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

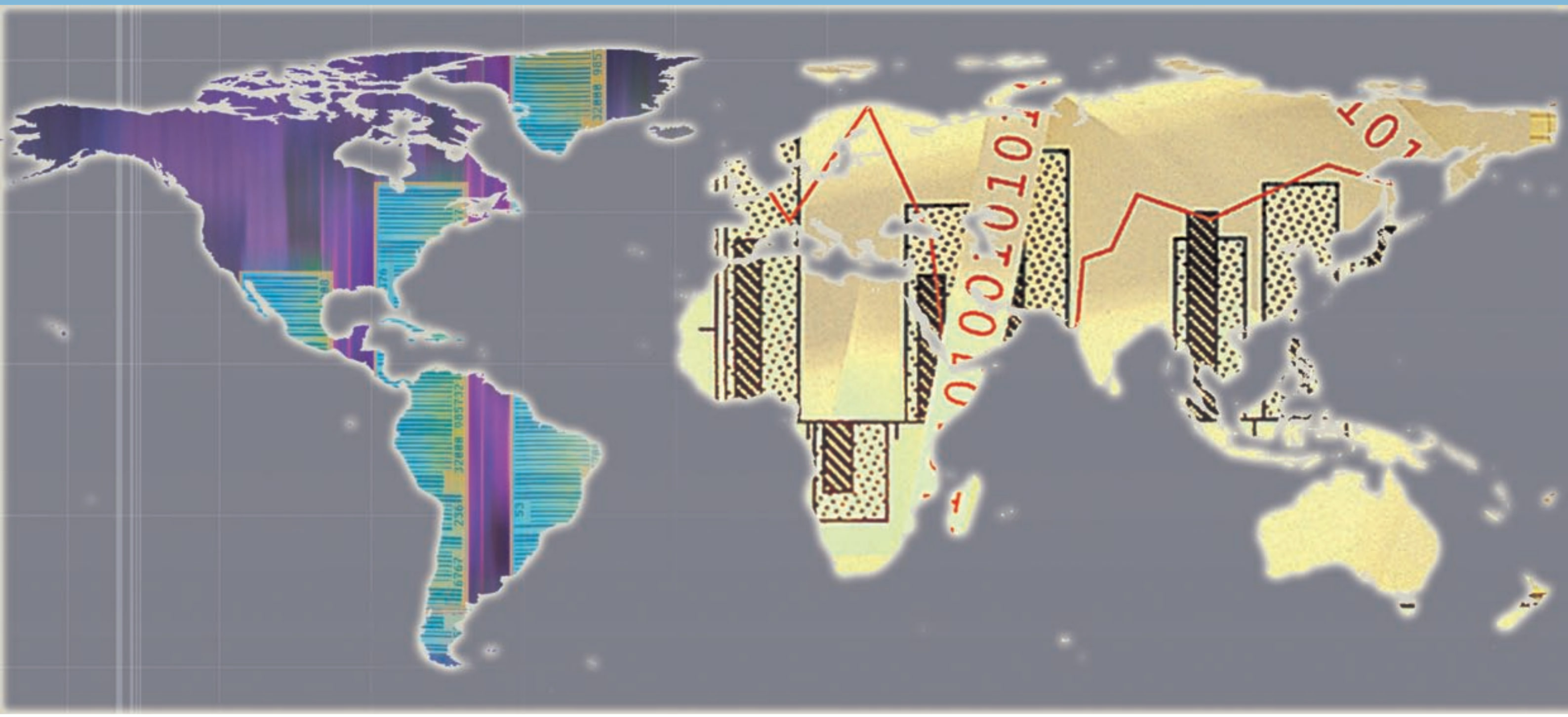
Please contact publications@unido.org for further information concerning UNIDO publications.

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 14/2009



Telecommunications and Industrial Development

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

RESEARCH AND STATISTICS BRANCH
WORKING PAPER 14/2009

Telecommunications and Industrial Development

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

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2010

Contents

List of tables:

Abstract

This paper is concerned with the importance of telecommunications infrastructure and industrial development. It starts by asking why some countries have managed to industrialize while others have not and whether this can be explained by telecommunications infrastructure. Thereafter, it relates the pace of industrialization to the rate at which investment in telecommunications infrastructure occurs. A third issue concerns whether the impact differs across stages of development. To answer these questions a panel of 80 developing and industrialized economies observed between 1970 and 2000 is used. Several econometric issues that have disturbed the literature on infrastructure are addressed as well. The results show that telecommunications infrastructure has strong explanatory power for why some countries have industrialized and others not, but this impact is seen to differ across stages of development. The largest impacts occur at the Upper-mid and Low income levels. Also growth of telecommunications infrastructure contributes to the pace at which countries industrialize, where the largest impacts were obtained for the most advanced economies, the poorest countries and for the fastest growing economies.

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

JEL Classification: C23; D24; H54; L60; L96; N60; O14

1. Introduction

A world without telephones where, people have to physically meet to communicate is difficult to conceive of. Yet this is the stark reality for people in parts of the developing world, although the recent advent and spread of mobile phones works to mitigate the situation. However, mobile phones are silent on issues relating to current cross-country differences in levels of industry. Although lack of efficient communication undoubtedly presents much discomfort, but it does not necessarily follow that development itself is impaired by such lack. [1] This paper first addresses whether telecommunications infrastructure exerts any explanatory power as to why some countries have managed to industrialize while others have failed to do so.

But why would telecommunications infrastructure have anything to do with industrial development? Part of the explanation is that telecommunication affects productivity by, for example, lowering the costs of colleting information and search for services, i.e. the cost of doing business falls. In a way, one can say that increased connectivity reduces the distance between economic actors. Like in the case of transport infrastructure, there is scope for network externalities because with more users, the derived value of those users increases.

Firms need to efficiently communicate with both input and output markets. Correct and swift information caters to optimal decision-making. Orders can be better matched, delivery times be shortened and made more timely, and costly inventory holdings be reduced. Likewise, it is crucial to have access to financial services and quickly learn about prices. It facilitates information flow and helps commercialize and diversify the economy. Modern communication allows for outsourcing and production in smaller units, i.e., increased specialization. The telecommunication sector employs people and generates income in addition to act as an input to production. Indirectly, telecommunications can aid the delivery of government services such as education (World Bank, 2008).

However, it is not only important to have telephones, they also have to function. While Chad may have 15,000 telephones, 91 per cent of all telephone calls are unsuccessful (Hulten, 1996, 1998). This suggests that the issue of infrastructure goes beyond new investment and also includes maintenance and repair.

---

[1] An indication that this might be the case in Latin American countries is provided by Calderón and Servén (2004b, a), who 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.

All of this has an impact on firms' productivity, competitiveness and cost of capital and, more broadly, the cost of doing business. All in all, telecommunications can be argued to cater to the interaction between economic units. As such, it functions as glue, not only inter-personally but also largely between supply and demand. Hence, its role is potentially crucial to the efficient functioning of the economy.

Despite these potentially powerful impacts on development, there are surprisingly few empirical cross-country studies dealing with the impact of telecommunications infrastructure on economic growth, and even fewer with an industry focus. The purpose of this paper is to address this shortage. More specifically, it starts by asking why some countries have managed to industrialize while others have not and whether this has anything to do with telecommunication. Secondly, the paper is concerned with the importance of such infrastructure for understanding differing cross-country rates of industrialization.

Thirdly, it is surmised that the importance of telecommunications infrastructure depends on the stage of development. For example, countries at an early stage may be less "telecommunications-intensive" in their production and, thus, have a smaller stock of such infrastructure, which should result larger returns on infrastructure investment. However, as economies develop and production shifts from agriculture to manufacturing, it is expected that production becomes more intensive in telecommunication, that the stock of it grows and the rate of return to infrastructure investment falls. But if demand for such services outgrow its supply, it is actually possible that the rate of return could grow, for example investment does not respond adequate and the too small stock becomes a constraint. Relieving of this constraint is likely to result in a high rate of return.

As countries become more and more service-oriented, the stock and demand will increase further. Whether this implies lower or greater rate of return cannot be said at the outset—there is a tension between bigger stock effect and high demand—and ultimately is an empirical question. However, it is difficult to say which industry is the most intensive user of telecommunications, manufacturing or the service sector. On the one hand, the impact could be largest in countries where manufacturing and services are well advanced—that is, in rich countries—but it is also possible, on the other, that the marginal return to investment in telecommunications is greater if the initial stock is small.

Because this paper covers a long time period, it is unable to accommodate the recent boom in mobile telephony. The world has seen a tremendous expansion of subscribers of telecommunication services from 1996 to 2006, from less than one to nearly four billion worldwide, and it is the mobile segments that mainly account for this expansion. In particular, with mobile telephony accessibility to telecommunications in, for example rural areas has increased immensely and outnumbers fixed lines by almost nine to one (Djiofack-Zebaze and Keck, 2008).

But this is not necessarily a problem, since the focus of the paper is on development and the existence in time of mobile telephony is simply too short to have any explanatory power for time period considered here. The panel data starts in 1970 and ends in 2000 and thus covers 30 years. The sample includes some 80 countries and covers the entire spectrum from least developed to OECD countries. Several econometric issues alluded to in the literature on public capital and infrastructure is dealt with, for example, the issue of state dependent omitted variables, reverse causation and endogeneity bias.

The results obtained are convincing. Telecommunications infrastructure has strong explanatory power for why some countries have industrialized and others not. And it is an impact that is seen to differ across stages of development. The largest impacts occur at the Upper-mid and Low income levels. The former can probably be explained with the notion that telecommunications contribute more in relatively complex economies, while the latter result is likely to be explained by the fact that the marginal returns to investment are diminishing in the size of infrastructure stock.

Growth of telecommunications infrastructure also contributes to the pace at which countries industrialize, with an impact of infrastructure largely at par with those of human capital and the agricultural productivity performance. In this case, the largest impacts were obtained for the most advanced economies, the poorest countries and for the fastest growing economies.

The paper is organized as follows: Section 2 discusses the existing literature and provides a connection between this work and the literature. Next, in Sections 3 and 4, the literatures on structural change as well as the so-called “deep determinants” are used as a guide to develop a small empirical model, which is, then, confronted with some econometric challenges identified in the empirical literature. The data are discussed in descriptive fashion in Section 5, while the multivariate regression analysis is undertaken in Section 6. Finally, conclusions are provided in Section 7.

2. Review of the empirical literature

The literature on infrastructure essentially began with Aschauer (1989), who found that investment in public capital had a very large return in the United States.[2] Although his work was confirmed by other researchers (e.g., Munnell, 1992), others found his results implausible (e.g., Gramlich (1994) is a nice summary of the early literature). Aschauer's work was also criticized on econometric grounds. Among the most common concerns were omitted variables, infrastructure being endogenous, causality running in the reverse direction and the fact that data might be nonstationary rendering regressions spurious. Subsequent work on infrastructure has tended to focus on one or several of these statistical issues and has, from time to time, managed to reduce the size of the estimated parameter to more reasonable levels.

To an overwhelming extent, past empirical work either tries to explain some aggregate measure, such as GDP per capita or aggregate productivity or their changes, or uses public investment or public capital as proxies for infrastructure. The consequence of the former is to average telecommunications intensive countries with those that uses such input less intensely, which might lead to policy confusion in terms of targeting sectors with the right policy measures. The latter, on the other hand, confounds the individual effects that, for example, telecommunications might have with that of, for example, roads or other non-infrastructural components of public capital. Concerning what these studies try to explain, very few focus on manufacturing, despite its being the most dynamic sector from a technological viewpoint and the one where telecommunications are most likely to have a large impact.[3] Combining dependent variable, telecommunications and cross-country comparisons, the conclusion must be that the empirical literature on the impact of telecommunications infrastructure on industrial development is sparse. Nevertheless, there are some important papers and these will be reviewed here.

Perhaps the most cited work is that by Röller and Waverman (2001), who address endogeneity and omitted state-dependent variables. To do so, the authors model the level of GDP and develop a simultaneous-equations model that contains equations for supply and demand for telecommunications—and thus endogenizes such supply and demand— and a telecommunications production function. Moreover, in their estimations, which are based on 21 OECD countries between 1970 and 1990, they control for fixed effects to deal with omitted variables that might be correlated with telecommunications. First, in the baseline no

---

[2] And later on cross-country samples of developing countries (Aschauer, 2000) and Mexico (Aschauer and Lachler, 1998).

[3] The study by Hulten, Bennathan and Srinivasan (2005) on Indian manufacturing is a rare exception.

fixed-effects model they find that 92 per cent of OECD growth can be attributed to telecommunications, which seems too large to be realistic. However, the authors believe that telecommunications also capture other growth-promoting factors and, therefore, turn to fixed-effects estimation to, at least, capture state-dependent ones. This leads to a much smaller and more reasonable estimate—now only about one third of OECD growth is explained—although they still feel the point estimate is on the high side. Even more interesting is that they find that once a critical mass is attained, increasing returns to investment in telecommunications set in. They interpret this as evidence of network externalities emanating from IT technology. One implication of this result is that growth effects may be higher for OECD than in the less-developed non-OECD countries. In other words, the impact could be increasing in income, something we will attempt to sort out in the empirical section of this paper.

