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Are Poor Countries Losing the Information Revolution?

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EXECUTIVE SUMMARY

This Report is a non-technical summary of research that explores whether there is an information and communication technology (ICT) gap between rich and poor countries, and whether that gap is growing or shrinking. It also discusses the link between that gap and gaps in income, both within countries and across them.

After defining this gap to include both ICT products and outputs (e.g. Internet, cellular phones, etc.) as well as inputs (engineers, scientists), we analyze the experiences of over a hundred countries. At the end of the paper we draw out some policy implications of our empirical findings for multilateral and bilateral agencies. We conclude:

(1) All developing countries, even the poorest, are improving their access to and use of modern ICTs, some at a dramatic rate. In virtually every country in the world, more individuals enjoy access to ICT today than ever before.

(2) However, the gap between the rich OECD countries and the poor developing countries is growing, both in terms of ICT products as well as in terms of incomes. The coincidence of these two trends is suggestive, but a decisive causal link cannot be established.

(3) Although these new technologies appear to be improving economic performance and welfare among the user populations, the link between ICTs and society-wide economic progress has been more elusive. Our study confirms what many researchers have found for developed countries, namely a lack of association between economic growth and use of ICTs. A possible hypothesis is that the

consolidation of the networks necessary to take advantage of these technologies takes time to form and that their positive effects will be felt in the longer run.

(4) It is quite clear that countries with similar levels of per capita incomes and economic structures exhibit wide variation in their ICT performances. Some developing countries are surging ahead while others are falling behind. We identify the pro-ICT policies that appear to be causing these differences in outcomes. In particular, we show that countries enjoy greater technological progress when they produce:

1. A climate of democratic rights and civil liberties that is conducive to innovation and adaptation of ICTs.
2. Respect for the rule of law and security of property rights.
3. Investment in Human Capital.
4. Low levels of government distortions.

However, we also find that many of these links are complex. Although there are great complementarities between ICT and economic and social progress, there are also some important trade-offs between equity, well-being and the unhindered development of ICTs. Simple claims about the links between ICTs and progress are not correct, and may in some cases be dangerously wrong.

(5) In two areas we lacked sufficient data to reach firm conclusions, but we can hazard educated guesses. We cannot tell whether the ICT gap is growing internally within countries between the rich and the poor; nor can we tell

> decisively whether ICTs are contributing to greater equality of incomes at national levels. However, we do know that comparable studies in developed countries suggest that information technologies can cause substantial increases in inequality. Whether this effect will be reversed in the long or medium run is still an open question.

A continuation of existing trends in the ICT have/have-not gap may contribute to a number of social problems including skewed economic outcomes and enhanced risk of social and political conflict. While the bad news is that the global equity problem is getting worse, the good news is that international and national bodies have an improved understanding of policies that can expand and accelerate the distribution of ICTs to poor populations in developing countries.

There is an ICT equity problem. There is a growing sense of urgency about the problem. And there is knowledge about how to reduce the problem.

1. Introduction

After an initial period of high optimism by many observers, questions have recently begun to arise about the distributive impact of the new communications and information technologies. Evidence indicates that the new Information and Communication Technologies (ICTs) can be highly beneficial to individual communities, projects and countries; we know that under the right circumstances ICTs can improve education, health, job creation, governance and other services.

We have weaker evidence and less serious speculation about the equity implications of these new technologies. Informed policy decisions require, however, that we know as much as possible about their likely economic and social equity impacts, either across the international community as a whole or within selected developing countries.

In this essay we take up a particular aspect of this question: we concentrate on whether poor countries and poor people are catching up with their rich counterparts. That is, we ask whether the data on ICT is characterized by *convergence* or *divergence* between developed and developing countries, as well as between poor people and rich people within economies.

