawi	Thailand
France	South Africa	Guatemala	Nicaragua	
Greece	Trinidad and Tobago	Guyana	Papua New Guinea	
Italy	Tunisia	Iran		
Japan	Turkey	Pakistan		
New Zealand	Uruguay	Paraguay		
Norway	Venezuela	Peru		
Portugal		Philippines		
Spain				
Sweden				
Switzerland				
UK				
USA				

Note: There are 57 countries in the dataset.

Table 2. Descriptive statistics (in logs)

Variable	Mean	Stand. Dev.	Min	Max
*Levels of**				
MVA per capita	6.188	1.560	3.007	8.736
PUB	2.198	1.193	-0.137	4.376
AGR	7.948	1.419	4.557	9.992
MEXP	3.340	1.041	0.488	4.554
INST	1.776	0.139	1.474	2.079
H	1.719	0.449	0.664	2.439
*Growth of***				
MVA per capita	0.023	0.025	-0.041	0.099
PUB	0.048	0.027	-0.007	0.114
AGR	0.027	0.016	-0.006	0.068
MEXP	0.023	0.038	-0.075	0.130
INST	0.007	0.008	-0.009	0.062
H	0.015	0.010	0.001	0.051

* In 2000.

** Average, 1970-2000.

Table 3. Comparison of infrastructure stocks across meta-countries, relative to high-income, per cent, year = 2000

	MVAPC	PUB
High	100.00	100.00
Low	1.68	4.88
Lower-mid	7.12	11.42
Upper-mid	19.79	31.10
Tigers	6.33	12.28

Table 4. Infrastructure and Manufacturing per capita, OLS, Random-effects (RE), Fixed effects (FE), RE instrumental variables and FE instrumental variables

	OLS	RE	FE	RE-IV	FE-IV
Constant	0.541***	0.540**	0.865**	0.709***	1.675***
	(3.53)	(1.98)	(2.50)	(2.59)	(5.40)
PUB	0.650***	0.499***	0.493***	0.262**	1.123***
	(21.08)	(17.58)	(16.73)	(2.21)	(23.11)
AGR	0.438***	0.414***	0.380***	0.442***	0.258***
	(21.50)	(11.81)	(9.10)	(10.61)	(6.75)
MEXP	0.100***	0.143***	0.139***	0.156***	0.089***
	(8.83)	(9.01)	(8.61)	(10.28)	(7.29)
INST	0.254***	0.176***	0.169***	0.012	-0.026
	(2.99)	(3.24)	(3.09)	(0.22)	(0.49)
H	0.290***	0.555***	0.552***	0.694***	0.123**
	(6.18)	(10.47)	(10.47)	(7.34)	(1.97)
T	-0.017***	-0.019***	-0.018***	-0.020***	-0.005**
	(5.98)	(9.61)	(8.34)	(7.05)	(2.51)
T*PUB	-0.005***	-0.003***	-0.003***	-0.001***	-0.009***
	(4.94)	(4.59)	(4.40)	(0.41)	(11.14)
N	1411	1411	1411	1274	1284
Endogenous				PUB	PUB
R^2	0.94	0.93	0.69	0.93	0.62
F [a]	3884.40***	2035.92***	178.13***	336.93***	288.77***
	(7,1403)	(7)	(7,1347)	(7,1267)	(64,1220)
F [b]					102.00***
					(56,1220)
First t-test [c]	0.311***			0.386***	0.455***
Final t-test [d]	-0.103			-0.355***	0.582***
First stage [e]					
ΔPUB_{t-1}				5.15***	
$Urbpop^2_{t-1}$				5.71***	20.85***
$\Delta Urbpop^2_{t-3}$					4.17***
Sargan [f]					0.378***
χ^2 (instr.-1)					

Note: All variables are in logs and absolute t-values in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent, respectively, small-sample correction carried out for FE and FE-IV, robust standard errors. N = number of observations, Endogenous = endogenous explanatory variable, Δ = first difference operator, OLS = Ordinary Least Squares, RE = Random-effects estimator, FE = Fixed-effects estimator, RE-IV = Random-effects Instrumental Variables estimator and FE-IV = Fixed-effects Instrumental Variables estimator.

PUB = public capital stock per capita, AGR = agricultural value added per worker, MEXP = manufacturing exports in manufacturing value added, INST = economic freedom, H = educational attainment level for population aged 15+, T = linear time trend and TINT = interaction term between trend and ΔPUB.

a For OLS: F-test for joint significance of parameters, F[k, N-k-1]. a For RE: Wald-test for joint significance of parameters, F[k]. a For FE: F-test for joint significance of parameters, F[k+i, N-(k+i)].
a For RE-IV: Wald-test for joint significance of parameters, F[k, N-k]. a For FE-IV: F-test for joint significance of parameters, F[k+i, N-(k+i)]. b For FE-IV: F-test for whether the fixed effects are statistically significant F[i-1, N-(k+i].
c T-test for whether PUB is endogenous in the first test round
d T-test for whether PUB is endogenous in the last test round e First stage t-values for instruments
f $\chi 2$-test for validity of instruments, $\chi 2$ (instr.-1).

