Consulting Assistance on Economic Reform II

DISCUSSION PAPERS

The objectives of the Consulting Assistance on Economic Reform (CAER II) project are to contribute to broad-based and sustainable economic growth and to improve the policy reform content of USAID assistance activities that aim to strengthen markets in recipient countries. Services are provided by the Harvard Institute for International Development (HIID) and its subcontractors. It is funded by the U.S. Agency for International Development, Bureau for Global Programs, Field Support and Research, Center for Economic Growth and Agricultural Development, Office of Emerging Markets through Contracts PCE-C-00-95-00015-00 and PCE-Q-00-95-00016-00. This paper is funded by Contract PCE-Q-00-95-00016-00, Delivery Order 15.

Telecommunications, Information Technology and Economic Development

David Canning

CAER II Discussion Paper 53
December 1999

For information contact:
CAER II Project Office
Harvard Institute for International Development
14 Story Street
Cambridge, MA 02138 USA
Tel: (617) 495-9776; Fax: (617) 496-9951
Email: caer@hiid.harvard.edu

Telecommunications, Information Technology and Economic Development

A Report on a Research Project[1]

David Canning

Harvard Institute for International Development

December 1999

Correspondence:
Professor David Canning
School of Management and Economics
Queen's University Belfast
Belfast BT71NN
Northern Ireland
U.K.

e-mail: d.canning@qub.ac.uk
phone: 44-1232-273281

[1] This paper draws from three supporting technical papers under the research entitled "Telecommunications, Information Technology, and Economic Growth." The author would like to thank Orest Koropecky of USAID for his comments on the paper.

Table of Contents

1. Executive Summary 1
2. Introduction 2
3. The Economic Impact of the Information Revolution 6
4. Communication Networks in Developing Countries 8
5. Evidence of the Role of Telecommunications in Development 11
6. Promoting Information Technology 15
7. Conclusion 17

References 19

1. Executive Summary

This paper provides a general overview and summarizes the results of four technical research papers produced for the project. The results fall into three parts: a study of the effect of telecommunications systems on economic growth, the future role of information technologies in developing countries, and the role of telecommunication infrastructure in promoting access to, and use of, the Internet.

We begin by looking at how the telephone networks have affected economic development in the past. A variety of empirical methods are used to study the role of telephone systems in economic development. The central problem we have to address in this work is to find the effect of the telephone network on economic development while being careful not to pollute our results with the feedback effect from increased income levels to the demand for telephones. The econometric methods used in these studies try to isolate the effect from telephones systems to economic growth. The results suggest that telecommunications can have a large impact on subsequent economic growth. This provides evidence for the idea that good communications systems allow greater success in export markets and quicker diffusion of technology.

We then turn to look at how information technology will affect development in the future. The main conclusions are that information technology is likely to be most effective in developed countries in raising productivity in the service sector and increasing the rate of innovation. For most developing countries the main attraction of information technology is to increase international communications and the openness of the economy. While information technology is likely to lead to greater globalization and integration of developing countries into world markets and higher levels of income on average, it will also tend to increase the wage premium to educated workers, widening income inequality in developing countries. The growth in inequality poses a threat to the stability of developing countries and may lead to a rejection of globalization by some.

Given the importance of embracing new information technologies, we are faced with the question of how countries can best achieve this. An empirical cross-country study of the determinants of Internet use highlights the importance of the availability, quality and cost of telephones as a major factor. In particular the extent of the telephone system played a major role in determining which countries were first to gain access to the Internet, and still plays an important role in determining the level of Internet use in countries that are connected. In addition, the quality of the telephone systems is important in determining the number of Internet hosts within a country. In turn, there is widespread evidence that competition in telephone provision has significant benefits in all dimensions (coverage, quality and cost) as compared with public provision. In addition, a competitive environment in telecommunications and in Internet provision is more likely to encourage the adoption of new technologies as they develop.

2. Introduction

The most important factor in modern economic development has been the rise of technology. The driving force of the industrial revolution came from two key technological developments, the steam engine and the printing press. The steam engine generated power for factories, ships and trains, providing both the means for mass production and a method of distribution. The printing press was an important factor in disseminating technology, giving technological developments a wide audience. There was also a revolution in the production of human capital. Before the printing press, education was conducted mainly by personal tutors. Cheap books were the mainstays of a revolution in the education methods, the schoolroom. While the abiding image of the industrial revolution is the factory, the schoolroom may have been an equally important change in production methods.

Before 1600 the world had one mode of production: a large, uneducated, agricultural labor force that provided food for itself and enough surplus for a small group of artisans and aristocracy. By the second half of the 19th century, technology had changed the face of the developed world. Railways and the telegraph linked large industrial cities dominated by manufacturing. Water and sanitation systems prevented the spread of infectious diseases in the cities and compulsory primary education provided a workforce capable of operating and maintaining machinery.

The 20th century saw further technological innovation. Steam power gave way to electricity, while cars, planes and the telephone supplanted trains and the telegraph. However, while these new technologies led to huge improvements in efficiency, they did not change the structure of society fundamentally. The most striking feature of the changes that did occur in the 20th century in the developed world were the massive improvements in the productivity of agriculture and manufacturing. A vastly greater value of material output is being produced than ever before, but with only around 30% of the workforce being engaged in industry.