Esfahani and Ramírez (2003) develop a structural model of infrastructure and output growth. Their model takes into account institutional and economic factors that mediate in the infrastructure-GDP interactions. The data cover 75 countries and span from 1965 to 1995, which are used in decadal form, thus providing a maximum of three observations per country. The implied elasticity for phones on GDP growth is between 0.08 and 0.10, and converted into monetary terms the impact generally exceeds the cost of provision of those services. However, the realization of this potential depends on institutional and economic characteristics, which affect steady-state asset-GDP ratios, as well as adjustment rates when asset-GDP ratios diverge from their steady-state.

Another result of the paper is that the steady-state elasticity of infrastructure with respect to total investment is greater than one. This means that factors that prevent countries from investing at high rates tend to particularly hinder investment in infrastructure. Among those factors identified is government credibility (low risk of contract repudiation). The interpretation given is that in the long run governments can manage to invest in infrastructure, while in the short and medium run this is more difficult and might require external assistance.

Lee, Levendis and Gutierrez (2009) focus on telecommunications and economic growth in 44 sub-Saharan African countries between 1975 and 2006. While controlling for bi-directional causation, they also distinguish between the effects of mobile and land-line phones on growth and explicitly model the degree of substitutability of the two phone types. More specifically, by including an interaction term between the two, the authors allow the marginal contribution of mobile phones on growth to be a function of already existing land-lines. To address the issue of reverse causality they use the two-step difference GMM estimator developed by

Blundell and Bond (1998). Interestingly, the results depend on the time period chosen. With a longer time period (1975-2006), land-lines dominate the picture, with also the coefficient for mobile phones being statistically insignificant. For the shorter period (2000-2006), mobile phone infrastructure is what counts. The reason for this result is, of course, that mobile phones are a relatively recent phenomenon and that a long time period analysis does not do justice to its role for economic growth. The bottom line, nevertheless, is that telecommunications infrastructure matters for growth.[4]

Canning and Pedroni (2004) take charge with the issue of spurious regression by testing whether output per capita and phones per capita are cointegrated. They base their work on 67 countries for data covering 1960 to 1990. They find that this, indeed, is the case, and that causation runs in both directions. Furthermore, they find cross-country heterogeneity in terms of causality as well as regarding the sign of the long-run parameter. Interestingly, the average estimated value is close to zero, but with significant nonzero long-run effects in individual countries. In other words, there seems to be no global under provision of telecommunication infrastructure. However, there are instances of both excess and shortage of phones at the country level. The observed heterogeneity suggests the need to also examine country groups, but in their paper this does not seem to alter their conclusions. Here, the issue of country groups will be revisited.

Hulten and Isaksson (2007) suggest that at different stages of development different kinds of infrastructure are important for explaining differences in income and productivity levels. To this end, for 112 countries between 1970 and 2000, they regress total factor productivity (TFP) levels on, *inter alia*, telecommunications infrastructure (number of phones and fixed telephone lines) using OLS and the fixed-effects estimators. They divide the country sample into six groups, assuming that income levels adequate proxy for development stage. In addition, they create two groups of fast-growing economies, namely, the original four East Asian "tigers" and a second group comprised of second-generation Asian fast growers.

---

[4] Repkine (2009) also examines the impact of modern telecommunications infrastructure employing meta-frontier analysis. In the paper, it is argued that the benefits of telecommunications are greater when a person has access to modern infrastructure such as mobile phones and internet compared with someone who only uses land-lines. The author, indeed, finds that higher levels of telecommunications capital intensity—this is the measure employed to reflect the argument posited above—are associated with both higher country-group efficiency and smaller technological gap. However, the impact of the former is far greater than that on the latter.

For the sample as a whole and based on the fixed-effects estimator, the number of phones per capita and fixed telephone lines per capita are positively related to TFP, both with a coefficient of 0.13. In other words, a 10 per cent increase in telecommunications infrastructure is associated with a 1.3 per cent increase in TFP. Whereas the OLS estimator produces positive and statistically significant coefficients for all country groups, the fixed-effects one yields a negative coefficient for low income countries for both categories of telecommunications infrastructure. Based on the fixed-effects estimator and number of phones, the largest point estimates are obtained for the two highest income groups, estimates that are about twice as large as those for the Asian fast-growers, and three times larger than for Lower-mid incomers. For fixed telephone lines the income groups line up slightly differently, with Lower-mid joining the top incomers. The impact of telecommunications is, thus, highest for the most developed economies and smallest for the poorest. The notion of differing impact of telecommunications infrastructure at different stages of development is appealing and is taken up in this paper too.

Based on Barro (1990), Noriega and Fontenla (2005) develop a model for Mexico where public and private capital are complements. Evidence for the role of telecommunications (number of telephone lines) is then sought by way of time series econometrics—bivariate vector autoregression—and long-run derivatives, covering a time period of 1950 to 1994. The impulse-response analysis shows that shocks to telecommunications infrastructure are always positive, has an optimal effect on output growth after about five years and then continues to increase. However, the effect on real output per worker is only significantly different from zero after 13 years. This effect turns out to be permanent for the time horizon of 20 years considered. In other words, the impact of energy infrastructure, in the case of Mexico, only shows up after a rather long lag and if generalized to other countries a contemporaneous regression might not be able to capture the effect.

In a study on South Africa, Fedderke and Bogetic (2009) investigate two different measures of telecommunications infrastructure, namely the number of fixed and total phone lines (fixed plus mobile). The authors distinguish between direct and indirect effects, where the former concerns labour productivity growth and the latter TFP growth based on a value added production function. They analyse two datasets: one that is aggregate and one at three-digit manufacturing sector level. Because of the focus of this paper, only results for the manufacturing sector will be reported. The manufacturing dataset is a panel dataset, with observations from 1970 to 1993. The authors are mindful of reverse causation and endogeneity bias and, therefore, undertake estimations with and without instruments for telecommunications infrastructure.

Without instrumentation, the elasticity of labour productivity with respect to telecommunications is statistically insignificant, while with instruments it is rendered significant. The elasticities of fixed and total phone lines are, respectively, 0.05 and 0.41, showing the importance of mobile phones despite the fact that the data end in 1993 already. In the case of total factor productivity growth and instrumentation, the elasticity of the former climbs to 0.07, while that of the former falls to 0.02 and is statistically insignificant. Furthermore, without instrumentation, nearly all estimates are negatively signed, overall suggesting that the impact of telecommunications infrastructure on TFP growth is small and perhaps even negative.

Easterly and Rebelo (1993) is another study that uses instrumental variables estimation. Their sample includes some 100 countries for the time period of 1970 to 1988, with one observation per country and decade. Their results seem to support Aschauer (1989) that, generally, public spending on telecommunications infrastructure has supernormal returns, based on estimated coefficients ranging from 0.59 to 0.66.[5] The coefficients climb as high as to 2 when infrastructure is being instrumented and the question is what to make of such implausibly large estimates. Nevertheless, there is also some evidence that causality runs from telecommunications to GDP per capita growth. Interestingly, Foster (2008) reports that, across Africa, infrastructure has added 99 basis points to per capita economic growth over the period 1990 to 2005. This contribution is almost entirely attributable to the advancement in the penetration of telecommunication services, which could be an indication that telecommunications infrastructure has very strong effects. Yet, the Easterly-Rebelo results seem to be over the top.

Using principal components analysis, Calderón and Servén (2004a) for the time period 1960 to 2000 and across 121 countries construct an infrastructure composite consisting of telecommunications, electricity-generating capacity and roads. 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. Independent of estimator, the stock of composite infrastructure enters significantly with a positively signed coefficient, while the quality composite is only significant in one case but then with a clearly smaller

---

[5] Actually, the authors use a composite infrastructure index consisting of transport and telecommunications.

parameter. They also consider each of the infrastructures one by one. Those results indicate that also telecommunications infrastructure alone is statistically significant, independent of specification, as well as when the quality of such services are included. As before, the coefficient of the latter is much smaller than the one for the former.[6]

In summary, except for Hulten and Isaksson (2007), no study considers differential growth effects at different stages of development. There are some studies focusing on manufacturing, but they are country-specific (e.g., South Africa). Furthermore, different works tend to address different econometric issues. This said, at least at the aggregate level there is a positive correlation, and even causation, between telecommunications infrastructure and GDP per capita growth. The present paper will extend the literature by considering the relation between telecommunications infrastructure and differential manufacturing levels and growth rates across countries and over time, as well as at different stages of development.

3. An empirical model of industry and telecommunications

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 et al, 2004) and international integration (e.g., Frankel, xxxx). The second strand has focused more on proximate determinants, or a combination of deep and proximate determinants. This empirical literature has evolved into an industry and has shown that more than 100 different determinants in various settings have some explanatory power.

Interestingly, this literature has somewhat evolved with industrialization, and subsequent development into a knowledge and service economy, in the industrialized world. Determinants are often chosen with this in mind and, therefore, seldom concern poor developing country settings where the agricultural and labour-intensive manufacturing sectors still play major roles. Clearly, an empirical model cannot include such an amount of right-hand side variables. An approach to build a parsimonious empirical model is to draw from the deep determinants literature. It seems worthwhile also to draw from the discussion in the development economics literature (e.g, Hirschman, 1958; Rostow, xxxx; Chenery, 1986; Syrquin, 1986; Murphy, Schleifer and Vishny, 1989), where structural change and sectoral linkages are often emphasized, as is infrastructure.

[6] Calderón (2009) 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).

Deep determinants are represented by institutions, proxied by economic freedom, which captures items such as 'rule of law', property rights and contract enforcement, international integration represented by manufacturing exports, human capital measured as years of schooling, while country-specific effects in panel-data models capture geography.[7] From the structural change literature, it proved important to account for the interrelationship between industrial development and agriculture, as well as the role of telecommunications infrastructure, the latter, of course, being the focus on this paper. Therefore, agricultural production per worker and the stock of telecommunications infrastructure measured as the number of telephones per capita and the number of fixed telephone lines per capita were added to the determinants.

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, one view holds that the marginal productivity of labour in the leading modern sector (i.e., manufacturing) and is 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. This is, of course, the so-called Lewis-model, which is an example of how the manufacturing sector may pull resources away from agriculture (Lewis, 1954).

On the other hand, another view, which also leads to a positive link between agriculture and manufacturing, argues that improved agricultural productivity releases labour input to manufacturing, or pushes resources away from agriculture to manufacturing (e.g., Imbs, xxxx; Schultz, 1964). Jorgenson (1961) and Sachs (2008) even 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.
There are several other reasons for why a statistical correlation between agriculture and manufacturing might ensue. For example, if the migration leads to shortage in food

[7] In estimations not shown here, 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.

production (forward linkages) or the two sectors' marginal productivities converge, agricultural growth can constrain manufacturing growth (Fei and Ranis, 1961). Furthermore, the agricultural sector's exports provide foreign exchange, which can be used to import material and capital goods to industry, and with a functioning banking sector, successful agricultural savings can be channelled to and invested by industry. Redistribution of agricultural surplus can also be taxed and provided as support to manufacturing.

Industrialization also raises demand for agricultural goods (Johnston and Mellor, 1961). As workers migrate to industry, agricultural productivity must increase to meet the increasing demand for its goods. Agriculture is also a client of manufacturing. For example, fertilizers are important inputs in agricultural production. 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.[8]

There are also several reasons to believe that human capital has a big role to play for industrialization. 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 unable to learn, adopt and adapt new techniques and technologies will not be able to move up value chains.

Small domestic markets hold industrial development in many developing countries back. Opening up to exports and creating exports opportunities offers scale effects. More interestingly, producing at larger scale could also help firms reaping benefits of scale, for

---

[8] 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.

example, 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 also 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 access to knowledge externalities. Earning foreign exchange also means increased ability to import capital goods and materials from abroad at international prices, which may be lower than those offered at home. A positive coefficient is thus expected.

It is clear from a massive amount of work that institutions and their quality play a role for development, including that of industry. One channel is through productivity growth. 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 increases the contribution of industry to aggregate productivity performance. Institutions are important for investment as well. Incentives to invest decrease unless the ownership of the resulting property can be secured. Moreover, possibilities to borrow are constrained without valid and secure collateral and will hold back investment. If the impartiality of courts is at risk, it jeopardizes the value of contracts and negatively affects risk-taking behaviour and, thus, businesses. Good institutional quality reduces the uncertainty of economic interaction and increases market efficiency by lowering the risk for unforeseen expropriation of assets or breach of contracts and, thus, promotes long-term large investments and productivity (North, 1990).[9]

Generally, countries without coastline or sea navigable rivers find it relatively difficult to develop; likewise, location in the tropics or in disease-stricken areas face similar difficulties (e.g., Sachs, 2003). Although the direct impact on industrial development might be smaller than for the agricultural sector, industry suffers indirectly through its linkages with

[9] Andonova and Diaz-Serrano (2009) analyse the role of local institutions on the performance of the telecommunications sector because the technology relies on sunk investments and is characterized by economies of scale and scope. Interestingly, the authors show this is not the case for cellular telephony, since such networks are cheaper and need fewer subscribers to reach minimum efficient scale. Furthermore, they are less site-specific than fixed-lines installations and have lower capital requirements. This compensates for lack of institutional quality. For the telecommunications infrastructure analysed in this paper, however, institutions are expected to be crucial for the very reasons stated here.

agriculture. Geography, through proximity to buyers, also affects exports, and the longer the distance, the smaller the export opportunity. Unfortunate geographical location may, therefore, hamper industrial development.