Table 5. Infrastructure and Manufacturing per capita, Fixed-effects, Groups

		OECD	Upper-Mid	Lower-Mid	Low	Tigers
OLS	PUB	0.415***	0.649***	0.263***	1.254***	0.481***
		(11.55)	(6.73)	(3.67)	(6.86)	(9.42)
	T*PUB	0.023***	-0.001	-0.009***	-0.023***	0.006***
		(11.71)	(0.15)	(2.60)	(3.72)	(4.15)
RE	PUB	0.209***	0.512***	0.076**	1.254***	0.481***
		(7.82)	(10.93)	(2.38)	(6.86)	(9.42)
	T*PUB	0.016***	-0.005**	-0.005***	-0.023***	0.006***
		(9.86)	(2.13)	(2.90)	(3.72)	(4.15)
FE	PUB	0.194***	0.512***	0.074**	0.853***	0.473***
		(7.33)	(11.20)	(2.30)	(6.22)	(7.38)
	T*PUB	0.014***	-0.005**	-0.005***	-0.011*	0.005***
		(9.09)	(2.11)	(2.74)	(1.91)	(2.99)
RE-IV	PUB	0.305***	0.876***	0.534***	0.849***	0.901***
		(3.70)	(3.06)	(2.91)	(4.12)	(6.01)
	T*PUB	0.014***	-0.018*	-0.015***	-0.010	-0.003
		(7.41)	(1.76)	(5.74)	(1.37)	(0.76)
FE-IV	PUB	0.261***	0.840***	0.464***	0.676***	0.858***
		(3.14)	(2.93)	(2.72)	(6.04)	(7.26)
	T*PUB	0.012***	-0.017*	-0.012***	-0.005	-0.005*
		(6.25)	(1.66)	(4.66)	(1.22)	(1.86)

Note: All variables are in logs and absolute t-values in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent, respectively.
Blank implies that PUB was not endogenous

PUB = public capital stock per capita, T*PUB = interaction term between trend and PUB.

Table 6. **Infrastructure and Industrial Development, OLS, Random-effects (RE), Fixed-effects (FE), RE instrumental variables and FE instrumental variables**

	OLS	RE	FE	RE-IV	FE-IV
Constant	-0.021***	-0.017**	-0.013**	-0.046***	-0.015**
	(3.39)	(2.54)	(2.01)	(3.08)	(2.22)
ΔPUB	0.263***	0.297***	0.278***	0.642***	0.286***
	(5.27)	(10.18)	(6.54)	(3.77)	(4.08)
ΔAGR	0.122***	0.123***	0.121***	0.122***	0.124***
	(5.17)	(5.27)	(5.13)	(5.48)	(5.54)
ΔMEXP	0.009	0.005	0.003	0.002	-0.000
	(0.89)	(0.55)	(0.28)	(0.23)	(0.04)
ΔINST	0.169**	0.194**	0.227***	0.279***	0.240***
	(2.19)	(2.49)	(2.86)	(3.98)	(3.59)
ΔH	0.469***	0.383***	0.268***	0.344***	0.278***
	(5.96)	(4.58)	(2.98)	(3.98)	(3.94)
T	0.001*	0.000*	0.001*	0.002***	0.001*
	(1.83)	(1.68)	(1.69)	(2.77)	(1.69)
T*ΔPUB	0.017***	0.013***	0.008*	-0.008	0.008*
	(5.27)	(3.96)	(1.72)	(0.88)	(1.72)
N	1293	1293	1293	1277	1250
Endogenous				PUB	PUB
R^2	0.19	0.19	0.11	0.17	0.11
F [a]	35.59***	180.93***	17.01***	24.65***	19.91***
	(7,1285)	(7)	(7,1231)	(7,1270)	(62,1188)
F [b]					3.06***
					(54,1188)
First t-test [c]				-1.732 ***	-1.150***
Final t-test [d]				0.206 ***	-0.155
First stage [e]					
PUB_{t-2}				11.05***	
PUB_{t-3}					52.87***

Note: All variables are in logs and absolute t-values in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent, respectively, small-sample correction carried out for FE and FE-IV, robust standard errors. N = number of observations, Endogenous = endogenous explanatory variable, Δ = first difference operator, OLS = Ordinary Least Squares, RE = Random-effects estimator, FE = Fixed-effects estimator, RE-IV = Random-effects Instrumental Variables estimator and FE-IV = Fixed-effects Instrumental Variables estimator.

PUB = public capital stock per capita, AGR = agricultural value added per worker, MEXP = manufacturing exports in manufacturing value added, INST = economic freedom, H = educational attainment level for population aged 15+, T = linear time trend and TINT = interaction term between trend and ΔPUB.

a For OLS: F-test for joint significance of parameters, F[k, N-k-1]. a For RE: Wald-test for joint significance of parameters, F[k]. a For FE: F-test for joint significance of parameters, F[k+i, N-(k+i)].
a For RE-IV: Wald-test for joint significance of parameters, F[k, N-k]. a For FE-IV: F-test for joint significance of parameters, F[k+i, N-(k+i)]. b For FE-IV: F-test for whether the fixed effects are statistically significant F[i-1, N-(k+i]. c T-test for whether PUB is endogenous in the first test round
d T-test for whether PUB is endogenous in the last test round e First stage t-values for instruments.