There is clearly a new spate of technological innovation underway at present. The widespread availability of computers and information networks promises to bring large gains in productivity. For the developed world, the central question is whether this represents a change in degree, providing more of what we already have, or a change in structure, a revolution in the mode of production, that will have profound social as well as economic consequences.

This question will be addressed in detail in the next section, where we examine the forces that will be unleashed by cheap information storage, computing power and information networks. The implication is that these forces will be massive, with improvements in productivity but also a revolution in the structure of economic relationships. The central feature of the new economic landscape will be competition, with huge rewards to the most innovative and efficient producers, and nothing for the rest. Rapid innovation, and cutthroat competition, are already the norm in the high technology manufacturing industries, and will become the norm throughout the economy.

In addition, as with the book, information technology promises to speed up the long run rate of innovation by increasing the generation and dissemination of ideas. Information technology, like the book, promises to be a major innovation because it promotes further innovation. It remains an open question if information technology will also revolutionize learning, allowing cheap mass education. This is essentially a question of whether computer-based learning can replace the classroom, the teacher and books as the dominant mode of transmitting knowledge.

It is important to distinguish between technology and information on the one hand and knowledge on the other. The existence of technology gives us the potential to carry out many tasks. However, in order to do this the technology must be embodied, either in machinery or in peoples' heads. The existence of technology in a book no one ever reads is not knowledge and is not useful. The rapid advance of technology has left us in a state of information overload, with much more technology and information being available than individuals can possibly acquire. The entire education system can be thought of a mechanism for structuring existing technology and information to make it accessible and useful to students.

In one way, information technology adds to the problem of information overload by making more information accessible. However, its power to sort and search through databases to find relevant and useful information that can add to the knowledge of the user promises to speed up the process of acquiring useful knowledge.

The focus of this paper is how information technology will affect the developing world. The term "the developing world" is itself a product of the industrial revolution. For while the leading nations industrialized, making use of the new technologies, most of the world stagnated, opening up a gap in development between the developed countries of Europe, North America and their offshoots in Australia and New Zealand, and the poorer countries of Africa, South America and Asia.

The central point is that technology does not automatically improve productivity. To use a new technology usually requires new types of capital, built and installed by highly skilled engineers, and operated by trained workers; technology and investment are complements. The focus in development economics has been on how to engineer a high level of investment, in the right forms of physical and human capital, to take advantage of the high level of technology that developing countries can acquire from developed countries.

The consensus in the development literature now emphasizes the need for an open economy with competitive markets, and with limited government intervention in cases of market failure. This consensus in large part reflects the economic success of the Asian "Tigers" who have made the leap from underdevelopment to developed economies in the space of one generation as compared to the relative failure of the economies of South America, Africa, and South Asia. The lesson of East Asia seems to be that economic development requires high levels of investment, in both human and physical capital, but

also that there must be close involvement with the world economy to ensure a flow of technology. Most developing countries are trying to learn from the East Asian experience, with an emphasis on education, attracting foreign investment, and trade, particularly exports of manufactured goods.

While this seems a reasonable strategy, two problems remain. One is geography. Some countries with inhospitable climates and remote locations offer very poor prospects for local production or for integration into the world economy. The landlocked topical countries of central Africa pose a serious challenge to even the best development policies. The second issue is the possibility of a development trap. At very low levels of development, under $1000 per capita per year, it is very difficult to invest in education, or physical capital. Development may be very slow until a critical threshold is reached where there is a sufficient surplus over necessities to finance investment. While these problems remain, the lessons of the East Asia seem to point the way for other developing countries.

The rise of information technology poses a challenge to this development strategy. At one level the challenge is simply that technological advances promise to be most beneficial to countries with highly educated workforces, promoting faster growth in the developed countries and widening the gap that developing countries must bridge. In itself, this is not bad, since a bigger gap potential means greater gains for developing countries that do transform themselves.

The real issue is whether information technology will change the nature of the development gap. The developing countries have an advantage in low wage costs. However, they can only compete successfully in goods where the technological gap between their low-wage workers and high-wage workers in developed countries is not too great. For East Asia, specialization in areas where they had a comparative advantage led to the ascent of a quality ladder, though textiles, toys, and shipbuilding to electronic goods and cars. The point about this quality ladder is that mastering each rung generated the technological and organizational sophistication to enable the next rung to be reached. This quality ladder is to a large extent the same one followed historically by the leading developed countries.

A fundamental problem for developing countries would emerge if information technology broke this quality ladder. High tech methods of producing manufacturing goods using information technology might get so cheap as to allow developed countries to wrest the production of these goods back from the developing world. Workers in developing countries would still have a comparative advantage in something, for example in servicing tourism or making local craft goods. The problem is that these goods may not be on a quality ladder leading to further technological development. So far this has not happened, as information technology has led mainly to new manufacturing products and to improvements in the productivity of services. Despite this, the major worry for developing countries is that new technologies will break the ladder of progressively more sophisticated manufactured goods through which they can progress on the way to development.

They also offer the hope of a great leap forward in technology. The new technologies are so different from the old that it may be possible for a relatively underdeveloped country to adopt the new technologies, and produce "advanced" goods without working its way laboriously up the quality ladder. The requirements for this approach are a reasonable number of very highly educated workers, and excellent communication networks, to allow the industry to become completely integrated into the world economy. It remains to be seen if this strategy can play a major role in economic development.