4. Econometric modelling strategy

The large estimated infrastructural impacts have in several instances been explained with econometric flaws. Among the more common complaints are spurious correlation due to nonstationary data that do not cointegrate, infrastructure being endogenous with respect to the variable being explained, causality running in the direction of infrastructure rather than the performance variable, and omitted variables.

One way to address spurious correlation is by carrying out the regression using first differences. This is, for example, what Hulten and Schwab (1991) did for TFP and infrastructure. While applying first differences addresses nonstationarity 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 manufacturing 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.

Instead of using first differences, one may wish to apply cointegration techniques, which allow for estimation of long-term relations, which is what Canning and Pedroni (2004) did and found support for. In this paper, the results obtained by them are exploited in the sense that it is *assumed* that also manufacturing and telecommunications infrastructure are cointegrated.

A second serious critique levelled concerns reverse causality, i.e., that the estimated relation rather shows that industrialization leads to increased investment in infrastructure rather than the other way around, or that the estimated coefficient includes bi-directional causation. That the coefficient gets inflated because of bi-directionality seems reasonable to expect. And related, telecommunications infrastructure may be endogenous to industrialization this paper, also leading to an overestimation of the impact of the former on the latter. This paper, therefore, devotes significant efforts to test and account for endogeneity bias and reverse causation.[10]

A third issue is omitted variables. Some researchers, for example Holtz-Eakin (1994), have used panel-data estimation techniques, such as the Fixed-effects (FE) estimator, to mitigate the effects of omitted variable bias (and other econometric concerns as well). An advantage of the FE estimator is that it can handle the effect of omitted variables that may be correlated with telecommunications infrastructure. Failing to do so can affect the estimated coefficient in either direction, depending on the nature of the correlation between infrastructure and the omitted variable.

In addition, because public investment is likely to be tax-financed, richer countries tend to have bigger stocks of telecommunications infrastructure. The FE estimator is able to capture such effects as well by way of fixed effects. To some extent, FE also helps mitigate the adverse consequences of endogeneity bias, for example, if foreign aid used to finance public investment is allocated predominantly to the poorest developing countries the fixed effects will catch that. However, a drawback of the FE estimator is that it only accounts for the within country variation. As such, it ignores statistical variation between units, which, in some cases, is the most relevant. Although it is well-known that the RE estimator may implausibly assume that the country-specific effects and the explanatory variables are uncorrelated, the strength of the estimator is that it provides an estimate that weighs in variation between countries. If this assumption does not hold, the estimates will be affected.

This paper attempts to account for both between and within variation, while correcting for endogeneity bias, reverse causation and omitted variables. By employing both the FE and Random-effects (RE) estimators, several of these issues are addressed at the same time, while endogeneity bias and reverse causation are dealt with by application of instrumental variables (IV) versions of FE and RE. These estimation methods are applied to both levels and growth regressions. In both types of regressions, those effects can be interpreted as accounting for omitted initial conditions, for example the initial stock of infrastructure and other variables

[10] This can be done in several ways. Calderon and Serven (2004) apply SYS-GMM in a growth framework to account for endogeneous infrastructure and find that the relation is robust to such adjustment. Other researchers, for example Fernald (1999), have applied the Seemingly Unrelated Regression Estimation (SURE) techniques and concluded that transport infrastructure, at least in the case of the U.S., relates significantly to output.

included and excluded or, more generally, as a way to account for the initial development level, or omitted state variables, such as geography or cultural traits.

As has been alluded to before, it is hypothesized that the marginal effect of telecommunications infrastructure is larger for relatively poor countries. The thinking behind this hypothesis is that when the stock of infrastructure is small, which is the case in low income countries, each additional investment of infrastructure is relatively large. For example, if there are only a few telephone lines, adding another constitutes a significant addition, whereas in relatively advanced economies another telephone line only implies a marginal increase and, thus, a marginal impact on manufacturing. To this end, the approach of Hulten and Isaksson (2007) is followed. Hence, the group indicator applied is the income level in year 2000, which leads to what they call "meta-countries". These meta-countries are: High income, Upper-Middle income, Lower-Middle income, Low income and Tigers, where the last group singles out seven first- and second-generation Asian fast-growers. Table 1 lists the countries belonging to each group.

To establish a first impression, the paper starts with an OLS estimation of:

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

where X is a vector including agricultural labour productivity, manufacturing exports per capita, human capital and institutions, and Z is a vector of telecommunications infrastructure and ε is the standard i.i.d. residual.

The next step is to re-estimate (1) by RE and FE:

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

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

In the IV versions of (2), the vector Z_{it} is replaced with the fitted counterpart $\tilde{z}_{it}$

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

Equations (1) to (3) are also estimated in first difference form to answer whether growth of infrastructure helps explain industrial development.[11]

There are two types of instruments, external and internal. The former type of instruments includes variables suggested and found reasonable by Canning (1995, 1998). Those instruments are lags 1-3 of population and urban population density, and the growth of these variables. The instrument vector I_{it} also includes lags 1-3 of internal instruments, that is, those exogenous explanatory variables in X_{it} that are assumed to be exogenous. In addition, in the levels regression lags 1-3 of infrastructure growth are used as instruments, while in the growth regression lags 1-3 of infrastructure level replaces its growth counterpart. The choice of lag length is entirely arbitrary but kept low to preserve degrees of freedom, but also because it does not make much sense to go for higher order.

Unfortunately, as is almost always the case with IV-estimation, it is possible to argue that some of the external instruments chosen are, indeed, 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 size of population may not present such a problem in the FE estimation, since the country-specific effects should account for that. Population growth and the rate of urbanization should also to a lesser extent be correlated with the *level* of manufacturing, although one find that relatively rich countries have a slower growing population *and* high manufacturing per capita.

Easterly (2009) argues that 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.

A sequence of tests determines the final instrument vector. In the first step, the five variables used as instruments and their three lags are included in the instruments vector. The error from

[11] In this case, 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 concern.

this regression is included in a second step regression to test for its statistical significance using a simple T-test. Statistical significance at conventional levels suggests whether infrastructure is endogenous or not. 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, as suggested by Hill, Griffith and Lim (2008). In addition, lags 1-3 of each variable are jointly tested, for example lags 1-3 of population, as is jointly all lags of each variable, for example the first lag of all instruments. For these joint tests, an F-value of at least 10 is needed to qualify as valid instruments. In each step, the vector of instruments is tested for joint validity using Sargan's over-identifying test, since too many instruments may overfit endogenous variables. Finally, the battery of tests ends by ensuring in the first stage regression that the instruments finally chosen, indeed, all are statistically significant.

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 endogenous 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 out there are only a few cases when the original test procedure erroneously leads to the conclusion of exogeneity, but when that occurs infrastructure is nonetheless taken to be endogenous.

5. Data

Data on manufacturing value added per capita (MVA), in constant US$ 2000, are drawn from UNIDO's World Productivity Database (Isaksson, 2010), while the two indicators of telecommunications infrastructure—number of fixed mainland telephone lines (TELMA) and number of telephones (PHONE), both per capita—are obtained from Canning (1995, 1998), with extrapolations up to 2000 based on Calderón and Servén (2004a).[12] **For most of the**

[12] There are at least two reasons why physical measures of infrastructure are to be preferred to monetary values. 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 telephone lines or some other infrastructure capacity today that is being measured (Fernald, 1999).

sample period, providers of telecommunications services are state-owned and it is only towards the end of the 1990s that liberalization of the sector started to spread (Djiofack-Zebaze and Keck, 2008). Human capital (H) is measured as the average attainment level for the population aged 15 and older (Barro and Lee, 2000). The variable for institutions (INST), proxied by economic freedom, is supplied by Gwartney, Lawson and Emerick (2003), while agricultural labour productivity (AGR) and manufacturing exports MEXP), both in constant US$ 2000 are obtained from the World Development Indicators (World Bank, 2007).

The data cover 79 (PHONE) and 80 (TELMA) advanced and developing countries, observed annually from 1970 to 2000. The number of countries actually used in the estimations is a function of the combined data availability of all 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.

In order to analyze 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 seven fast-growing Asian countries, for simplicity called Tigers. The latter group of countries may be of particular interest for their ability to sustain good economic growth for an extended period of time and the question is, did investments in telecommunications infrastructure 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 short-term variations in growth. Table 1 shows the list of countries in the dataset and their meta-country membership.

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, as is that of telecommunications infrastructure. Although this does not necessarily imply a correlation between the two, this is, indeed, the working hypothesis of this paper. But also the range of agricultural productivity and manufacturing exports is significant, while those of human capital and institutions appear to be less so. Nonetheless, the sample of countries exhibits quite some variation at levels. The range of growth rates start from the negative territory and continues to fairly high levels, e.g., 10.1 per cent for manufacturing value added per capita. Interestingly, mean telecommunications infrastructure growth by far exceeds those of the other variables, while the average change for institutions is much slower than for the other variables.

Ratios between stocks of telecommunications infrastructure of meta-countries relative to the High incomers are large and may add fuel to the notion that manufacturing performance gaps between industrialized and non-industrialized countries could find its explanation there (Table 3).[13] Closest to the High incomers' manufacturing levels, at just over 15 per cent, is the income group Upper-mid. Tigers follow at a relative level of 9.55 per cent, while the other developing countries lag further behind. In particular, Low incomers only attain just over one per cent. In the cases of TELMA and PHONE, Upper-Mid reaches between 22.18 and 20.33 per cent, respectively, of that of High-income countries, while the other country groups all position below 10 per cent. Again, the relative level of Low incomers is about one per cent. It may be somewhat surprising to observe that the Tiger economies are not very different from the Lower-mid incomers, and are actually somewhat below, in this respect. It is, thus, beyond doubt that the quantity of telecommunications infrastructure is much smaller in developing countries. 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 telecommunications infrastructure, agricultural productivity and human capital; all the other ones will be positively sloped too. The growth illustrations are more difficult to decipher. However, accumulation of telecommunications infrastructure, human capital and agricultural productivity growth are positively related to industrial development, while change in manufacturing exports and institutions appear fairly flat. Multivariate regression analysis will help sort out whether these two-way relations will continue to hold when controlling for other determinants.

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

[13] The story is reminiscent of those in UNCTAD's LDC report (2006) and World Bank's World Development Report (1994). Interestingly, the former adds that also the quality of infrastructure is remarkably lower in developing countries and, in particular, in LDCs. For example, on average between 1999 and 2001, 20 per cent of total electricity output in the LDCs was lost in transmission and distribution, compared with 13 per cent in other developing countries and 6 per cent in OECD. Although it was the intention of this paper to also account for the telecommunications quality aspect, those data proved to be of insufficient quality.

why some countries' industries grow faster than others'. Both sets of results start by analyzing pooled datasets, that is, all countries, but this analysis is followed by results for meta-countries.

6.1. Manufacturing per capita

All countries

Table 4 contains the results of three estimators, Ordinary Least Squares (OLS), Random-effects (RE) and Fixed-effects (FE). OLS, which is based on pooling the data across countries and time provides the benchmark estimation, while the 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 fixed effects and infrastructure as well as with the 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.

This gives the principal 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 right-hand side variables, the advantage is that it weighs in the between-country variation. Variation between countries may actually be more important than that occurring within countries.

To the vector of right-hand side variables, a trend variable (T) accounting for technological change common to all countries, is added.[14] Because infrastructure is expected to have profound long-term effects on the adoption of global technology and, hence, national technological change, the trend variable enters in interaction with the two telecommunications infrastructure variables, denoted TINT. A fairly straightforward interpretation of it may be a measure of how infrastructure strengthens or weakens the effect of technological change on manufacturing, or how the incidence of technological change affects the impact of telecommunications infrastructure on manufacturing. Perhaps the simplest interpretation would be to understand it as an indication of how the impact of telecommunications infrastructure has changed over time. In any case, the expected sign of the coefficient is a positive one.

[14] 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 throughout the paper.

Starting with the pooled estimator (OLS), the coefficient of TELMA is statistically significant and positive, with a coefficient of 0.43. It suggests that a 10 per cent increase of TELMA is associated with an increase of manufacturing amounting to 4.3 per cent. The total effect increases to 5.9 per cent when the effect of the interaction term is included. Large positive effects on manufacturing are obtained from AGR, INST and H, which display elasticities between 0.36 and 0.48, which all are in the vicinity of that obtained for TELMA. MEXP is also positively related to manufacturing, but with a rather small point estimate (about 0.1). Very similar results were obtained for PHONE, except that its total effect at 0.42 is lower than for TELMA. Also, the influence of institutions and human capital appear stronger in this case.