Table 7. Infrastructure and Manufacturing per capita, Fixed-effects, Groups

		OECD	Upper-Mid	Lower-Mid	Low	Tigers
OLS	ΔPUB	0.329***	0.473***	0.194*	0.081	0.453***
		(5.65)	(2.93)	(1.84)	(0.20)	(3.58)
	T*ΔPUB	0.008	-0.001	0.007	0.019	0.012
		(1.02)	(0.11)	(0.92)	(1.05)	(0.99)
RE	ΔPUB	0.330***	0.471***	0.194*	0.081	0.453***
		(5.85)	(2.91)	(1.84)	(0.20)	(3.58)
	T*ΔPUB	0.011	-0.001	0.007	0.019	0.012*
		(1.32)	(0.12)	(0.92)	(1.05)	(0.99)
FE	ΔPUB	0.330***	0.448**	0.304***	-0.064	0.399***
		(6.02)	(2.53)	(2.65)	(0.18)	(3.07)
	T*ΔPUB	0.014	-0.004	0.003	0.023	0.010
		(1.61)	(0.37)	(0.32)	(1.34)	(0.84)
RE-IV	ΔPUB	0.213**	0.744***			
		(2.48)	(2.62)			
	T*ΔPUB	0.024**	-0.018			
		(2.43)	(1.14)			
FE-IV	ΔPUB	0.228***				
		(2.73)				
	T*ΔPUB	0.023**				
		(2.35)				

Note: All variables are in logs and absolute t-values in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent, respectively.
Blank implies that PUB was not endogenous
PUB = public capital stock per capita, T*PUB = interaction term between trend and PUB.

Table 8a. Rate of return on public investment, no adjustment

	ALL	OECD	Upper-Mid	Lower-Mid	Low	Tigers
OLS	2.045	1.610	1.641	0.432	5.777	2.186
RE	1.612	0.944	1.110	-0.046	5.777	2.186
FE	1.591	0.845	1.110	-0.053	4.407	2.094
RE-IV	0.865	1.078	1.522	1.112	4.486	3.246
FE-IV	3.534	0.919	1.470	1.027	3.876	2.958

Table 8b. Rate of return on public investment, adjustment to β

	ALL	OECD	Upper-Mid	Lower-Mid	Low	Tigers
α_{MVA}	0.180	0.186	0.177	0.174	0.131	0.231
OLS	0.343	0.275	0.265	0.050	0.730	0.482
RE	0.265	0.151	0.172	-0.033	0.730	0.482
FE	0.261	0.133	0.172	-0.034	0.550	0.461
RE-IV	0.131	0.176	0.244	0.169	0.561	0.727
FE-IV	0.610	0.146	0.235	0.154	0.481	0.660

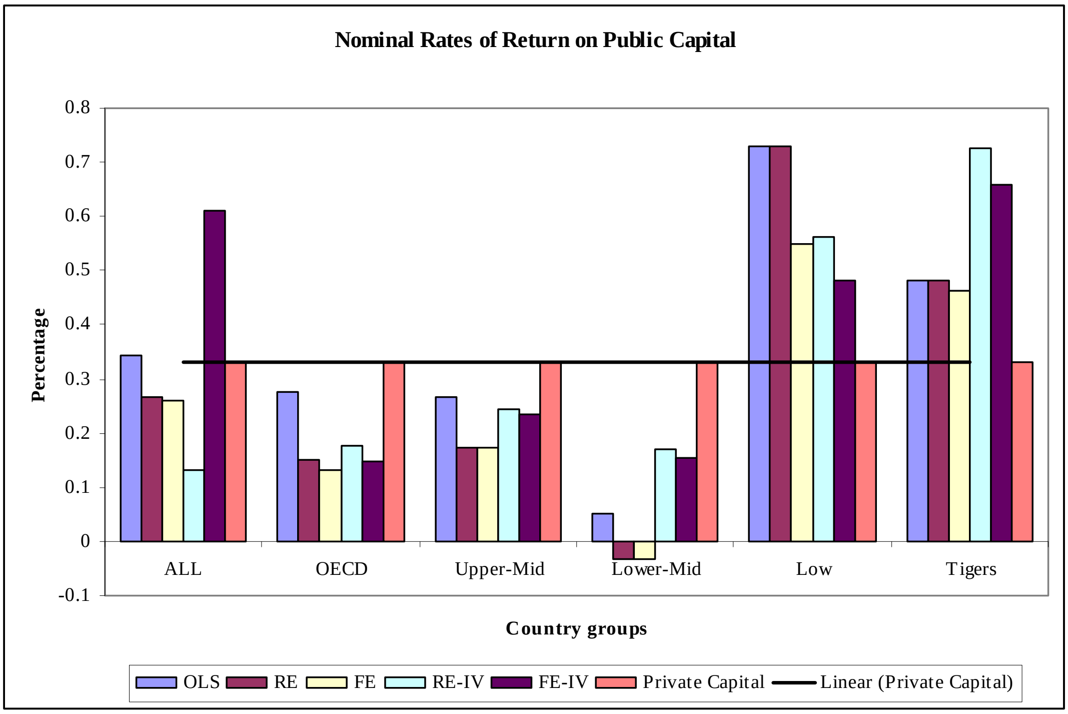
Note: αMVA is calculated as the average of the 1980 and 2000 nominal manufacturing value added shares in GDP, with data from the World Development Indicators 2009 (World Bank, 2009).