Information technology and communications networks will speed up the process of globalization in developing countries, increasing the extent of the market and increasing competition. In this more competitive environment, information technology will be central to success and countries that lag behind will find themselves increasing excluded from the global marketplace. Section 2 elaborates on the theme of how information technology is likely to affect economic growth in general. Section 3 applies these arguments to examine the role of information technology in developing countries.

The main predictable impact of information technology on developing countries will be the reduction in the cost of selling goods and coordinating production both internally and in international markets. An important question is whether embracing information technology will have a discernible impact on a country's rate of economic growth in practice. We can tackle this question by looking at how the differing patterns of adoption of telecommunications infrastructure by developing countries over the last fifty years have influenced their growth rates. Telephones share some of the features of information technology; they allow cheap and fast communication. They do not have the information storage and computing power of modern information technology but we should see the impact of the pure communication effect, if it exists. One part of the project has therefore been to look at the impact of telecommunications infrastructure on economic growth. The results of this study are reported in section 4.

If we accept that information technology will make a large contribution to economic growth and that developing countries should embrace information technology, we are still left with the question of how a country should go about promoting the use of information technology. In section 5 we look at the determinants of Internet use. We find that good telecommunication infrastructure seems to play an important role in allowing access to the Internet and that countries with poor telephone systems lag significantly in Internet use.

This points to a strategy of improving access to the Internet by promoting investment in telecommunications systems. In this context there is increasing evidence that significant improvements in telephone systems can be achieved through privatization and competition. This is partly due to the recent technological development of alternative telephone systems that allow increased competition between providers. The argument that telephone networks are a natural monopoly no longer seems plausible. While some problems of market failure remain, these are best dealt with by regulation rather than by direct government provision.

The rapid technological changes taking place in information technology make it an area that is unlikely to benefit from government intervention. The role of government may be to ensure the provision of access to information networks through good telecommunications networks, but to leave the choice and supply of information technology up to users.

3. The Economic Impact of the Information Revolution

Information technology promises advances in three areas. Firstly, by increasing the power of information storage, retrieval, and processing systems it will increase productivity in the service sectors that rely on information. Secondly, the improved communications made available by the Internet will increase the extent of the market and enhance competition. In addition, it will allow more geographical distance between parts of a production process. Finally, it offers the possibility of revolutions in education and in innovation, perhaps permanently increasing the rate of technological progress and diffusion.

While the industrial revolution led to huge productivity gains in agriculture and manufacturing, productivity in services has been relatively static. The teacher, the banker, the policeman, the barber, the general medical practitioner, the administrator, and the cook have all seen improvements in technology, but at a much slower pace than in manufacturing. Economic growth has created growing demand for food, manufactures and services. While food and material goods are being produced ever more efficiently with fewer and fewer workers, increasing numbers of workers are being absorbed into services as the only way of meeting the demand.

This leads Jones (1997) to take a pessimistic view of the future of technological progress. The problem is Baumol's "cost disease". Even if technological progress continues apace in manufacturing, the increasing proportion of the workforce engaged in services means that overall productivity growth in the economy would be slow. A central issue is how much productivity in services will improve through the use of information technology. The new information technology has the potential to spread technological progress to services creating an information revolution. Any improvement in productivity in services will have a large effect in developed countries simply because this is where most people now work and the scope for productivity gains is largest. If an improvement in service sector productivity does occur, we can be more optimistic amount the prospects for future long run economic growth.

One important aspect of information technology is the improvement in communications offered by the Internet. This allows large amounts of information to be communicated quickly and at very low cost. Improvements in transport and communication play a vital role in contracting economic space. Good transport and communications infrastructure increases the extent of the market each firm faces, and increases the degree of competition from competitors.

As Adam Smith pointed out, increases in the extent of the market allows economies of scale. In addition, increased competition means that only low cost producers can survive. One example of these mechanisms in operation is the effect of road networks and cars on retail shopping. Before the car, neighborhoods had a rich variety of small local shops within walking distance. Now, large shops congregate in malls, serving an area of around 20 miles, or a 30-minute drive.

Some simple economic models of imperfect competition point towards reductions in transport and communication costs leading to an increase in firm size to exploit scale economies. However, the general effect will be to magnify any cost advantages a firm has. Whereas inefficient firms can survive in a shielded local market, with the Internet, firms at a cost disadvantage will be very hard pressed to survive. This increased competition will have the effect of stimulating all forms of cost saving.

Not all industries will create large firms in response to improvements in communication systems. Scale economies are essentially economies of specialization, and specialization can take place by people working in different firms with trade in intermediate products through the market. The firm is essentially a response to market failure; the firm is more efficient at organizing production where price signals between its parts fail and the costs of organization are not too large. An improvement in communications, and in the operation of markets, may allow the exploitation of specialization economies in small firms. Canning (1996) shows that in 24 out of 27 industries, average firm size falls with the level of economic development. Developed countries are highly productive, but this is not because they exploit scale economies in large firms. A reduction in communication costs may therefore lead to a richer array of small firms linked through markets in intermediate goods.

A large market and intense competition may speed up innovation. The large market means there are large potential gains from a competitive edge gained through innovation while countries that lag in innovation may be unable to survive. Information technology also provides the means for speeding up innovation. It is now much easier to reach the frontier of what is known by using search engines and resources such as such as citation and patent databases. In addition huge increases in computing power have opened up new methods of innovation.