Some of these results may confound the impact of country-specific effects and those of the explanatory variables. By controlling for such effects it can be found out whether they affect the impact of the determinants. Judging from the regression results, individual determinants are correlated with state dependent factors, such as geography, as well as initial conditions, such as high or low income. It can, thus be concluded that employment of panel-data estimators affects the estimates significantly and that controlling for country-specific effects is a major issue. However, the similarity of result produced by the RE and FE estimators indicate that neither controlling for between-country variation, nor correlation between determinants and country effects, is of critical importance.

With the FE estimator, the parameter for TELMA climbs to 0.47, however, with a total effect of 0.45. The total impact obtained from RE is at 0.38 a little lower. The total impact for PHONE is of the same magnitude as for TELMA. Other important consequences of moving to panel-data estimators are registered. The point estimate of AGR has now increased to about 0.52, hence displaying an economically important link between industry and agriculture. The point estimate for MEXP has decreased to between 0.03 and 0.06, depending on estimator and specification. Similarly, the impact of an increase in human capital has fallen significantly. In the TELMA specification it is about 0.21, while when PHONE proxies for telecommunications infrastructure it is as low as 0.09 and not statistically significant. Finally, INST is no longer significant in any of the regressions.

One reason for the negatively signed technological change could be that the composition of the sample in that manufacturing is growing the fastest in mid- and upper-mid income economies and 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 turn out to be negative.

So far, a large impact of telecommunications infrastructure on manufacturing has been recorded. But, how much of this effect reflects causality running from telecommunications to manufacturing? To address this issue, TELMA and PHONE are assumed to be endogenous. Two panel-data estimators are employed, namely, the instrumental-variables estimators of RE and FE.

Table 5 contains the results of the IV estimators. The estimated coefficients for TELMA and PHONE, as predicted, are much lower than earlier. For TELMA, the elasticity lies between 0.149 and 0.164, while for PHONE it is somewhat higher at between 0.216 and 0.223. Accounting for the interaction terms brings the estimates for TELMA and PHONE to similar levels, which is around 0.2. Hence, the conclusion is that an increase of telecommunications infrastructure by 10 per cent not only is associated with, but also causes, an increase in manufacturing amounting to two per cent. Thus, ignoring the endogeneity of telecommunications infrastructure leads to a significant upward bias of the estimates.

The other explanatory variables are also affected. In comparing FE-IV and FE results for TELMA, the parameter for AGR is reduced from 0.52 to about 0.4, while the one for MEXP has doubled to 0.07. The elasticity for H has increased the most, from 0.21 to 0.52. In the PHONE regression, changes are less dramatic. The most important change is that human capital re-enters the picture, with a statistically significant parameter of 0.37.

Taken together, although the causal impact of telecommunications infrastructure has decreased compared with the non-instrumented cases, it is an important explanatory variable for the existence of differing levels of manufacturing across countries. An additional conclusion is that human capital and linkages to agricultural productivity appear to be as important as telecommunications infrastructure for explaining industrial performance.

Meta-countries

How do these "average" results hold up across different stages of development? In other words, the degree of parameter heterogeneity across meta-countries is tested here. Recall that there is no clear expectation as to which meta-country should benefit the most from telecommunications infrastructure.[15] For example, if such infrastructure needs already developed manufacturing and service sectors for it to impact significantly, then its effects will be largest for relatively rich countries. However, if it is rather the existing stock that matters, in the sense that there is diminishing marginal return to such investment, then the biggest parameters will be recorded for countries with relatively low income. Moreover, it is also possible that the largest impact is felt in meta-countries that are not necessarily the most advanced, but the most capital- or manufacturing-intensive. In that case, the largest impact might occur at, for example, Upper-mid income level.

To learn more about this, the point estimates, whether or not statistically significantly different from zero, will be evaluated. The reason for accepting also statistically insignificant parameters for this purpose is that statistical significance only measures whether there is enough variation *within* each group to measure the infrastructural impact, which is not the main purpose. However, the obvious drawback of the approach adopted here is that a parameter not statistically indistinguishable from zero is being evaluated. Therefore, insignificant parameters will nevertheless be treated with caution.

Table 6, with one panel each for TELMA and PHONE, provides the results for all the five different estimators discussed above. Due to space limitations, only the coefficients relevant for telecommunications infrastructure are presented. Empty slots mean that telecommunications infrastructure was not tested to be endogenous.[16]

Starting the reporting with the assumption that telecommunications infrastructure is exogenous, and based on the FE estimator, the coefficient of TELMA is positively signed and statistically significant for the following income groups— ranked according to their respective total effects—Upper-Mid (0.45), Low (0.41), Tigers (0.29), and Lower-Mid (0.24). For High Incomers, the impact is actually negative, though statistically significant. The same pattern appears for PHONE, although the total effects are a little smaller. For the High Incomers, these results mean that further investment in TELMA or PHONE would be counterproductive, at least from the viewpoint of industrial development. For all income groups, except that of the Tigers, the impact of TELMA is falling over time. There is thus a

---

[15] However, the World Bank (1994) shows how the share of telecommunications infrastructure increases with income, which might suggest that the marginal impact of such infrastructure could decrease with income.

[16] The test procedure described above was carried out also at meta-country level.

double negative impact for the High Incomers and a double positive effect for the Tigers, implying that non-linearity may be an issue.

It seems that both reasons for a relatively large impact—a well developed economy and low initial stock—are simultaneously at play. And it also means that, instead of being inversely related to income levels in a smooth fashion, the impact varies somewhat unpredictably. For example, the impact for Lower-mid and Tiger economies is smaller than for Low- and Upper-mid incomers. One interesting aspect of such "impact plateaus" is that the impact of telecommunications infrastructure could be a second source of non-linearity. Furthermore, this characteristic could depend on complementarities not in place. For instance, for telecommunications infrastructure to fully support production, its distribution might require strong institutions. Hence, institutional bottlenecks could impair on its efficient functioning and once the necessary institutions are in place, the large impact of telecommunications infrastructure is restored.

Turning to the IV estimators, and contrary to the experience for the full sample, estimated elasticities are larger. In the case of TELMA, the largest impact is still recorded for Low and Upper-mid incomers (0.56 and 0.53, respectively), with no significant difference in results. Based on the FE-IV estimator, Tigers and Lower-mid incomers share the third place (both 0.26), while the RE-IV suggests that Tigers are still ahead of the other income group. For the High-income group, RE-IV actually delivers a positive TELMA impact of 0.37. However, this does not hold for the FE-IV estimator. This could suggest that between effects are important for this group of countries.

For PHONE, Upper-mid records the largest total impact (0.54), followed by Tigers (0.43), Low (0.42) and Lower-mid (0.24). The Tiger economies actually take first place based on the RE-IV estimator. Because of the perceived correlation between the random effects and right-hand side variables and, thus, bias involved in the random-effects estimator, the FE-IV results may appear more reliable.

The conclusion thus far is that there is that telecommunications infrastructure undoubtedly is an important explanatory factor for explaining cross-country differences in manufacturing levels. Furthermore, it is equally clear that the impact differs across stages of development in such a way that the largest effect is recorded for developing countries with relatively well developed industry (Upper-mid) as well as for those with a small stock of telecommunications infrastructure. The latter effect seems to dominate the former in that the impact for High incomers is not statistically significant or even negative. The latter suggests that, at least for industrial development purposes, the existing level of telecommunications infrastructure does not call for further investment. Finally, possible non-linearity was detected in that the smallest impact was recorded at the Low-mid income level.

6.2. Growth of Manufacturing per capita

All countries

The growth regressions are identical to the level ones, except that all variables are expressed as first log differences. In this case, the interpretation of a time trend is less straightforward, but the trend is primarily included because of an interest in learning how the impact of telecommunications growth changes over time. And as expected, the estimations do not produce any statistically significant results for the trend. However, the interaction term is statistically significant in nearly all regressions.

Table 7 presents the OLS, RE and FE results for ΔTELMA and ΔPHONE. It is clear that the rate of industrialization is positively related to the growth of telecommunications infrastructure. However, the magnitude of the impact depends on the estimator. The largest effects are delivered by ignoring country-specific effects (i.e., OLS). An increase of mean ΔTELMA by one percentage point (from six to seven per cent) is associated with almost a 0.47 percentage point increase of the speed at which manufacturing grows. This effect is not to be ignored, as it implies that mean manufacturing growth increases from 3.6 per cent to 4.1 per cent. The effect of PHONE is slightly smaller. But when accounting for the interaction term, the impact is reduced to 0.26 and 0.23 for ΔTELMA and ΔPHONE, respectively, or manufacturing growth rate increasing from 3.6 to between 3.83 and 3.86. An additional interpretation is that the impact of telecommunications infrastructure is decreasing over time.

Some of this growth turns out to relate to country-specific effects because the FE produces a significant total estimate of about 0.13 for TELMA and only 0.1 for PHONE. This means that a percentage point increase in the growth of telecommunications infrastructure is only associated with an industry growth from 3.6 to about 3.7. These effects are not too large when compared with the usually large effects sometimes obtained in the literature.

Still focusing on the FE estimator, the second most important determinant appears to be growth of human capital (ΔH), which enters with a parameter of about 0.2 for both regressions. Again, OLS produces an upward biased estimate. Change in agricultural labour productivity is also positively related to industrial development, where a 10 percentage point increase is associated with about 0.14 percentage point increase of industry growth, independent of the estimator and regression. Finally, neither ΔMEXP nor ΔINST is statistically significant. The conclusion so far is that growth of telecommunications infrastructure is the most important growth-contributing factor of the ones considered.

There are two changes to report when allowing ΔTELMA to enter as an endogenous variable. The first is that the total impact of telecommunications increases to 0.31 in the FE-IV and 0.39 in the RE-IV. This is much larger than the elasticity obtained under the assumption that ΔTELMA is exogenous. The second change is that institutions are now statistically significant with a parameter of 0.19 in the FE-IV. All the other previous results are robust to the change of estimator. However, it is worth reporting that only in the case of RE-IV does the final test reject the null of exogeneity. Hence, it is possible that allowing for endogeneity introduces some kind of bias, perhaps via the instruments.

The results for ΔPHONE are much closer to the non-IV results—again the tests cannot reject the null of exogeneity—although the total impact is a little larger. As in the case of the FE-IV estimator, institutions enter significantly, while all other results remain as before. Nonetheless, the conclusion must be that telecommunications infrastructure exerts a positive and economically meaningful impact on industrialization.

Meta-countries

The pooled results appeared fairly similar for both types of telecommunications infrastructure. However, allowing for heterogeneity across meta-countries tells a different story. The OLS results suggest that the positive effect is attributed mainly to Low (a total impact of 0.21) and High incomers (0.06); for all other income groups ΔTELMA is not significant. Allowing insignificant parameters to enter the discussion changes the ranking so that the largest impact now is recorded for Upper-mid (0.31), which is followed by Low (0.21), Tigers (0.18), Lower-mid (0.09) and High incomers (0.06).

This result holds also for the RE estimator, while with the FE estimator only the parameter for High-income countries is statistically significant. This could mean that country-specific effects are correlated with growth of telecommunications infrastructure. Again, including insignificant parameters put Upper-mid on top of the list (0.43), followed by High and with the other meta-countries indistinguishable from each other at between 0.04 and 0.06. This result is, thus, very different compared with that obtained for the level regressions. One possibility is that the notion that a well developed manufacturing sector is needed for telecommunications to have a strong impact is at play here and that existing infrastructure stocks do not matter much for growth rates. The FE-IV results bring about one change, namely that the largest impact takes place in the fast-growing Tiger economies. The RE-IV also increases the impact for Low to 0.21 (statistically insignificant).

The picture for ΔPHONE confirms the non-IV results for ΔTELMA in that the largest impacts are registered for High (about 0.25) and Low (about 0.22) incomers for statistically significant parameters. However, this time the parameter is statistically significant also for Lower-mid economies, although the total effect is only 0.08. Allowing for insignificant parameters essentially puts Upper-mid at par with Lower-mid. The Tiger economies once again enter the picture with an estimate of 0.18 for the FE-IV estimator.

Taken together, the conclusion is that growth of telecommunications infrastructure positively impacts on the growth of manufacturing. However, the effect differs depending on development stage. For countries with more complex economies the growth impact is significantly large, which it is also for the Asian fast-growers and at the lowest income level. There is, thus, an important difference between how telecommunications infrastructure impacts on manufacturing levels and growth, and in terms of for which income groups such infrastructure has the largest impact.

7. Conclusions

There are strong a priori reasons to believe that telecommunications infrastructure is important for industrial development. One important function of it is to lower the costs of colleting information and search for services. It facilitates firms' need to efficiently communicate with both input and output markets, and correct and swift information caters to optimal decision-making. Orders can be better matched, delivery times be shortened and more timely, and costly inventory holdings be reduced. As such, it functions as glue, not only inter-personally, but also largely between supply and demand. Hence, its role is potentially crucial to the efficient functioning of the economy. All of this has an impact on firms' productivity, competitiveness and cost of capital and, more broadly, the cost of doing business.

The motivation for this paper was the surprisingly few empirical cross-country studies dealing with measuring the impact of telecommunications infrastructure on growth. Especially lacking is research an industry focus. To address this gap, this paper essentially asked two questions. Firstly, why have some countries managed to industrialize while others have not, and is this related to telecommunications infrastructure? Secondly, to what extent can the differing rates of industrialization observed across countries be explained by such infrastructure?