Table 8c. Rate of return on public investment, adjustment to r_Z

	ALL	OECD	Upper-Mid	Lower-Mid	Low	Tigers
α_{MVA}	0.180	0.186	0.177	0.174	0.131	0.231
OLS	0.367	0.299	0.290	0.075	0.756	0.505
RE	0.290	0.176	0.196	0.003	0.756	0.505
FE	0.286	0.157	0.196	0.001	0.576	0.484
RE-IV	0.156	0.200	0.269	0.194	0.587	0.750
FE-IV	0.635	0.171	0.260	0.179	0.507	0.683

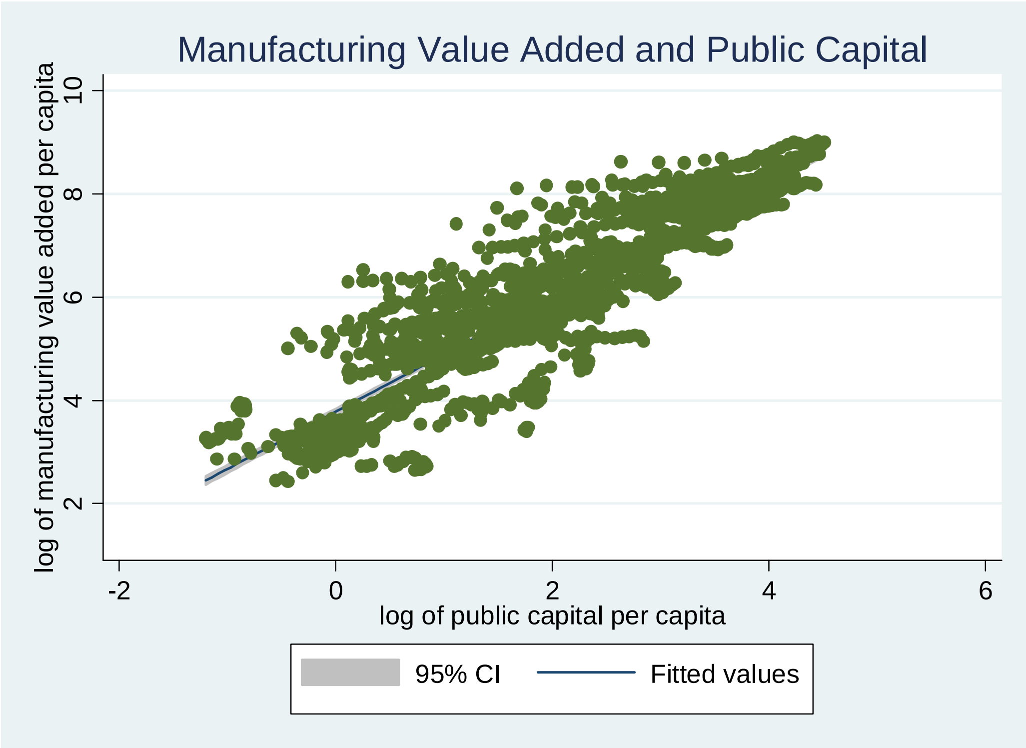
Note: αMVA is calculated as the average of the 1980 and 2000 nominal manufacturing value added shares in GDP, with data from the World Development Indicators 2009 (World Bank, 2009).

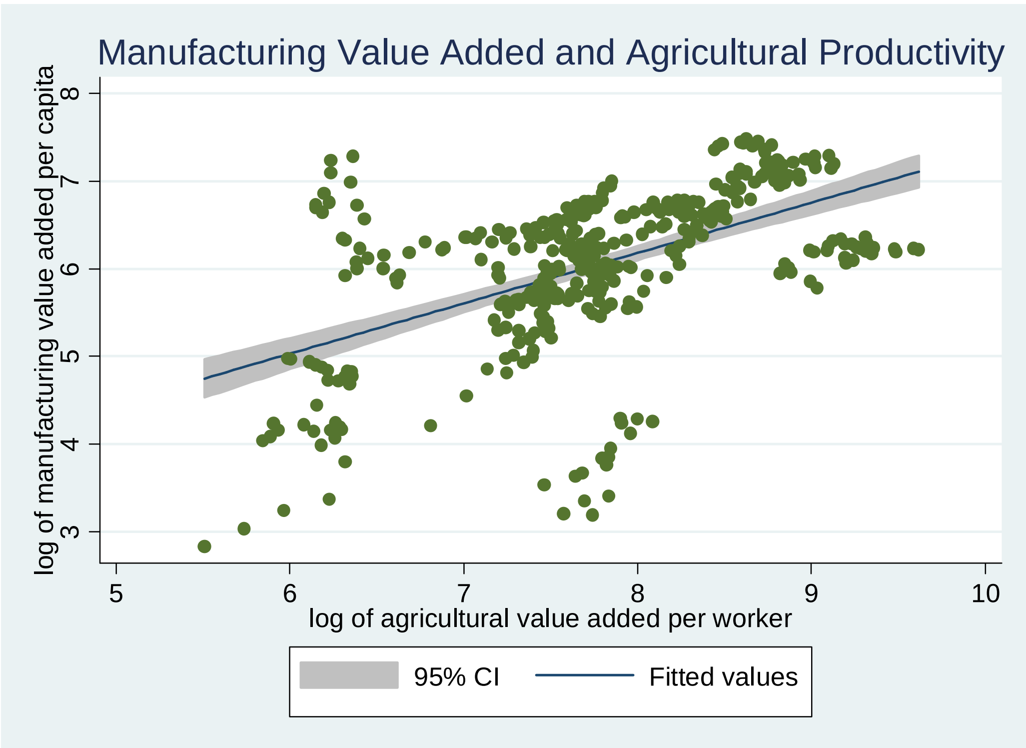
Figure 1. Nominal Rates of Return to Public Capital, adjustment to β