Increases in service sector productivity and improved communications are likely to increase world income levels while leaving the world economy's current structure relatively unchanged. A really big increase in the rate of innovation would have profound consequences on society. One important change, which we are already seeing, is an enormous expansion in the importance of innovation to production, and a consequent increase in the rewards earned by innovators as a share of total income.

A striking feature of the new information-based technology companies is that their products' value is largely in the software, the idea. Such software is very expensive to create, but once this fixed cost has been paid the cost of copies of the software for

distribution is close to zero. While this is most obvious in the software business, it is increasingly the case in most high tech production industries.

What we appear to be seeing in the United States is an increase in education premiums, a rise in the reward of those able to innovate and implement new innovations relative to the rest of the workforce. Globalization has the power to exacerbate this tendency by removing the local geographic advantages of unskilled and uneducated workers in a more developed country. Historically, the factors of production needed to operate in close proximity to reduce transport costs and allow activities to be monitored and coordinated. This is less and less the case and as transport and communication costs fall, unskilled workers in developed countries will increasingly find themselves in competition with workers in poorer countries. While the empirical evidence for this effect in the United States has so far been small (most of the increase in the wage gap between educated and uneducated workers is attributed to new technologies rather than competition from imports) this effect may become much bigger in the future.

At its most extreme this is a scenario in which there is rapid technological progress and economic growth in the developed world, but the fruits of this growth are shared very unequally. In the long run we may end up with a rich, highly educated, upper class and an uneducated underclass with a very low income level. Even among the highly educated, there are likely to be large differences in incomes as rewards are concentrated on the successful few that make important innovations first. The high levels of competition promote efficiency but also generate risk and insecurity. Rapid technological progress reduces job security and may make built up skills redundant.

This polarization of society, together with increased risk and insecurity, is likely to lead to large scale unrest and political instability. The rising inequality associated with the development process may lead to a rejection of globalization and the market economy and a return to closed economy models of development or even communist systems. The electoral success of the communist party in Eastern Europe is at least partly due to the obvious inequalities being generated in the region's embrace of the market.

4. Communication Networks in Developing Countries.

The picture in developing countries is somewhat different. These countries are playing catch-up and are likely to lag behind the more developed countries in all forms of technology and infrastructure including information technology and communication infrastructure. A striking feature in the market for ideas is the predominance of the developed countries in terms of publishing articles in scientific journals and of registering patents. Developed countries led in innovation out of all proportion to their levels of education and of income. This is essential because of the skewed reward structure for ideas. There is a big reward for having an idea first, but none for having it second. This means that the small advantages of the developed countries in terms of their capabilities for producing ideas translate into big differences in achievement.

Developing countries are much more likely to use information technology to access ideas than to generate them. The main benefits of information technology in a developing country will be access to information and communications. Improvements in the productivity of the service sector are likely to be smaller than in developed countries because of the lack of complementary inputs. Information technology requires a highly trained workforce, which developing countries lack.

One consequence of this is that developed countries will gain a comparative advantage in tradable services. The comparative advantage of developing countries is likely to remain in raw materials and manufacturing using "old", easily mastered, technologies. Increasing imports of services from the developed world may actually bring benefits to developing countries if these information-rich services can be used to increase efficiency in the production, or marketing, of manufactured products.

The main impact of better communication will be increasing globalization of the economy. With greater information flows, the most competitive manufacturers will get the biggest rewards. This promises to allow developing countries to seize a large share of world markets when they have a competitive advantage. Market share is likely to become more volatile as information flows and competitive pressures reduce the need to depend on traditional supplies and trading relationships. This vision does not change the appropriate development strategy very much, but it does indicate that the stakes, both in terms of the rewards for success and the penalties for failure, are likely to be greater in the future.

One aspect of information technology is bringing suppliers closer to consumers. Another, equally important feature is in enriching markets for intermediate goods. An important part of economic development is the creation of backward and forward linkages that allow a firm to specialize in the activities it is good at. Firms can buy accountancy and marketing services and partly finished goods, add their own contribution, and sell on to another firm that continues the production process. Such specialization at the level of the firm is only possible if there is a market structure that provides a wide variety of intermediate goods.

In developing countries, many of these intermediate goods markets are missing, making it difficult for entrepreneurs to enter and produce on a small scale. McDonald's hamburger restaurants specialize in cooking food and providing restaurant services. However, when McDonald's set up its Moscow branch it faced very difficult problems in obtaining supplies. Eventually, the only way to overcome these supply problems was for McDonald's to set up and operate its own cattle farm to produce beef and its own production plant to produce packaging materials. In more developed countries McDonald's would buy these intermediate inputs from other specialist firms. A similar story occurs in mining in many developing countries where mining companies not only build mines but also basic infrastructure such as road and telephone systems for their own use, and housing and hospitals for their workers. While large companies can overcome the problems of missing input markets by producing these inputs themselves, they do so at the cost of moving out of their own specialty. For small firms, the costs of such

activities are usually prohibitive. This lack of intermediate goods markets, and the need to procure their own intermediate goods, probably explains why manufacturing plants tend to be so large in developing countries as compared to developed countries.