It was surmised that the importance of telecommunications infrastructure depends on the stage of development. To investigate this issue, the approach of Hulten and Isaksson (2007) was followed. Meta-country groups defined by income levels, as well as a fast-growing country group called Tigers, were formed. It was suspected that countries at an early development stage may be less "telecommunications-intensive" in their production and, thus, benefit less from telecommunications infrastructure than relatively advanced economies. A related issue was whether capital-intensive manufacturing or the service sector is the most intensive user of telecommunications and, if the former, the largest impact of telecommunications infrastructure may not be felt at the highest income level. However, it is also possible that the marginal return to investment in telecommunications is greater if the initial stock is small. In that case, the largest impact would be recorded for the meta-country at the lowest income level.

To answer the questions posed, a panel starting in 1970 and ending in 2000 covering 80 developing and advanced countries was used. Several econometric issues alluded to in the literature on infrastructure were dealt with, for example, the issue of state dependent omitted variables, initial conditions and endogeneity bias. Telecommunications infrastructure was proxied with the number of telephones and fixed telephone lines, both per capita.

The results obtained are convincing. Telecommunications infrastructure has strong explanatory power for why some countries have succeeded industrializing and others not. But the impact is found to differ across stages of development. The largest impacts occurred at the Upper-mid and Low-income levels. The former can probably be explained with the notion that telecommunications contribute more in relatively complex economies with strong manufacturing orientation. The latter result is likely to be explained by the fact that the marginal returns to investment are diminishing in the size of infrastructure stock so that large impacts occur when the stock is small.

Growth of telecommunications infrastructure also contributes to the pace at which countries industrialize. However, the impact of infrastructure is only slightly greater than those of human capital and the agricultural productivity performance. In this case, the largest impacts were obtained for the most advanced economies, the poorest countries and for the fastest growing economies. It is, thus, beyond doubt that telecommunications infrastructure contributes both to short- and long-term industrial development.

One of the reasons for investigating the impact of telecommunications infrastructure at different stages of development was, indeed, the possibility of threshold effects. However, a different approach to the one adopted here, that is to form meta-countries based on income levels, would be to allow the data to do the job. The approaches suggested by Hansen (1999) and Caner and Hansen (2004) are two possible ways to deal with this. Also, data quality across countries is likely to differ significantly, which means that the stages of development analysis may be biased.[17] 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.

As has already been said, the role of dynamics has been neglected. Although the dynamics of the explanatory variables may not be so important, it is possible that some of those variables may be capturing the effects of lagged manufacturing. For example, if past manufacturing is correlated with telecommunications through persistence, the impact estimated here may be exaggerated. The approach developed by Blundell and Bond (1998) may be appropriate in this case. In addition, the role maintenance, for example, highlighted by Hulten (1996, 1998) and the quality of telecommunications infrastructure have not been addressed. Lastly, in this paper only the endogeneity of telecommunications has been addressed. However, it is possible that also a few of the other determinants are endogenous and if those variables are correlated with infrastructure the results obtained here could be biased.

Can it be concluded that investment in telecommunications infrastructure is capable of driving industrialization by creating demand over and above its own investment? In other words, is such investment a necessary condition in the sense of triggering growth? Unfortunately, no such conclusion can be drawn because it is possible that only when countries are poised for growth but are facing infrastructural bottlenecks that governments react by relieving the economy of such bottlenecks. When there is strong demand but there are supply constraints public investment in telecommunications infrastructure can do wonders and, thereby, cause growth by relieving such constraints. If there is little demand, it probably will not help much to build another telephone line and growth will not be driven by public investment. Although it seems somewhat easier to conceive of the latter, the regression results, indeed, suggest that it is telecommunications infrastructure that causes manufacturing growth and not the other way around.

[17] 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 US national accounts (Jorgenson and Landefeld, 2009).

Incidentally, if public investment occurs in a low demand situation, in terms of causality it could actually mimic and be the reciprocal of high demand and low public investment statistically speaking and, thus, statistically reinforcing the direction of causation going from infrastructure to growth. The policy decision of governments, therefore, needs 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.[18]

This paper has sought to contribute to the empirical literature on telecommunications infrastructure and industrial development and has done so by establishing that the former causes the latter. This has previously only been discussed at the GDP level, seldom with particular focus on telecommunications and not accounting for differing stages of development, the exception being Hulten and Isaksson (2007). The policy conclusion emanating from this paper is fairly clear, that is, for most developing countries it pays off to invest in telecommunications infrastructure. This is further supported by Estache (2006), who, based on others' empirical work, reports that expected returns to investment in telecommunications infrastructure is between 30 and 40 per cent.

To further verify the results obtained in this paper, it may prove important to address the caveats mentioned above. This is left for future research, however.

References

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.

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.

Andonova, Veneta and Luis Diaz-Serrano (2009), "Political institutions and Telecommunications, *Journal of Development Economics*, Vol. 89, pp. 77-83.

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

[18] In the case of telecommunications, it is not obvious that it is the government that is the main provider of such services. This is one area where privatization seems to have increased competition and delivered more efficient services in several countries. Although telecommunications might share more characteristics with private than public goods, it is probably in the public interest, and hence relevant for governments, that a well-functioning telecommunications infrastructure exists.

Aschauer, David A. and Lachler, U. (1998), “Public Investment and Economic Growth in Mexico,” *Policy Research Working Paper No. 1964*, Washington, DC: The World Bank.

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.

Barro, Robert J. and Jong-Wha Lee (2000), “International Data on Educational Attainment: Updates and Implications,” *NBER Working Paper No. 7911*, Cambridge, MA: NBER.

Blundell, Richard and Stephen Bond (1998), “Initial Conditions and Moment Restrictions in Dynamic Panel Data Models,” *Journal of Econometrics*, Vol. 87(1), pp. 115-43.

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.

Caner, Mehmet and Bruce Hansen (2004), "Instrumental Variable Estimation of a Threshold Model," *Econometric Theory*, Vol. 20, pp. 813-43

Canning, David, (1995), “A Database of World Infrastructure Stocks, 1950-1995,” *Working Paper*, Harvard Institute for International Development.

Canning, David. (1998), “A Database of World Stocks of Infrastructure, 1950-1995,” *The World Bank Economic Review*, Vol. 12(3), pp. 529-47.

Djiofack-Zebaze, Calvin and Alexander Keck (2008), “Telecommunications Services in Africa: The Impact of WTO Commitments and Unilateral Reform on Sector Performance and Economic Growth,” *World Development*, Vol. 37(5), pp. 919-40.

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.

Esfahani, H.S. and M.T. Ramírez (2003), “Institutions, Infrastructure and Economic Growth,” *Journal of Development Economics*, Vol. 70(??), pp. 443-77.

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.

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.

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

Foster, Vivien (2008), *Overhauling the Engine of Growth: Infrastructure in Africa*, Executive Summary (draft), African Infrastructure Country Diagnostic, Washington, DC: World Bank.

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.

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.

Hansen, Bruce (1999), "Threshold effects in non-dynamic panels: Estimation, testing and inference," *Journal of Econometrics*, Vol. 93, pp. 345-68.

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

University Press.
Holtz-Eakin, Douglas (1994), “Public Sector Capital and the Productivity Puzzle,” *Review of Economics and Statistics*, Vol. 76(??), pp. 12-21.
Hulten, Charles. R. (1996), “Infrastructure Capital and Economic Growth: How Well You Use It May Be More Important Than How Much You Have,” *NBER Working Paper No. 5847*, Cambridge, MA: NBER.
Hulten, Charles. R. (1998), “Infrastructure Capital and Economic Growth: How Well You Use It May Be More Important than How Much You Have,” *mimeograph*, revision of NBER Working Paper No. 5847.
Hulten, Charles. R. and Robert M. Schwab (1991), “Is There Too Little Public Capital? Infrastructure and Economic Growth,” *paper presented at the American Enterprise Institute on ‘Infrastructure Needs and Policy Options for the 1990s’*, Washington, D.C.: American Enterprise Institute.
Hulten, Charles, R., Esra Bennathan and Sylaja Srinivasan (2005), “Infrastructure, Externalities, and Economic Development: A Study of Indian Manufacturing Industry,” *report to the World Bank research project ‘Growth and Productivity Effects of Infrastructure: Regional Study in India’*, Washington, D.C.: World Bank.
Hulten, Charles R. and Anders Isaksson (2007), “Why Development Levels Differ: Differential Growth in a Panel of High and Low Income Countries,” *mimeograph*.
Jorgenson, Dale W. and J. Steven Landefeld (2009), “Implementation of a New Architecture for the US 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(??), pp. 309-34.
Lee, Sang H., John Levendis and Luis Gutierrez (2009), “Telecommunications and Economic Growth: An Empirical Analysis of Sub-Saharan Africa,” *Serie Documentos de Trabajo*, No. 64, Facultad de Economía, Universidad del Rosario.
Munnell, Alicia.H. (1992), “Policy Watch: Infrastructure Investment and Economic Growth,” *Journal of Economic Perspectives*, Vol. 6, pp. 189-98.
Murphy, Kevin M., Andrei Schleifer and Robert W. Vishny (1989), “Industrialization and the Big Push,” *Journal of Political Economy*, Vol. 97(5), pp. 1003-26.
Noriega, Antonio and Matias Fontenla (2005), “Public Infrastructure and Economic Growth in Mexico,” *mimeograph*, Universidad de Guanajuato.
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.
Repkine, Alexandre (2009), “Telecommunications Capital Intensity and Aggregate Production Efficiency: a Meta-Frontier Analysis,” *mimeograph*, College of Commerce and Economics, Konkuk University.
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.
Röller, Lars-Hendrik and Leonard Waverman (2001), “Telecommunications Infrastructure and Economic Development: A Simultaneous Approach,” *American Economic Review*, Vol. 91(4), pp. 909-23.
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.
UNCTAD (2006), *The Least Developed Countries Report, 2006*, New York and Geneva: United Nations.
World Bank (1994), *World Development Report 1994: Infrastructure for Development*, Washington, D.C.: World Bank.

World Bank (2007), *World Development Indicators 2007 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.

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, DC: World Bank.

Table 1 List of countries

HIGH INCOME	UPPER-MID	LOW-MID	LOW INCOME	TIGERS
	Income per capita = 6,001 and above in year 2000, excluding OECD + Israel	*Income per capita = 3,001-6,000 in year 2000*	*Income per capita = up to 3,000 in year 2000*	
Australia	Argentina	Algeria	Bangladesh	China
Austria	Barbados	Colombia	Benin	India
Belgium	Botswana	Costa Rica	Bolivia	Indonesia
Canada	Chile	Dominican Republic	Cameroon	Korea, Republic of
Denmark	Mauritius	Ecuador	Central African Rep.	Malaysia
Finland	Mexico	Egypt	Congo	Singapore
France	Panama	El Salvador	Ghana	Thailand
Greece	South Africa	Fiji	Guinea Bissau *	
Italy	Syria	Guatemala	Honduras	
Japan	Trinidad and Tobago	Guyana	Kenya	
New Zealand	Tunisia	Iran	Malawi	
Norway	Turkey	Jamaica	Mali	
Portugal	Uruguay	Jordan	Nepal	
Spain	Venezuela	Pakistan	Nicaragua	
Sweden		Paraguay	Niger	
Switzerland		Peru	Papua New Guinea	
UK		Philippines	Rwanda	
USA		Sri Lanka	Senegal	
			Tanzania, U. Rep. of	
			Togo	
			Uganda	
			Zambia	
			Zimbabwe	

80 countries in the TELMA dataset, 79 countries in the PHONE dataset.

* Not included in the phone dataset.