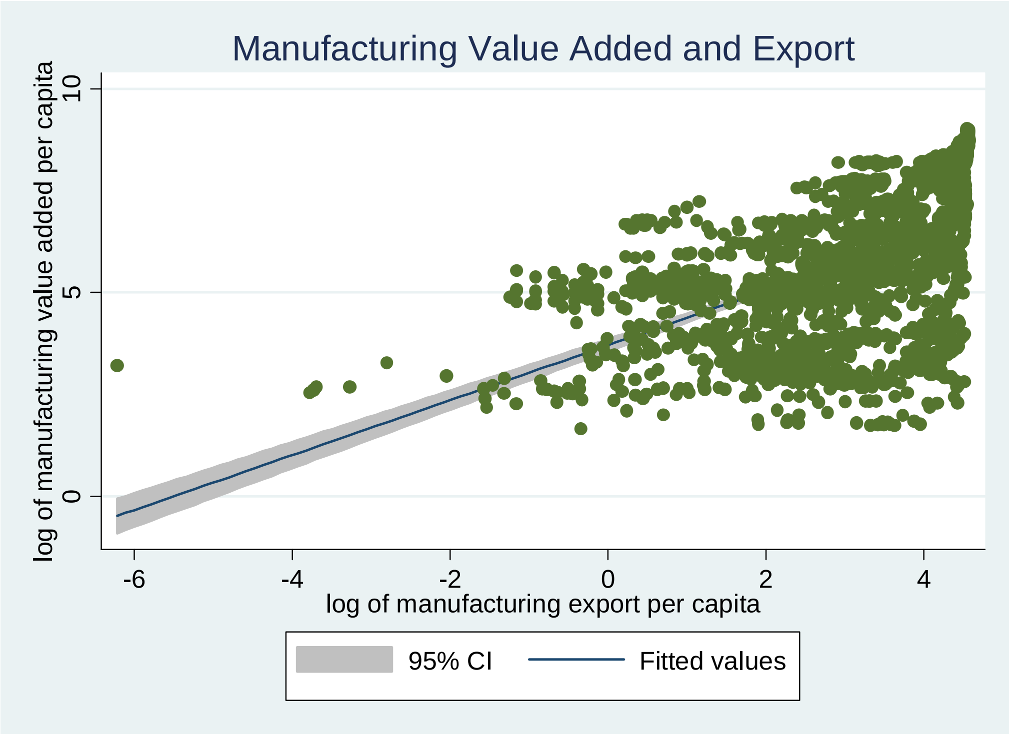


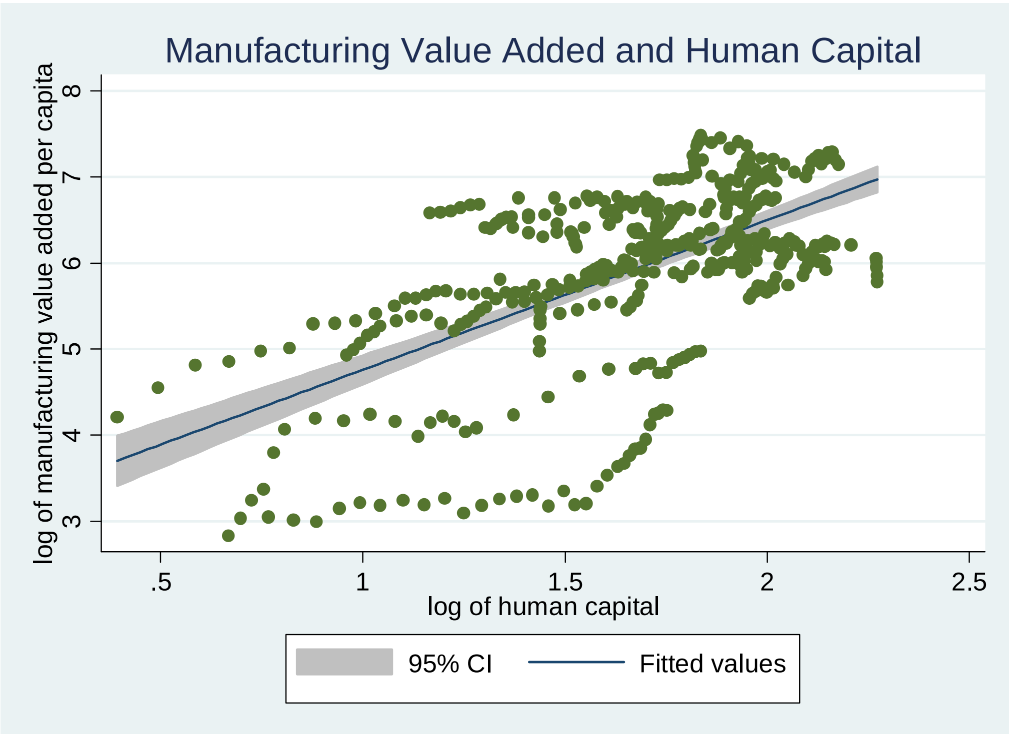
Appendix I:

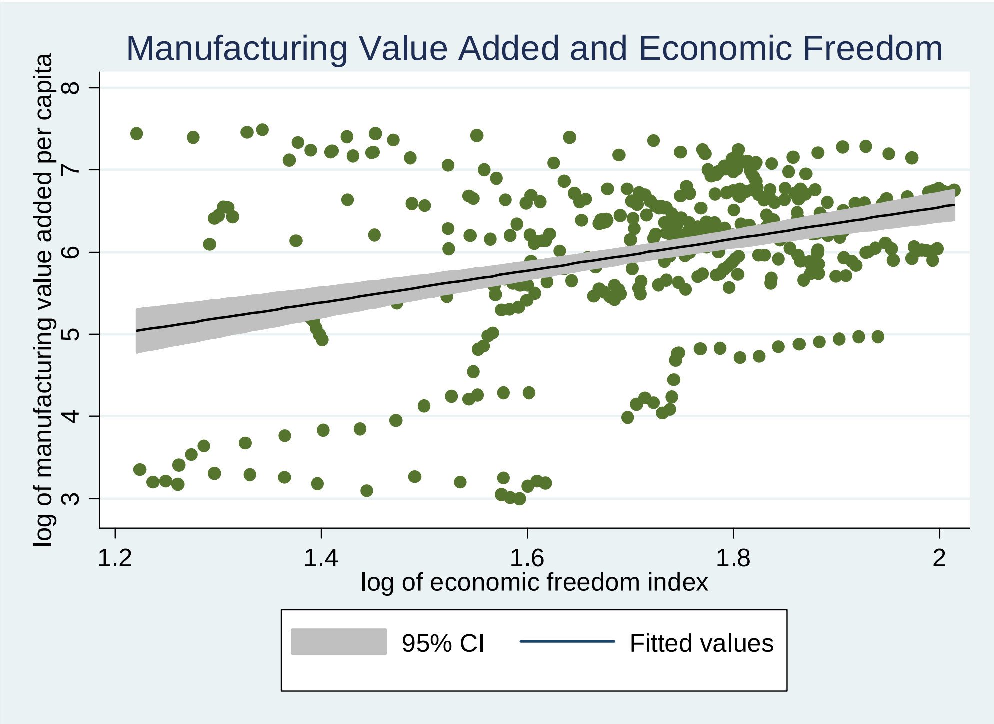
Two-way illustrations of manufacturing per capita and selection of RHS variables





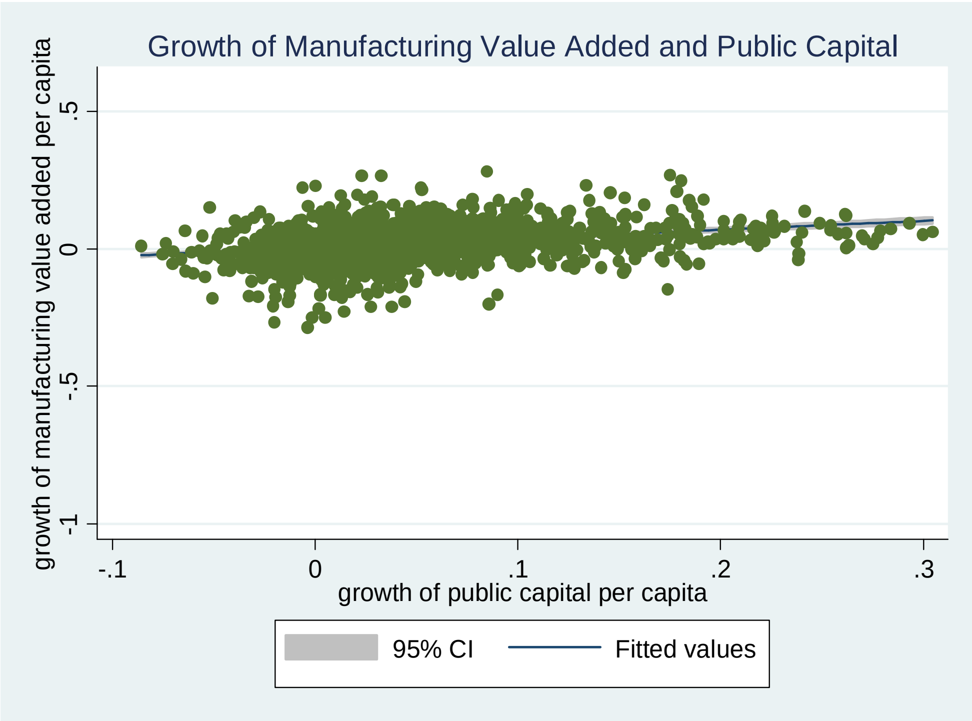

Manufacturing Value Added and Export
log of manufacturing value added per capita
0
5
10
-6
-4
-2
0
2
4
log of manufacturing export per capita
95% CI
Fitted values