Information technology, by allowing the development of markets for intermediate goods, may allow an increase in the number of small firms operating in developing countries. The problem of small firms and the lack of markets for intermediate goods may really be a major difficulty in achieving a takeoff into economic growth. Small firms cannot enter and operate without a large number of intermediate goods markets, while the operation of intermediate goods markets require a large number of small firms to be actively trading. If this is the case, reduced communications costs and access to international intermediate goods markets may allow the creation of a vibrant small firm sector in developing countries that is essentially integrated into the global market rather than local markets. These small firms can then generate local demand and supply networks that encourage further new firms to be set up.

In the short run, the creation of small enclaves of firms operating in the global market using modern information technology, while the majority of people in a country continue to operate in traditional settings, is likely to exacerbate income differentials. In the longer run, such enclaves can been seen as a method of technology transfer, accessing technology from the advanced countries and gradually disseminating it throughout the developing economy. In this way, these enclaves can perform a similar role to foreign direct investment, proving not only a source of income but also of technology spillovers to the wider economy. India, which has a relatively high number of university graduates given its income level, has been relatively successful in pursuing this strategy, though it remains to be seen how large the technology spillovers for the rest of the economy will be.

An important determinant of economic development is not just what people do, but how much their activities enhance future growth through "learning by doing." Lucas (1988) emphasizes that while developing countries will specialize where they have a comparative advantage, future economic growth depends on the extent to which "learning by doing" in these specialties leads to future productivity growth. Development policy should therefore encourage activities that may not have the highest payoffs today, but which build capabilities for the future. Familiarity with modern information technology may be exactly such a capability-enhancing activity.

The new information technology offers some challenges and some opportunities to developing countries. However, to spurn it is simply not an option. To cut oneself off from the global economy is the surest method of stifling economic development. The policy issue is how developing countries embrace information technology. The problem of obtaining the "right" level of investment in information technology faces the two parallel problems of market failure and state failure.

Market failure is likely in creating the infrastructure required for advanced information technology networks if the size of the market is only sufficient to allow one provider, a

monopolist. The market will also fail if the benefits of information technology are spillovers that go to the general economy and not directly to the user. Both these are likely to be problems to some extent.

On the other hand, while government provision may be efficient in theory, in practice, developing countries may have very inefficient public sectors. Government regulation of private monopolies, a favored solution in many developed countries has the problem that it requires sophisticated mechanism design and monitoring capabilities that are scarce resources in developing countries. State failure is as widespread as market failure.

While it is impossible to come to a definitive answer on these issues it seems that deregulation and private provision is the appropriate policy for most developing countries. This economizes on government resources and for many new technologies it seems to be possible for relatively small firms to enter, and compete, successfully. The best policy may be to have a fairly free market with regulation only in clear cases of monopoly power.

5. Evidence of the Role of Telecommunications in Development

Telecommunications reduce both the time and the cost involved in transmitting information. While they do not facilitate storing or processing information, they do have some characteristics of an "information technology". We might therefore expect telecommunications to have some of the impacts discussed in section 2. In particular, they should increase the size of the market, and increase competition, as consumers' costs of search are reduced. They also increase the possibilities of spreading innovation and of coordination in production.

One way of looking at the benefits of telephone systems is to carry out project-based estimates of the rate of return on investment in telecommunications. The World Bank's *World Development Report* (1994) gives an average financial rate of return on investment for telecommunications projects of around 20%. While this is a very satisfactory rate of return, the actual benefits may be much greater. Most of the benefits of telephones may be reflected in market structure and the spread of technology with benefits that far outweigh the price charged for a telephone call. If telephones have a positive externality it will not be reflected in the private returns earned by investors in telecommunications. To find this spillover effect we need to look at the impact of telephone provision on total output.

To try to estimate the overall effect of telephones on economic growth we can look at how growth responds to investment in telecommunications. Do countries with better telephone networks grow faster? How big is the contribution of a telephone system? This issue is addressed in three other CAER II Discussion Papers, "Telecommunications Infrastructure, Human Capital, and Economic Growth," "Telecommunications and Aggregate Output," and "Infrastructure and Long Run Economic Growth." These papers are largely technical and concentrate on estimating the effect of telephone systems on

economic growth, taking account of the existence of reverse causality. Since the demand for telephones rises with economic prosperity we must be careful to identify the effect of telephone systems on growth and not the opposite effect.

There is a large literature on the determinants of economic growth and many different factors have been put forward to explain growth. Openness of the economy, the level of education, the quality of institutions, geography, life expectancy and population growth are just some of the variables that have been proposed as being important for growth. Gramlich (1994) reviews efforts to estimate the productivity effect of infrastructure capital, such as telephone networks. The first paper, "Telecommunications Infrastructure, Human Capital, and Economic Growth," uses an approach akin to that of Barro (1991) and tries to explain cross-country differences in growth rates over the period 1965 to 1990 with, among other things, the initial stock of telephones per capita.

All the research papers in the project use physical measures of infrastructure, such as kilometers of paved roads, kilowatts of electricity generating capacity and number of telephones taken from Canning (1998). Using physical measures of infrastructure may be better than using stock estimates that have been computed by aggregating investment series. While simple physical measures do not correct for quality, monetary investment in infrastructure may be a very poor guide to the amount of infrastructure capital produced. Furthermore, prices for infrastructure capital vary widely across countries and government investment may be very inefficient, particularly in developing countries (see Pritchett (1996)).