Table 2 Descriptive statistics (in logs)

Variable	Mean	Stand. Dev.	Min	Max
*Levels of**				
MVA per capita	5.630	1.787	2.237	8.736
TELMA	3.719	1.739	0.495	6.444
PHONE	4.043	1.775	0.506	6.830
AGR	7.524	1.534	4.557	9.992
MEXP	3.150	1.135	0.488	4.554
INST	1.747	0.155	1.342	2.079
H	1.577	0.545	-0.338	2.439
*Growth of***				
MVA per capita	0.022	0.027	-0.094	0.101
TELMA	0.064	0.031	-0.061	0.194
PHONE	0.058	0.032	-0.062	0.196
AGR	0.025	0.016	-0.028	0.068
MEXP	0.027	0.046	-0.174	0.272
INST	0.007	0.009	-0.025	0.067
H	0.016	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

	MVA	TELMA	PHONE
High	100.00	100.00	100.00
Low	1.20	1.44	1.32
Lower-mid	7.38	8.62	7.58
Upper-mid	15.03	22.18	20.33
Tigers	9.55	7.16	6.13

Table 4 Telecommunications and Manufacturing value added per capita, OLS, Random and Fixed effects

	OLS	RE	FE	OLS	RE	FE
Constant	0.080	0.141	0.234	-0.431***	-0.338	-0.117
	(0.46)	(0.53)	(0.55)	(2.63)	(1.31)	(0.28)
TELMA	0.431***	0.463***	0.466***			
	(19.26)	(20.03)	(17.90)			
PHONE				0.420***	0.504***	0.505***
				(19.06)	(19.78)	(17.61)
AGR	0.396***	0.517***	0.520***	0.424***	0.520***	0.511***
	(17.47)	(16.27)	(10.66)	(19.04)	(16.79)	(10.81)
MEXP	0.098***	0.037**	0.031**	0.098***	0.059***	0.053***
	(9.63)	(2.49)	(1.97)	(9.62)	(4.07)	(3.45)
INST	0.478***	-0.056	-0.071	0.550***	0.032	0.014
	(4.15)	(0.99)	(1.25)	(4.69)	(0.61)	(0.27)
H	0.358***	0.234***	0.208***	0.360***	0.130**	0.089
	(9.42)	(4.09)	(3.31)	(9.17)	(2.16)	(1.36)
T	-0.040***	0.010***	-0.020***	-0.030***	-0.008***	-0.006*
	(11.45)	(3.28)	(6.02)	(8.64)	(2.72)	(1.80)
TINT	0.001	-0.005***	-0.001**	-0.000	-0.003***	-0.004***
	(1.53)	(7.81)	(1.99)	(0.56)	(5.85)	(5.67)
N	1723	1723	1723	1722	1722	1722
R^2	0.93	0.92	0.60	0.93	0.92	0.60
F [a]	4116.49***	2065.59***	154.00***	3814.51***	1973.75***	148.86***
	(7,1715)	(7)	(7,1636)	(7,1714)	(7)	(7,1636)

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, robust standard errors, N = number of observations, OLS = Ordinary Least Squares, RE = Random-effects estimator and FE = Fixed-effects estimator.

TELMA = telephone main lines per capita, PHONE = number of telephones 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 TELMA/PHONE.

[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)].

Table 5 Telecommunications and Manufacturing per capita, FE-IV

	RE-IV	FE-IV		RE-IV	FE-IV
Constant	0.337*** (1.50)	1.570*** (4.94)		-0.290 (1.34)	0.857*** (2.60)
TELMA	0.164*** (3.79)	0.149*** (3.24)			
PHONE				0.216*** (4.04)	0.223*** (4.24)
AGR	0.517*** (18.06)	0.395*** (10.63)		0.565*** (19.07)	0.453*** (12.04)
MEXP	0.086*** (6.39)	0.070*** (5.24)		0.099*** (7.44)	0.081*** (6.30)
INST	0.012 (0.22)	-0.023 (0.41)		0.060 (1.05)	0.021 (0.37)
H	0.592*** (8.12)	0.515*** (6.48)		0.490*** (5.16)	0.373*** (4.11)
T	-0.029*** (10.63)	-0.023*** (7.96)		-0.018*** (6.03)	-0.012*** (4.04)
TINT	0.002*** (3.18)	0.002*** (3.13)		-0.000 (0.68)	-0.001 (0.87)
N	1567	1567		1549	1512
Endogenous	TELMA	TELMA		PHONE	PHONE
R^2	0.92	0.47		0.92	0.50
F [a]	288.08*** (7,1560)	157.10*** (86,1481)		310.32*** (7.1542)	162.69*** (85,1427)
F [b]		106.63*** (78,1481)			112.47*** (77,1427)
First t-test [c]	0.016	-0.026		0.092*	0.033
Final t-test [d]	-0.289***	-0.318**		-0.271***	-0.260*
First stage [e]			First stage [e]		
$\Delta Telma_{t-1}$	5.01***	4.73***	$\Delta Phone_{t-1}$	6.35***	6.84***
$\Delta Telma_{t-2}$	6.97***	6.70***	$\Delta Phone_{t-2}$	7.42***	7.70***
$\Delta Telma_{t-3}$	10.21***	10.24***	$\Delta Phone_{t-3}$	8.87***	9.26***
Sargan [f]		0.048			0.323

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-IV, robust standard errors. N = number of observations, Endogenous = endogenous explanatory variable, Δ = first difference operator.

TELMA = telephone main lines per capita, PHONE = number of telephones 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 TELMA/PHONE.

[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 TELMA/PHONE is endogenous in the first test round [d] T-test for whether TELMA/PHONE is endogenous in the last test round [e] First stage t-values for instruments [f] χ^2-test for validity of instruments, χ^2 (instr.-1).

Table 6 Telecommunications and Manufacturing per capita, OLS, Random-effects (RE) and Fixed-effects (FE) and RE and FE instrumental variables, Meta-countries

		OECD	Upper-Mid	Lower-Mid	Low	Tigers
OLS	TELMA	-0.104	-0.142	0.540***	0.635***	0.337***
		(1.61)	(1.15)	(5.84)	(8.89)	(4.42)
	TINT	-0.002	0.002	-0.008**	-0.010***	0.001
		(0.52)	(0.36)	(2.43)	(3.57)	(0.56)
RE	TELMA	-0.120***	0.531***	0.317***	0.559***	0.337***
		(2.68)	(14.16)	(4.42)	(9.26)	(4.42)
	TINT	-0.003	-0.005***	-0.004***	-0.008***	0.001
		(1.37)	(3.66)	(2.87)	(5.15)	(0.56)
FE	TELMA	-0.120***	0.533***	0.301***	0.541***	0.222***
		(2.68)	(14.53)	(3.79)	(9.01)	(5.73)
	TINT	-0.004*	-0.005***	-0.004***	-0.008***	0.004**
		(1.66)	(3.75)	(2.62)	(4.86)	(2.41)
RE-IV	TELMA	0.373*	0.671***	0.323***	0.784***	0.411***
		(1.75)	(5.30)	(2.77)	(5.68)	(4.29)
	TINT	-0.000	-0.009**	-0.004**	-0.013***	0.000
		(0.09)	(2.57)	(2.02)	(4.33)	(0.19)
FE-IV	TELMA		0.685***	0.323***	0.755***	0.191*
			(5.38)	(2.77)	(6.52)	(1.92)
	TINT		-0.010***	-0.004**	-0.012***	0.004*
			(2.71)	(2.05)	(4.87)	(1.61)
OLS	PHONE	0.083	-0.120	0.496***	0.480***	0.460***
		(1.26)	(0.82)	(6.14)	(5.63)	(6.77)
	TINT	-0.000	0.006	-0.006**	-0.010**	-0.000
		(0.17)	(1.07)	(2.15)	(2.54)	(0.02)
RE	PHONE	-0.004	0.507***	0.279***	0.460***	0.460***
		(0.09)	(13.59)	(4.66)	(8.91)	(6.77)
	TINT	-0.001	-0.004***	-0.004***	-0.008***	-0.000
		(0.45)	(3.05)	(2.83)	(5.17)	(0.02)
FE	PHONE	-0.006	0.510***	0.262***	0.464***	0.258***
		(0.14)	(13.62)	(4.13)	(9.47)	(5.82)
	TINT	-0.000	-0.004***	-0.004***	-0.008***	0.004**
		(0.21)	(3.04)	(2.57)	(5.34)	(2.29)
RE-IV	PHONE		0.610***	0.321***	0.594***	0.672***
			(4.07)	(3.77)	(5.82)	(5.72)
	TINT		-0.008*	-0.005***	-0.011***	-0.002
			(1.84)	(5.13)	(4.58)	(0.73)
FE-IV	PHONE		0.719***	0.317***	0.596***	0.461***
			(3.79)	(3.71)	(7.42)	(5.73)
	TINT		-0.011**	-0.005***	-0.011***	-0.002
			(2.05)	(5.04)	(5.44)	(0.64)

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 TELMA/PHONE was not endogenous
TELMA = telephone main lines per capita, PHONE = number of telephones per capita, TINT = interaction term between trend and TELMA/PHONE.

Table 7 Telecommunications and Industrial development, OLS, Random and Fixed effects

	OLS	RE	FE	OLS	RE	FE
Constant	-0.008	0.001	0.007	-0.001	0.021***	0.006
	(1.18)	(0.16)	(1.04)	(0.20)	(5.24)	(0.92)
ΔTELMA	0.468***	0.322***	0.258***			
	(6.10)	(4.49)	(3.56)			
ΔPHONE				0.376***	0.305***	0.296***
				(5.32)	(4.45)	(4.18)
ΔAGR	0.150***	0.143***	0.138***	0.156***	0.145***	0.140***
	(6.12)	(5.95)	(5.68)	(6.41)	(6.08)	(5.76)
ΔMEXP	0.011	0.006	0.005	0.009	0.004	0.003
	(1.04)	(0.66)	(0.52)	(0.94)	(0.47)	(0.34)
ΔINST	0.117	0.118	0.111	0.114	0.114	0.106
	(1.57)	(1.58)	(1.45)	(1.51)	(1.50)	(1.37)
ΔH	0.321***	0.262***	0.207**	0.340***	0.247***	0.187*
	(3.87)	(2.91)	(2.19)	(3.96)	(2.69)	(1.94)
T	0.000	0.000	0.000	0.000	0.000	0.000
	(1.02)	(0.30)	(0.13)	(0.12)	(0.45)	(0.98)
TINT	-0.013***	-0.009***	-0.008**	-0.009**	-0.010***	-0.012***
	(4.02)	(2.97)	(2.51)	(2.54)	(2.92)	(3.37)
N	1548	1548	1548	1543	1543	1543
R^2	0.10	0.10	0.05	0.10	0.09	0.05
F [a]	17.81***	79.70***	8.15***	19.20***	83.63***	9.31***
	(7,1540)	(7)	(7,1464)	(7,1535)	(7)	(7,1459)

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. N = number of observations, Δ = first difference operator.

TELMA = telephone main lines per capita, PHONE = number of telephones 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 TELMA/PHONE.

[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)].

Table 8 Telecommunications and Industrial development, Random and Fixed-effects instrumental variables

	RE-IV	FE-IV		RE-IV	FE-IV
Constant	-0.038 (1.57)	-0.031*** (2.69)		-0.012 (0.47)	-0.006 (0.75)
ΔTELMA	0.948** (2.50)	0.773*** (4.72)			
ΔPHONE				0.556 (1.37)	0.420*** (3.50)
ΔAGR	0.131*** (5.78)	0.135*** (6.29)		0.141*** (6.62)	0.146*** (6.89)
ΔMEXP	0.004 (0.52)	0.002 (0.20)		0.002 (0.28)	0.001 (0.18)
ΔINST	0.163** (2.34)	0.186*** (2.64)		0.112* (1.71)	0.156** (2.24)
ΔH	0.245*** (2.68)	0.239** (2.45)		0.227** (2.49)	0.203** (2.08)
T	0.002* (1.70)	0.002*** (3.22)		0.001 (0.75)	0.001* (1.95)
TINT	-0.035** (2.23)	-0.029*** (4.26)		-0.022 (1.19)	-0.018*** (3.10)
N	1524	1491		1543	1488
Endogenous	ΔTELMA	ΔTELMA		ΔPHONE	ΔPHONE
R^2	0.09	0.03		0.08	0.05
F [a]	15.76 *** (7,1517)	12.76 *** (84,1406)		15.76 *** (7,1536)	10.77 *** (84,1404)
F [b]		3.24 *** (76,1404)			3.83 *** (76,1404)
First t-test [c]	0.060	0.624***		-0.439	0.064
Final t-test [d]	0.778*	0.339		0.526	0.134
First stage [e]			First stage [e]		
$Telma_{t-1}$	6.81***	3.93***	$Phone_{t-1}$	6.62***	5.83***
$Telma_{t-2}$	7.07***	10.54***	$Phone_{t-2}$		2.00**
			$Phone_{t-3}$		4.48***
Sargan [f]		0.334			1.759

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, robust standard errors, Endogenous = endogenous explanatory variable, Δ = first difference operator and N = number of observations.

TELMA = telephone main lines per capita, PHONE = number of telephones 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 TELMA/PHONE.

[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 TELMA/PHONE is endogenous in the first test round [d] T-test for whether TELMA/PHONE is endogenous in the last test round [e] First stage t-values for instruments [f] χ^2-test for validity of instruments, χ^2 (instr.-1).