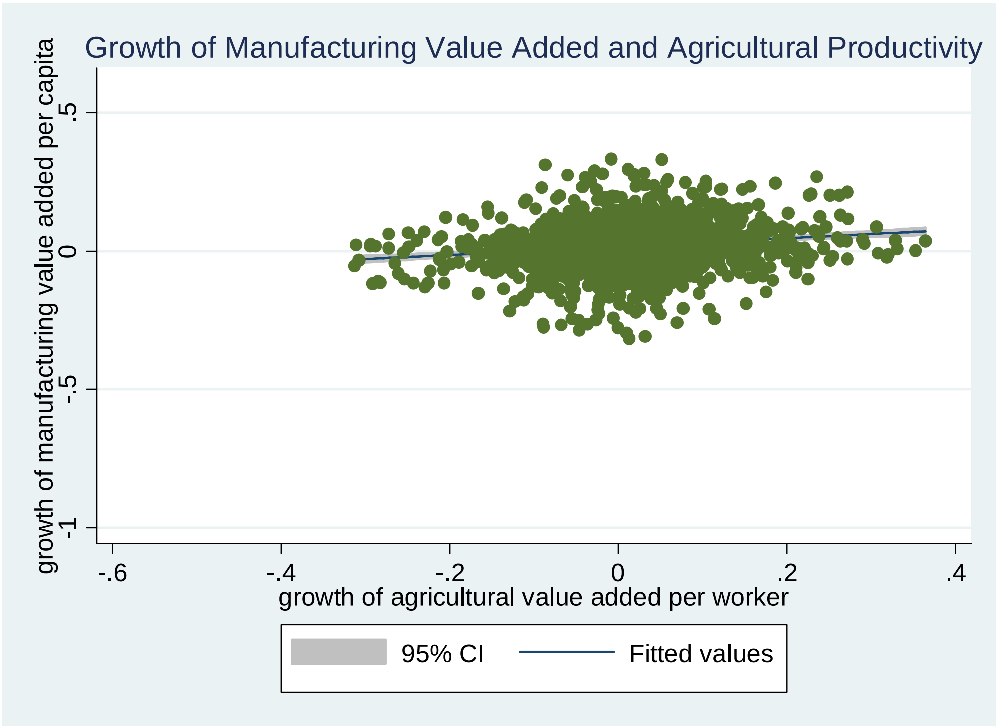

Manufacturing Value Added and Human Capital
log of manufacturing value added per capita
3
4
5
6
7
8
.5
1
1.5
2
2.5
log of human capital
95% CI
Fitted values

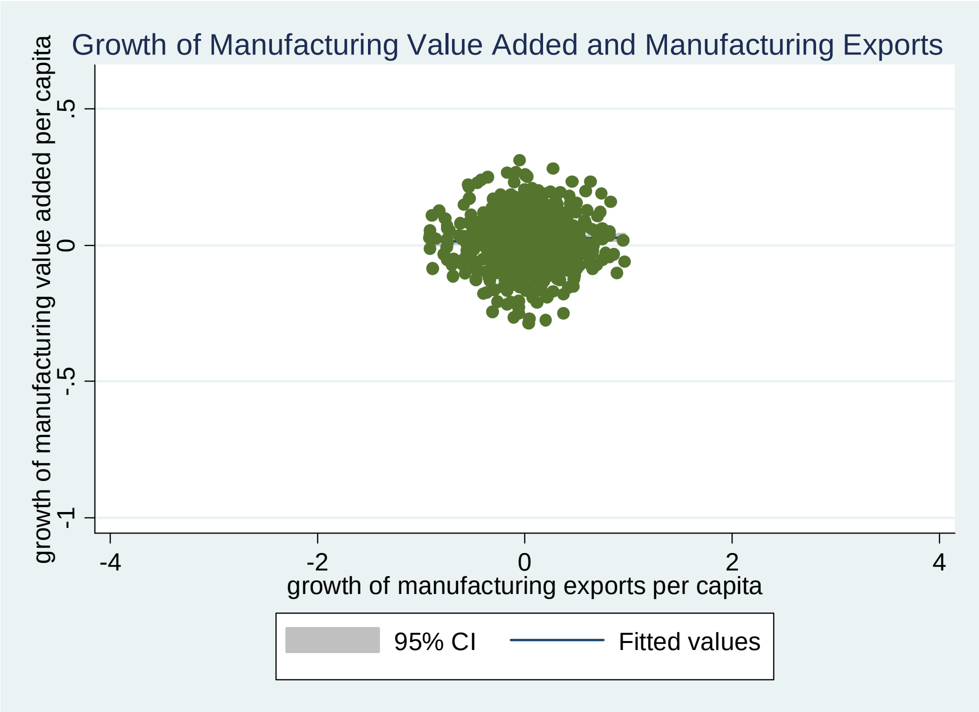

Manufacturing Value Added and Economic Freedom
log of manufacturing value added per capita
3
4
5
6
7
8
1.2
1.4
1.6
1.8
2
log of economic freedom index
95% CI
Fitted values

Appendix II:

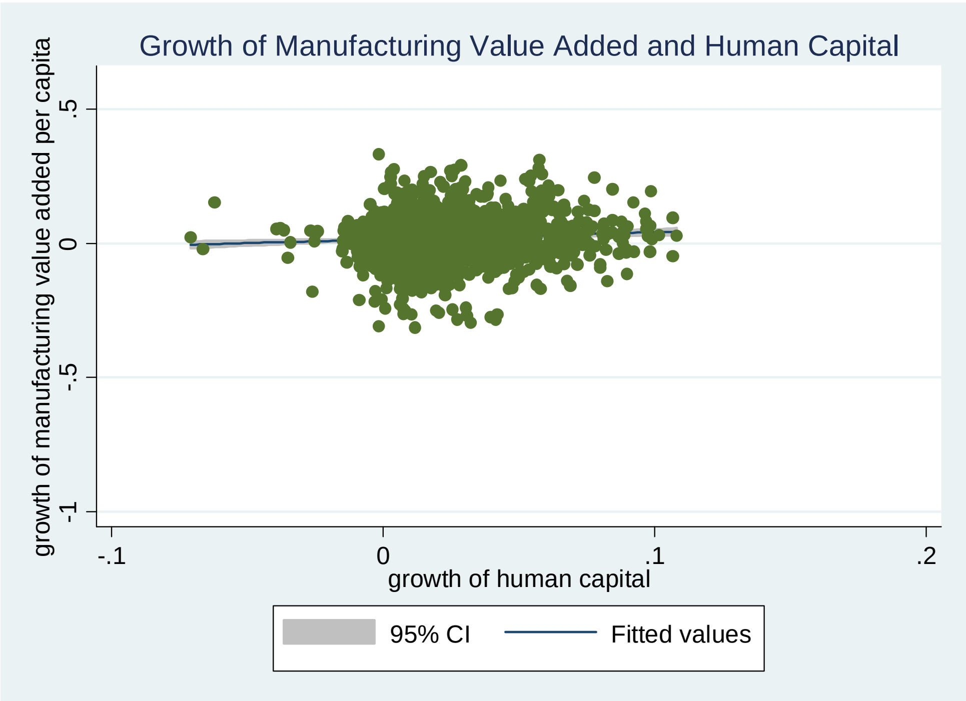
Two-way illustrations of change in manufacturing per capita and selection of RHS variables