This paper finds that in a simple model, a high level of telephones per capita and a high level of education (using measures of the stock of education from Barro and Lee (1993)) in 1965, are strong predictors of economic growth over the next 25 years. However, as further variables are added, it becomes more difficult to detect an effect of either telephones, or education, on subsequent growth rates. It could be that telephones do not really matter, and once we control for other factors, they are irrelevant in the growth process.

This lack of robustness is somewhat alarming. It appears that the results we find are sensitive to the specification of the growth regressions being run. At one level the lack of robustness is not surprising. Levine and Renelt (1992) conduct extensive specification searches in growth regressions and come to the conclusion that no variable is robust in every specification. However, there is a deeper problem in evaluating the importance of capital inputs such as education and infrastructure in growth regressions. These capital inputs are endogenous and tend to grow with economic growth. For example it is hard to say if education causes growth, or if increased incomes allow higher levels of education (Bils and Klenow (1996)).

This is often seen as a technical problem in estimation, requiring us to take pains to ensure we are measuring the effect of telephones on growth, and not the effect of growth on telephones. One way of overcoming this problem is to use the initial value of the capital stock as an explanatory variable. Alternatively, we can use more advanced

econometric methods to try to isolate the effect of telephone systems on economic growth from the feedback effect.

However, even if we do this, there remains a fundamental difficulty. The growth rate of output in an economy can be explained in two ways. One way is to use the proximate factors, such as inputs of capital and labor, to explain variations in output. This is the structural approach. Another is to argue that these inputs are themselves endogenous and are the results of economic forces. In this case, output is still explained by capital and labor, but these capital stock and labor input variables are themselves determined by other factors, such as government policy, geography and climate. Working through this system we can see that output is, in the end, determined by these exogenous variables. We can therefore explain output by such factors as government policy, geography and climate; this is the reduced form approach.

The problem is that in an ad hoc growth regression both structural and reduced form models will be estimated together, and the resulting parameter estimates will be a mixture of the parameters from the two models. It is therefore difficult to interpret the results of such an approach. In particular, "Telecommunications Infrastructure, Human Capital, and Economic Growth," shows that the estimates produced by a cross-country growth regression will be a mixture of the structural and reduced form coefficients with the mixing dependent on the period over which economic growth is measured. However, as the period of estimation increases, we tend to estimate the reduced form, giving weight only to the fundamental forces behind growth and not the structural relationships that underpin it.

The problem is that inputs such as physical capital, education, and telecommunications, are not the fundamental sources of growth. In a complete multidimensional model of growth we would have not only the proximate sources of growth, productivity gains and capital accumulation, but also the forces which drive productivity and investment. For example, a good institutional and legal environment may encourage investment and investment may promote growth. A complete model would encompass both mechanisms, both institutional factors influencing investment and investment leading to increased output. In a simple one-dimensional model of the type usually employed, we use both investment and institutions as possible explanations of growth. Such an approach cannot possibly uncover the mechanism at work. To the extent that institutions "explain" investment, investment will not be statistically significant in the single equation approach since it adds nothing to explaining growth. This does not of course mean that economic growth would be possible without investment.

Therefore if we follow an ad hoc approach, and use every possible factor that may explain growth in a cross country regression, we are likely to end up with an explanation in terms of the fundamental sources of growth such as geography, culture, and perhaps economic policy. All endogenous variables such as productivity, investment, education and telecommunications will tend to disappear from the explanation, being themselves largely explained by the fundamental exogenous forces. The solution to this problem is to think of the process of economic development as a multi-dimensional process. Growth

can be attributed to productivity gains and capital accumulation. Each of these, in turn, can be explained by other forces. Sachs and Warner (1997) and Gallup and Sachs (1998) look at the role of geographical factors as the determinants of long run economic performance while Hall and Jones (1999) focus more on cultural variables. Our aim here is to estimate the structural relationship between capital accumulation, particularly telecommunications investment, and economic growth. We can estimate this part of the growth process, leaving for another time the issue of what causes productivity and capital accumulation to differ across countries.

If we wish to estimate a structural equation, explaining growth by inputs of capital and labor, we can identify the model to be estimated from theoretical considerations. To do this we follow Mankiw, Romer and Weil (1992) and specify that output is due, in the first instance, to a production function. The neo-classical production function, in which output is due to technology, physical capital and labor, is augmented by education and infrastructure capital. Each country is assumed to have its own level of technology and technology is assumed to grow at the same rate in each country, though this growth rate can vary over time.

The second paper in the project, "Telecommunications and Aggregate Output," undertakes the estimation of this production function. The problem of reverse causality is dealt with by using panel data cointegration methods. Doing this we find that physical capital, human capital, and infrastructure capital appear to be important factors in the production function. We find that the productivity of physical and human capital are close to the levels suggested by microeconomic evidence on their private returns, while electricity generating capacity and transportation networks have roughly the same marginal productivity as capital as a whole. However, telephone networks appear to have a higher marginal productivity than other types of capital. Since investment in telephones earns a normal rate of return for the investors, this excess return at the macroeconomic level must be an externality,

The higher rate of return that we find for investment in telecommunications than for other types of capital is evidence of inefficiency, and hence shifting investment from other types of capital to telecommunications would raise the growth rate. "Infrastructure and Long Run Economic Growth," takes a different route to address the issue of efficiency directly. If telecommunications investment is too low, a positive shock to investment in telecommunications should raise the long run growth rate. On the other hand if telecommunications investment is too high, the cost of the extra investment (in terms of forgone investment in other sectors) outweighs the productivity gains and a positive shock to investment in telecommunications will reduce economic growth. At the optimum, the productivity and cost of extra telecommunications investment are exactly equal and a small shock to investment in telephones should have no effect on long run economic performance. Note that the production function approach used in "Telecommunications and Aggregate Output" only looks at the productivity side of the equation. Efficiency is really about whether the benefits outweigh the costs.