Table 9 Telecommunications and Industrial Development, OLS, Random-effects (RE), Fixed-effects (FE), and RE and FE instrumental variables, Meta-countries

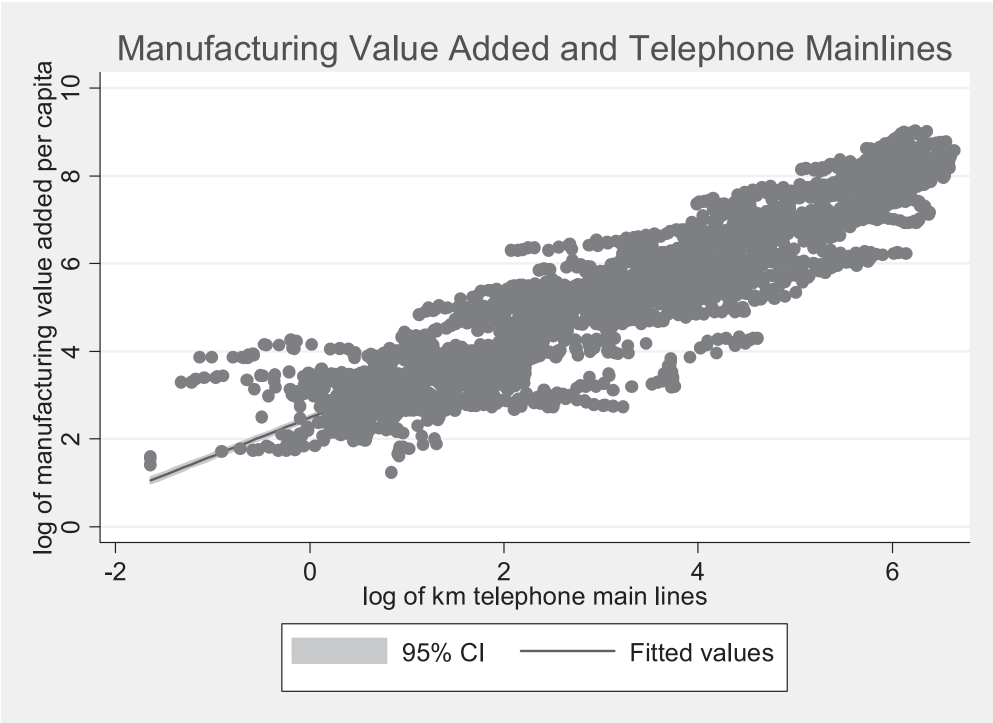
		OECD	Upper-Mid	Lower-Mid	Low	Tigers
OLS	ΔTELMA	0.570*	0.376	0.088	0.452*	0.225
		(1.73)	(1.54)	(0.61)	(1.90)	(1.54)
	TINT	-0.032***	-0.004	-0.000	-0.015	-0.003
		(4.08)	(0.43)	(0.07)	(1.62)	(0.36)
RE	ΔTELMA	0.590***	0.376	0.073	0.388*	0.225
		(4.12)	(1.54)	(0.53)	(1.69)	(1.54)
	TINT	-0.032***	-0.004	0.000	-0.013	-0.003
		(4.11)	(0.43)	(0.01)	(1.43)	(0.36)
FE	ΔTELMA	0.657***	0.277	0.042	0.173	0.072
		(4.32)	(0.97)	(0.30)	(0.82)	(0.57)
	TINT	-0.034***	-0.044	0.001	-0.008	0.002
		(4.31)	(0.31)	(0.19)	(0.85)	(0.31)
RE-IV	ΔTELMA	0.579*			0.569	
		(1.78)			(0.59)	
	TINT	-0.029*			-0.022	
		(1.69)			(0.58)	
FE-IV	ΔTELMA	0.312				0.815*
		(1.38)				(1.94)
	TINT	-0.014				-0.031
		(1.15)				(1.61)

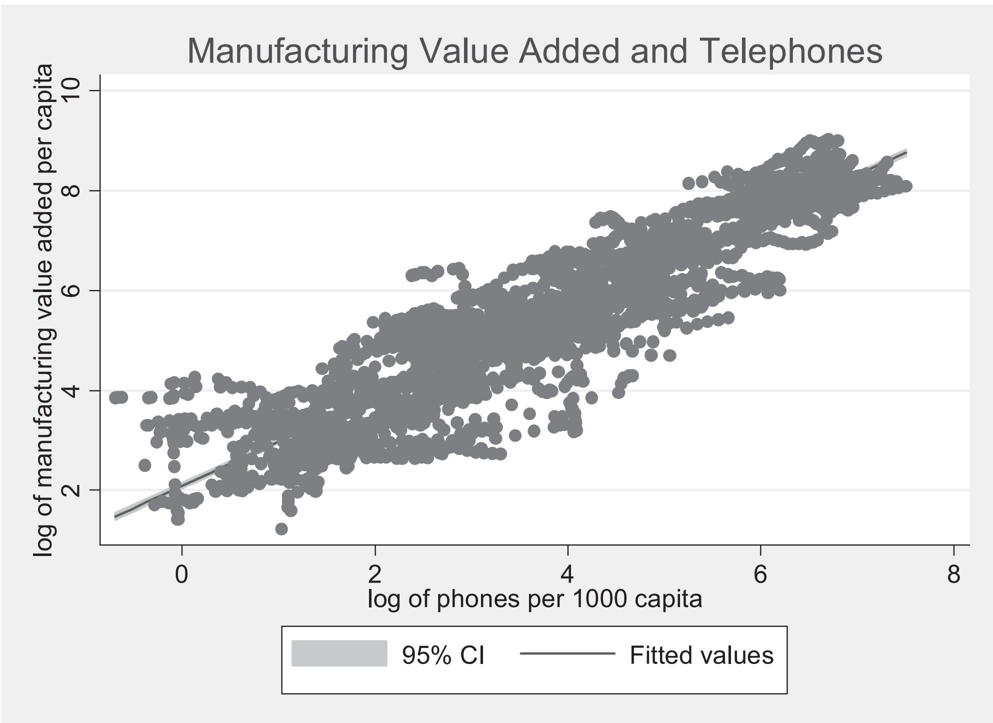
OLS	ΔPHONE	0.710***	0.216	0.212**	0.512*	0.066
		(4.13)	(0.80)	(2.28)	(1.85)	(0.53)
	TINT	-0.031***	-0.003	-0.007	-0.015	0.004
		(3.99)	(0.25)	(1.28)	(1.14)	(0.70)
RE	ΔPHONE	0.737***	0.214	0.215**	0.511*	0.066
		(4.22)	(0.78)	(2.32)	(1.88)	(0.53)
	TINT	-0.031***	-0.004	-0.008	-0.018	0.004
		(4.07)	(0.32)	(1.39)	(1.30)	(0.70)
FE	ΔPHONE	0.801***	0.231	0.212**	0.461	0.028
		(4.45)	(0.86)	(2.11)	(1.63)	(0.22)
	TINT	-0.034***	-0.008	-0.008	-0.018	-0.001
		(4.21)	(0.69)	(1.33)	(1.22)	(0.16)
RE-IV	ΔPHONE	-0.065				0.188
		(0.17)				(0.32)
	TINT	0.004				-0.001
		(0.21)				(0.05)
FE-IV	ΔPHONE	0.624***		-0.305		0.918***
		(2.59)		(0.97)		(2.75)
	TINT	-0.026**		0.019		-0.046***
		(2.23)		(1.14)		(2.64)

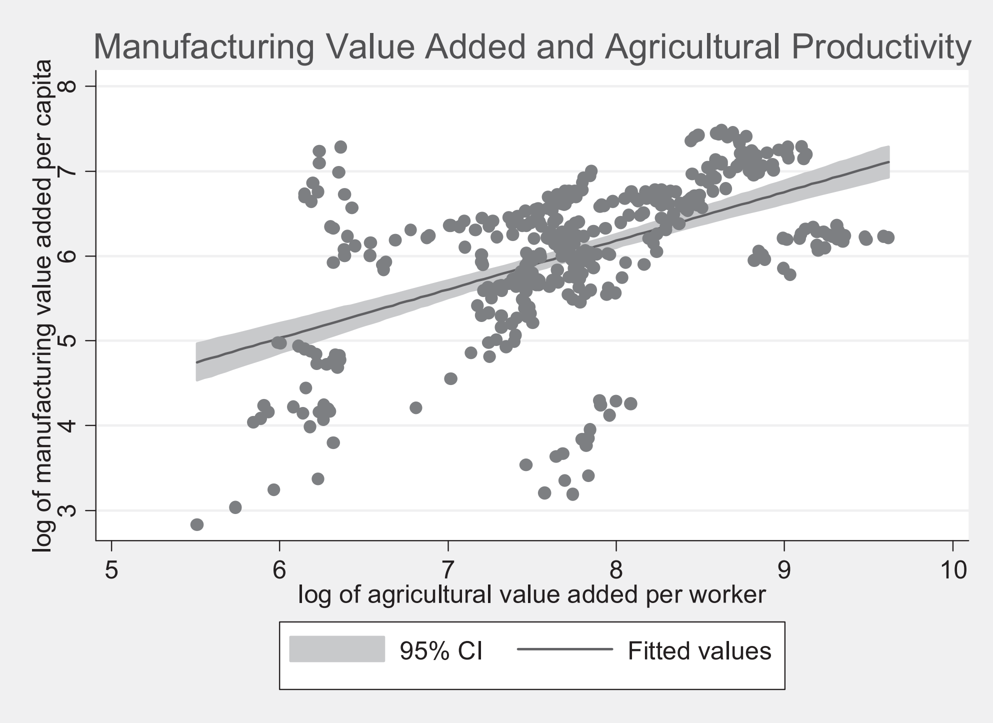
Note: All variables are in logs and absolute t-values in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 per cent, respectively.
Blank implies that TELMA/PHONE was not endogenous
TELMA = telephone main lines per capita, PHONE = number of telephones per capita, TINT = interaction term between trend and TELMA/PHONE.

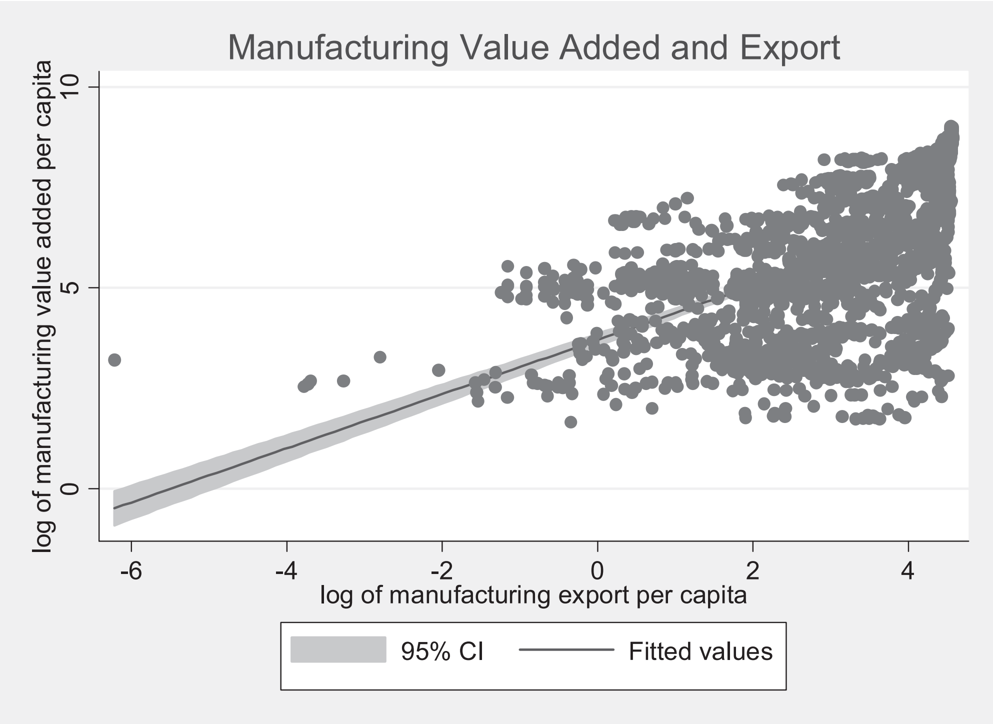
Appendix I:

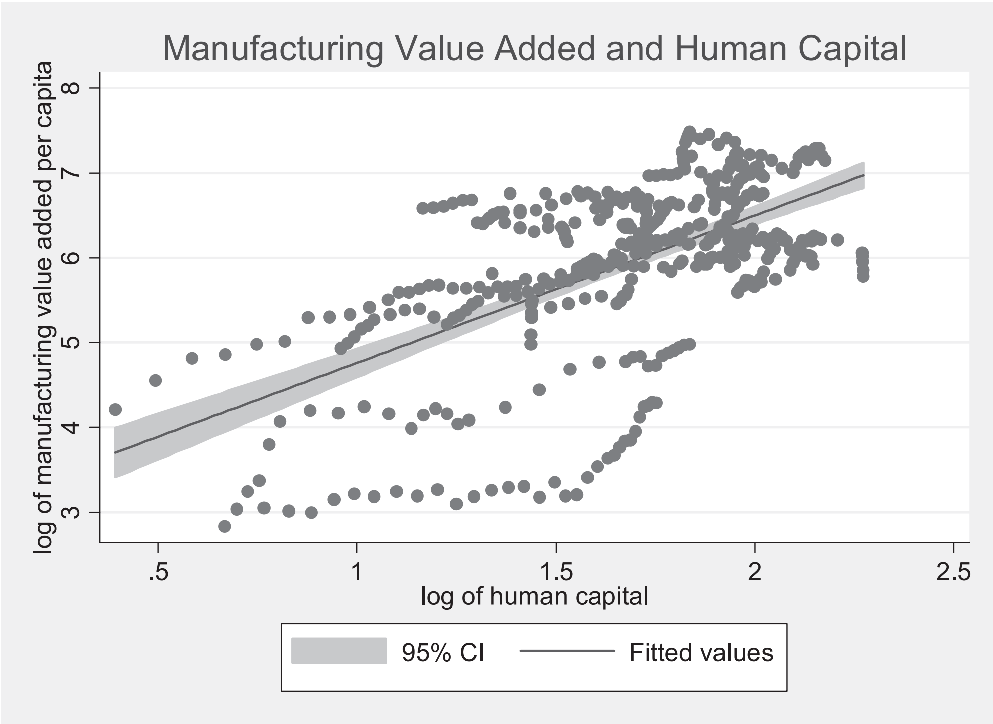
Two-way illustrations of manufacturing per capita and selection of RHS variables