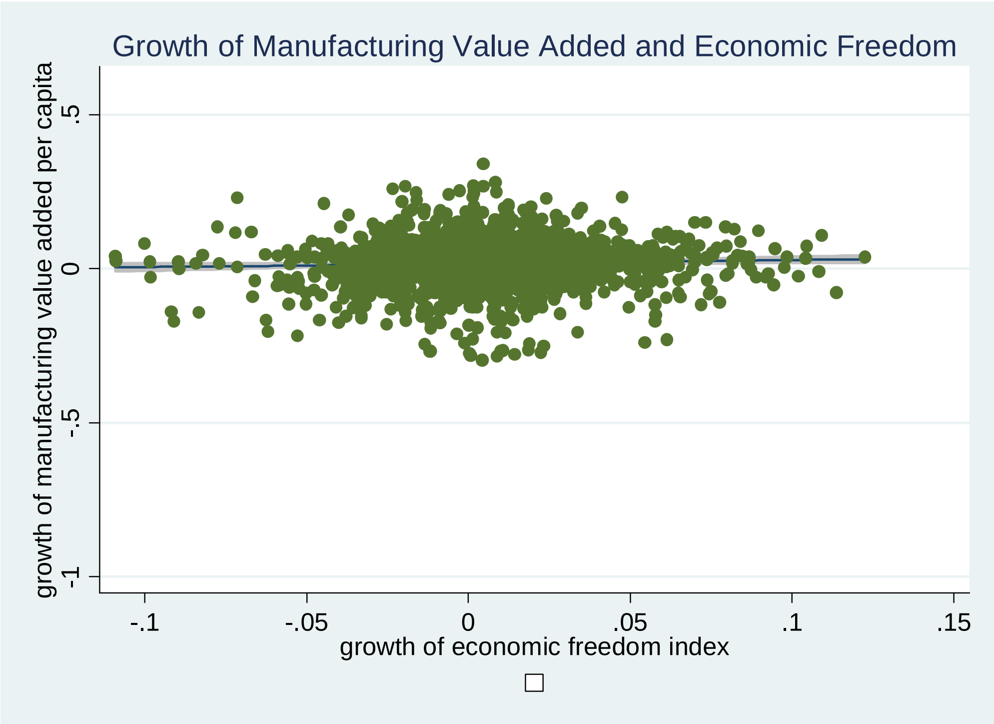




Growth of Manufacturing Value Added and Manufacturing Exports
growth of manufacturing value added per capita
-1
-.5
0
.5
-4
-2
0
2
4
growth of manufacturing exports per capita
95% CI
Fitted values



Growth of Manufacturing Value Added and Human Capital
growth of manufacturing value added per capita
-1
-.5
0
.5
-.1
0
.1
.2
growth of human capital
95% CI
Fitted values


Growth of Manufacturing Value Added and Economic Freedom
growth of manufacturing value added per capita
.5
0
-.5
-1
-.1
-.05
0
.05
.1
.15
growth of economic freedom index

Appendix III

Measuring Public capital

The perpetual inventory method (PIM) is used to estimate the stock of capital from the public investment data. Under the PIM, the stock of capital at the end of year *t* that is available for production in the following year, K_{t+1}, is equal to the depreciated amount of capital left over from the preceding year, $(1-\delta)K_t$, plus the amount of new capital added through investment during the year, I_t:

$$K_{t+1} = (1-\delta)K_t + I_t, \qquad \text{(A.1)}$$

The δ denotes the depreciation rate here, as in the text. By substituting backward in time to some initial period, equation A.1 can be expressed in terms of the depreciated stream of investment plus the initial capital stock, K_0:

$$K_t = (1-\delta)^t K_0 + \sum_{i=1}^{t} (1-\delta)^{t-i} I_i. \qquad \text{(A.2)}$$

This method of estimating the stock of capital requires time-series data on real investment, which is obtained from the Penn World Tables 6.1 (Heston, Summers and Aten, 2002), in purchasing power parity 1996 US dollars. The share of public investment in total investment for 48 developing countries is acquired from the International Finance Corporation, World Bank (World Bank, 2001), and real investment is simply multiplied by this share to arrive at real public investment. Similar information on public investment shares for 22 OECD countries source from OECD Analytical Database, Version June 2002. There is no information as to country-specific depreciation rates, so assume a common three per cent rate for each country is assumed.

To obtain a starting value for the capital stock of each country, the country is assumed to be at its steady state capital-output ratio. The steady-state benchmark value is obtained from the equation:

$$k = i/(g+\delta), \qquad \text{(A.3)}$$

where $k = K/Y$ (i.e. capital-output ratio), g = the growth rate of real Y (i.e. growth of GDP), and $i = I/Y$ (i.e. investment rate). The steady-state growth of GDP *(g)* and the investment rate *(i)*, respectively, are calculated as the annual average over 10 years (1970-1979). Inserting these into (A.3) gives k and the benchmark is obtained by multiplying k by initial GDP. Thereafter, 10 years of investment is added to the benchmark and this marks the initial capital stock, K_0.

Printed in Austria
V.09-89378—February 2010—200

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Telephone: (+43-1) 26026-0, Fax: (+43-1) 26926-69
E-mail: unido@unido.org, Internet: www.unido.org