The main result of the paper is the finding of a large degree of heterogeneity, with some countries being above the optimal level of telephones per capita and some being below the optimal level. This makes a simple policy of more (or less) investment in telephones unlikely to be right for the world as a whole. Instead we require study at the country level to see if the telephone system is adequate for its needs.

Overall the major finding of the research carried out for this section is in "The Contribution of Infrastructure to Economic Growth." Telephones do seem to have a higher level of productivity than other types of capital. This excess return at the macroeconomic level is evidence of a positive externality, an effect in excess of the private returns earned on investment in telephone systems. This is therefore evidence for the type of network effects that we have been discussing. Telephone networks may promote economic efficiency by reducing the power of local monopolies out of all proportion to the charges made on the telephone calls involved.

6. Promoting Information Technology

Once we accept that information technology will be an important component in development there remains the question of how countries can help firms and individuals adopt information technology and learn its uses. A central issue here is the decision of whether a country sees itself as a provider of information technology or a user of this technology. The infant industry argument for protectionism suggests that countries that wish to participate in providing information technology may want to champion local producers by restricting foreign competition in the domestic market. However, this is likely to be a disastrous approach. The world market for information technology is evolving so fast that it is impossible for any country to hope to catch up by selling inferior products locally. Such "learning by doing" is largely irrelevant if technology moves on every six months.

If developing countries are to succeed in producing information technology, it will only be if they play in international markets and compete, head on, with other producers. While some developing countries may succeed in some areas, for the immediate future the developing world will be mainly a user of information technology rather than a producer.

A vital implication of this, and the realization that information technology will play a large role in gaining export markets, is that information technology is treated as an investment good rather than consumption good. This is particularly true in terms of import tariffs. While taxing imports of computers and software may raise revenue, it may also stifle economic development. In practice, the issue may be more complex because import duties are a major source of tax revenue in many developing countries, despite the well known distortions caused by these duties, because their ease of collection makes them attractive when government bureaucracies are weak.

Competition in the supply of information technology will ensure the lowest prices and widest availability to users. Given the importance of this technology, it may be better to allow competition even at the expense of local firms being bought and controlled by foreign firms or being supplanted through direct investment by foreign firms. Foreign firms may be more efficient and better at introducing new technologies from abroad than local firms.

One component of the study, "Internet Use and Telecommunications Infrastructure," involves a close look at the determinants of Internet use across countries. While the Internet is just one component of the new information technologies, it is likely to play an important role in allowing developing countries access to global markets. In addition it is increasingly the way in which people access other information technologies.

Three measures of Internet use were examined: the number of hosts (Internet web sites), the number of Internet users, and the number of packets of information (a physical measure of the size of the information flow) that originated in each country in 1995. The number of users and packets of information sent rise one for one with a country's population and more than one for one with increases in income. This is in line with what we might expect; the Internet is used disproportionately by the better off. A more surprising result is that the number of Internet hosts is higher in developed countries but varies little with a country's population size. It appears that Internet sites may be close to public goods; as population expands, there is little need to increase the number of sites substantially since their use is not rival and one person's use of a site does not usually exclude others from that site.

More important for developing countries are the other factors that influence Internet use. We find that the quality and cost of the telephone system has an important impact on Internet use. We measure quality by the number of main lines per capita and the number of faults per main line. Hulten (1996) argues that the maintenance and quality of infrastructure may be more important than the absolute quantity available. Costs are reflected in the monthly line rental rate and the cost of a three-minute local telephone call. It is difficult to disentangle the separate effects of these different measures but we do find very significant impacts of representative measures of the quality of the telephone service on Internet use.

We can go further and look at Internet use in a two step procedure. In 1995 many developing countries had no Internet use at all. We first explain which countries were excluded from use, and then, conditional on a country having some Internet use, we find the determinants of the level of use. This gives an important insight into the nature of the effect of telephone system quality. System quality appears to be a threshold effect, mainly affecting whether or not a country had any Internet service of any kind. Once Internet use is in place, the quality of the telephone system appears to be less important.

One problem with this approach is that telephone provision may be a proxy for some other variable rather than important in itself. In particular, people who use the Internet are likely to be those with telephones. This may not be because telephones are so

important in themselves but rather that owning a telephone signals that a person is in the income class that is likely to want to use the Internet. The average income of a country may be less important in determining the demand for Internet use than the number of people above a particular income threshold. The number of telephones may be a reasonable approximation for the number of people in this income group. We can take account of this possibility by adding other measures, such as the number of television sets, and the number of cars, as better proxies for the number of people in this critical income bracket. When we do this, we still find that telephone provision has a significant impact on Internet use.