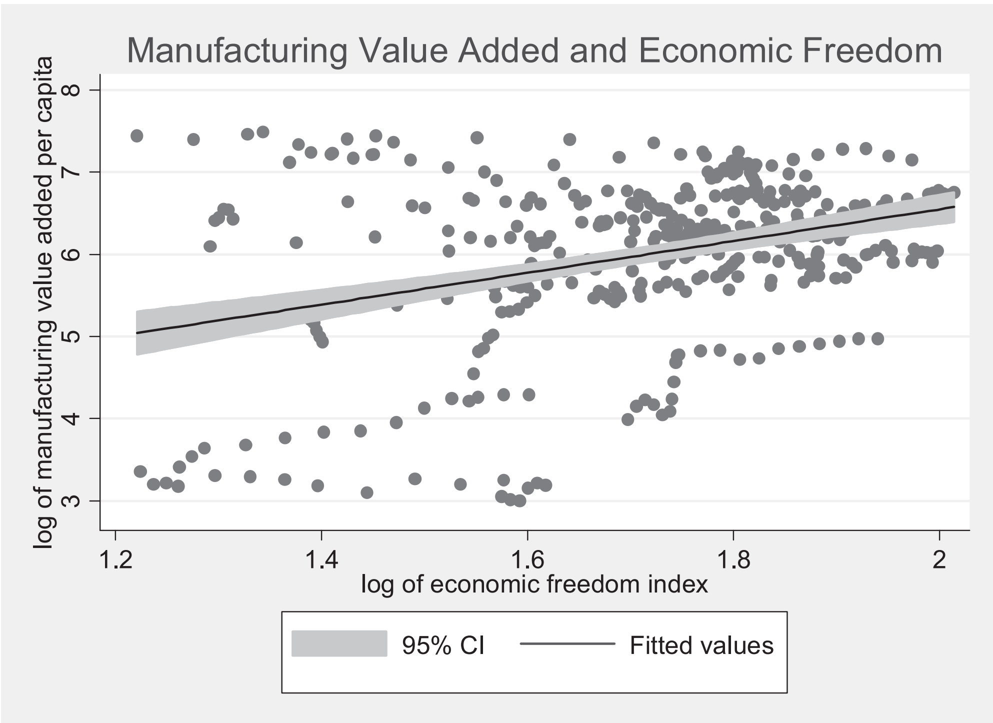





Manufacturing Value Added and Agricultural Productivity
log of manufacturing value added per capita
3
4
5
6
7
8
5
6
7
8
9
10
log of agricultural value added per worker
95% CI
Fitted values

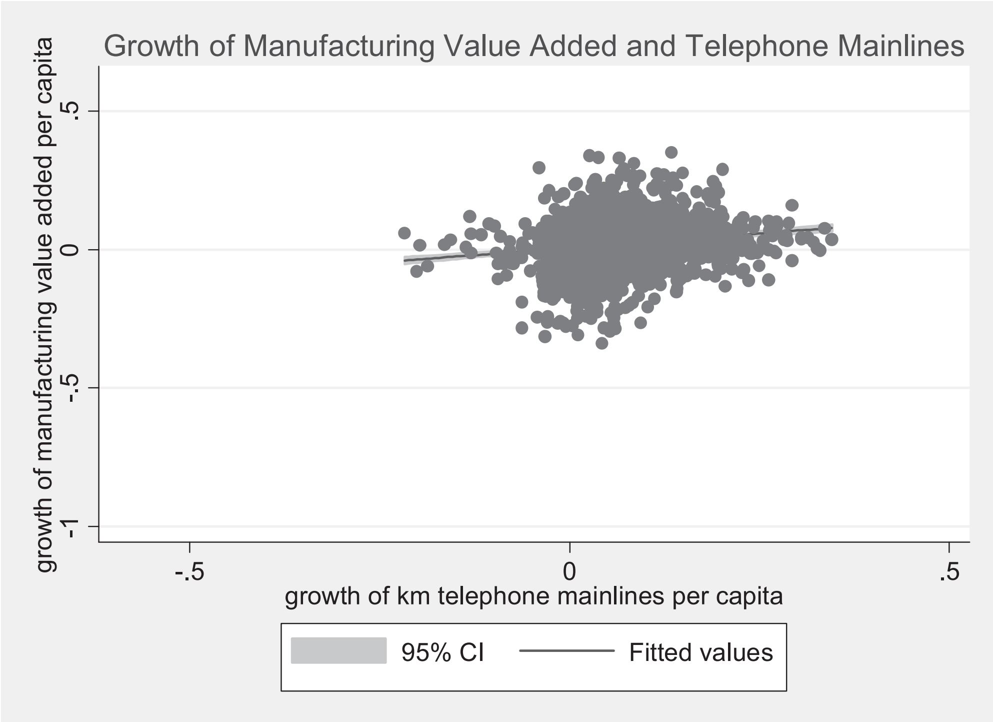

Manufacturing Value Added and Export
log of manufacturing value added per capita
0
5
10
-6
-4
-2
0
2
4
log of manufacturing export per capita
95% CI
Fitted values

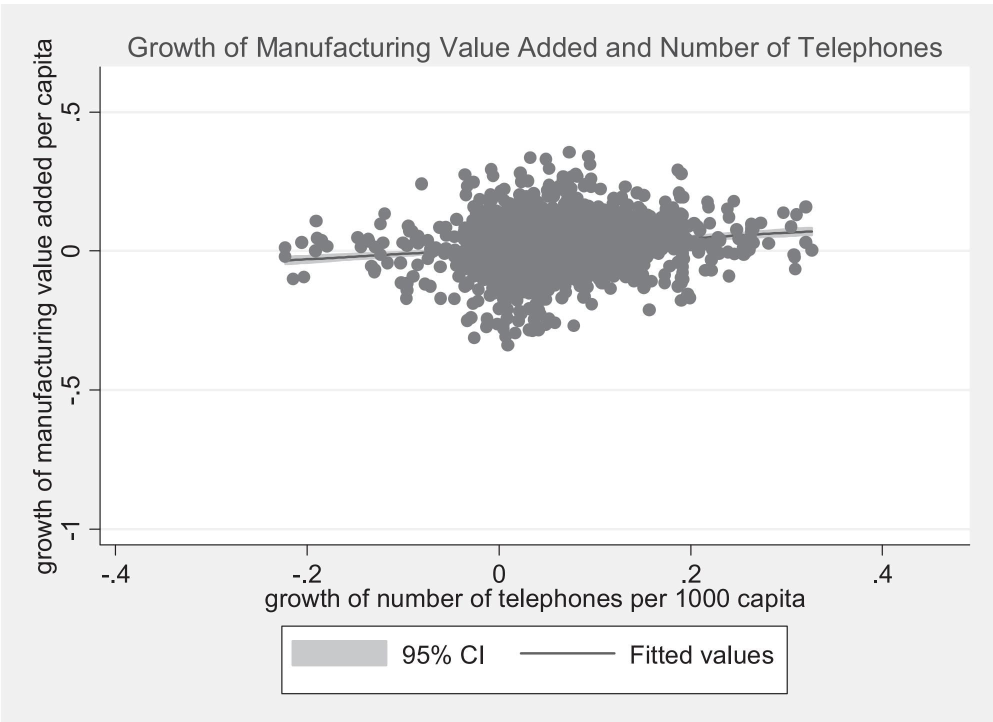

Manufacturing Value Added and Human Capital
log of manufacturing value added per capita
3
4
5
6
7
8
.5
1
1.5
2
2.5
log of human capital
95% CI
Fitted values

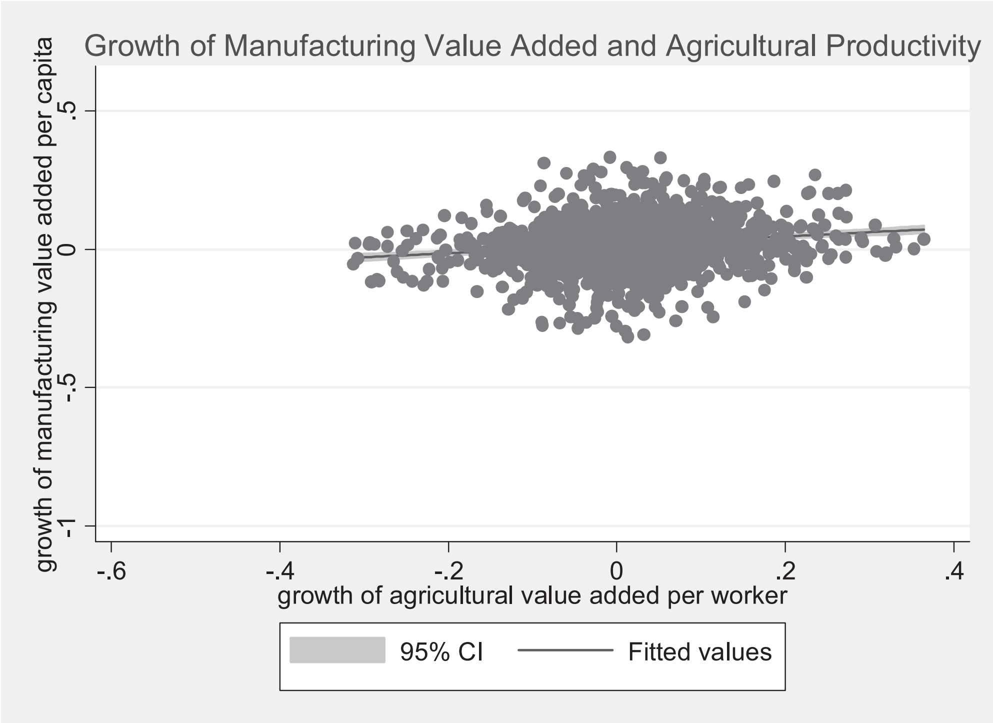

Manufacturing Value Added and Economic Freedom
log of manufacturing value added per capita
3
4
5
6
7
8
1.2
1.4
1.6
1.8
2
log of economic freedom index
95% CI
Fitted values

Appendix II:

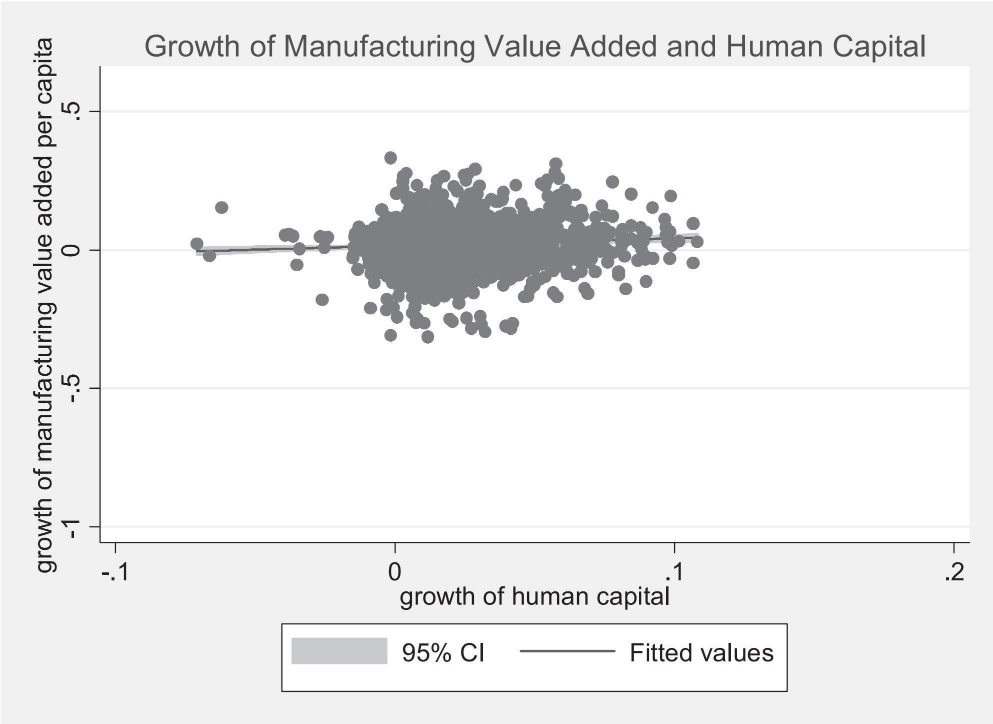
Two-way illustrations of change in manufacturing per capita and selection of RHS variables






Growth of Manufacturing Value Added and Agricultural Productivity
growth of manufacturing value added per capita
.5
0
-.5
-1
-.6
-.4
-.2
0
.2
.4
growth of agricultural value added per worker
95% CI
Fitted values


Growth of Manufacturing Value Added and Manufacturing Exports
growth of manufacturing value added per capita
.5
0
-.5
-1
-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
.5
0
-.5
-1
-.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

Printed in Austria
V.09-89449—January 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