This result in turn raises the question of how a country can promote better provision of telephone services. We now have two reasons for promoting telecommunications; the direct growth effects discussed in section 4, and the indirect effect of assisting the spread of information technology. Fortunately, recent experience points the way here very clearly. Countries that have privatized their telephone systems, and allowed competition, have seen dramatic improvement in quality of telephone services and reduction in their prices (Spiller and Cardilli (1997) and Waverman and Sirel (1997)).

The argument that telephone systems are a natural monopoly and so require government controls is wearing thin. Technological development has produced several different methods of providing telecommunications. In addition, for those parts of the service where competition is not possible, regulation, rather than direct government provision, seems more efficient.

The history of public provision of telephone systems has been very poor. The typical public system has had low levels of provision and long waiting lists, high frequency of faults and high prices. Opening up the telecommunications market to competition may result in local firms being acquired by foreign firms. This will lead to substantial gains in terms of lower communication costs to the other sectors of the economy if the foreign firm has access to advanced technology and government regulation prevents any abuse of market power.

7. Conclusion

The adoption of new information technology, particularly Internet use, is likely to allow developing countries to become more integrated into the world economy. In turn, if we can extrapolate the evidence from the effectiveness of telephone systems, this may have profound effects on developing countries' growth rates. Little is needed in the way of policy to directly encourage Internet use. In a deregulated environment the demand for Internet access is enormous and grows exponentially.

The one caveat to this is the need for a telecommunication infrastructure that allows easy access to the Internet. Again however, this can be achieved through deregulation of the telephone industry. While the natural monopoly power of telephone companies was a real concern in the past, the emergence of multiple competing telephone technologies

means competition is now possible. In addition, a competitive environment is likely to foster quick adoption of the rapidly evolving new technologies in telecommunications and the Internet.

Background Papers for this Report

Canning D., (1999), "Telecommunications Infrastructure, Human Capital, and Economic Growth," Consulting Assistance on Economic Reform II Discussion Paper, Harvard Institute for International Development.

Canning D., (1999), "Telecommunications and Aggregate Output," Consulting Assistance on Economic Reform II Discussion Paper, Harvard Institute for International Development.

Canning D. (1999), "Internet Use and Telecommunications Infrastructure," Consulting Assistance on Economic Reform II Discussion Paper, Harvard Institute for International Development.

Canning D. and Pedroni P., (1999), "Infrastructure and Long Run Economic Growth," Consulting Assistance on Economic Reform II Discussion Paper, Harvard Institute for International Development.

References

Barro R. J. (1991), "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics*, Vol. 106, pp 407-444.

Barro R. J. and Lee J.W. (1993), "International Comparisons of Educational Attainment," *Journal of Monetary Economics*, Vol. 32, pp 363-394.

Bils M. and Klenow P.J. (1996), "Does Schooling Cause Growth or the Other Way Around?" mimeo, Graduate School of Business, University of Chicago.

Canning D. (1996), "Specialization, Scale Economies and Economic Development," *Economics Letters*, Vol. 52, pp 95-100.

Canning D. (1998), "A Database of World Infrastructure Stocks, 1950-1995," *World Bank Economic Review*, Vol. 12, pp 529-548.

Gallup J.L. and Sachs J.D. (1998), "Geography and Economic Development," mimeo, Harvard Institute for International Development.

Gramlich E. M. (1994), "Infrastructure Investment: A Review Essay," *Journal of Economic Literature*, Vol. XXXII, pp 1176-1196.

Hall R. and Jones C. (1999), "Why Do Some Countries Produce So Much More Output than Others?" *Quarterly Journal of Economics*, Vol. 114, pp 407-437.

Harris R.G. and Kraft C.J. (1997), "Meddling Through: Regulating Local Telephone Competition in the United States," *Journal of Economic Perspectives*, Vol. 11, No. 4, pp 93-110.

Hulten C.R. (1996), "Infrastructure Capital and Economic Growth: How Well You Use It May Be More Important Than How Much You Have," mimeo, University of Maryland.

Jones C. (1997), "The Upcoming Slowdown in U.S. Productivity Growth," NBER working paper, 6287.

Levine R. and Renelt D. (1992), "A Sensitivity Analysis of Cross Country Growth Regressions," *American Economic Review*, Vol. 82, pp 942-963.

Lucas R.E. (1988), "On the Mechanics of Economic Development," *Journal of Monetary Economics*, Vol. 22, pp 3-42.

Mankiw N.G., Romer D. and Weil D.N. (1992), "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics*, Vol. 107, pp. 407-437.

Pritchett L. (1996), "Mind Your P's and Q's, The Cost of Public Investment is Not the Value of Public Capital," Policy Research Working Paper, No. 1660, Policy Research Department, World Bank.

Sachs J.D. and Warner A.M. (1997), "Fundamental Sources of Long Run Growth," *American Economic Review*", Vol. 87 (2), pp 184-188.

Spiller P.T. and Cardilli C.G. (1997), "The Frontier of Telecommunications Deregulation: Small countries Leading the Pack," *Journal of Economic Perspectives*, Vol. 11, No. 4, pp 127-138.

Waverman L. and Sirel E. (1997), "European Telecommunications Markets on the Verge of Full Liberalization," *Journal of Economic Perspectives*, Vol. 11, No. 4, pp 113-126.

World Bank (1994), *World Development Report, Infrastructure for Development*, Washington D.C.