By divergence we mean that developing countries' ICT use will not catch up with that of developed countries if existing trends continue. Convergence by contrast means that they will catch up at some point in the future – given existing trends. Thus there is convergence when the gap between poor and rich is shrinking, and divergence when it is growing. [i]

This Report poses and answers six empirical questions that are central to the growing policy debate over the potential development contributions of ICT to poor countries:

- Is there evidence of convergence or divergence between Less Developed Countries (LDCs) and Developed Countries (DCs) in their use of ICT products? In other words, is there a gap between the use of ICTs like computers, faxes, mobile telephones between North and South, and if so is the gap growing or diminishing?
- Is there convergence or divergence between LDCs and DCs in their commitment of capital and other critical inputs to ICTs?
- Is there convergence or divergence between LDCs and DCs in their GDP growth and other indicators of relative economic performance? Is the gap in the wealth between the richer and poorer countries growing or shrinking?
- Is there convergence or divergence within countries in the availability of these new technologies? Is there ICT convergence or divergence of incomes domestically?
- What is the link between ICT and trends in inequality across and within economies? Does higher exposure to technological progress contribute to lessening the gaps between the poor and the rich?

- What explains differences in technological progress across countries? What countries have taken advantage of the information revolution, and what have they done right?

The answers to these empirical questions should be of interest to International Financial Institutions, national governments in LDCs, Non-Governmental Organizations and the private sector operating in developing areas. Regrettably at this early stage of our understanding, most programmatic and policy decisions for developing countries are being made in a context of very little empirical information about the distribution and societal impacts of these powerful new tools.

If the analysis and answers to these six questions show that the gaps between developed and developing countries' ICT sectors are narrowing, then it may suggest one set of programs and policies that can be somewhat less urgently focused on equity dimensions, since private markets are adequately addressing equity concerns. On the other hand, if the evidence points in the other direction toward growing inequality, then it may point to market and other failures which call for a more proactive mix of programs and policies to address the equity dimensions.

Drawing on data from a variety of sources, our evidence shows that the majority of poor countries are being left behind by the information revolution. Along several distinct dimensions the number of poor countries that are managing to keep up with the rich is small. But we also show that there are policies that can be followed by those countries that want to improve their chances of joining the information revolution and gaining from it.

A caveat. This report uses the most reliable indicators of ICT across nations that exist to date. These indicators are drawn from reports published by well-known statistical organizations and reputable market research firms. We therefore have general confidence in the general reliability of the data we use, and believe the findings we reach to be correct, given the existing data. But we must point out that the cross-national coverage and the time series evidence are thinner than we would like. Although the problem of lack of adequate data is not uncommon in the field of development economics, the relatively new and extremely time-sensitive nature of the ICT phenomenon makes the contrast between the questions we ask and the answers we are able to give much starker in our case. In particular, our results almost surely err on the side of optimism, as countries with poor or no available data are most likely to be the same countries that are being left behind by the information revolution. All the findings of this report must therefore be considered as preliminary – rather than a full assessment of the information revolution, this is a report from its front lines. These findings will certainly require many more years of improved data to be confirmed with a satisfactory degree of confidence. However, the importance of our questions is so pressing that it would be irresponsible to postpone making an assessment of the existing evidence until the data becomes satisfactory.

2. Technology and Inequality

The information revolution is beginning to reshape the flow of investment, goods and services around the world economy. The global telecommunications market is a one trillion dollar plus market. Multinational and local companies rank robust ICT networks as a requirement for investment, and weak networks retard investment and growth. The computer components of automobiles cost more today than the steel components. From 1988 to 1997, the average number of computers per capita in the world multiplied more than ten-fold; in the US studies show that one-sixth of recent economic growth can be attributed to computer outputs. It is estimated that inter-company trade of goods over the internet will double every year for the next five years, going from $43 billion to $1.3 trillion by 2003.

Who benefits and who loses from these changes? Is the new information revolution likely to widen the gap between the rich and the poor, or is it a force that can be harnessed to achieve higher living standards for the 3.5 billion persons currently living on an income of less than 2 dollars a day?

The answers to these questions are far from clear. On the one hand, new technologies open up new spaces for competition and challenges to the established order. The recent history of the information revolution is full of stories of small start-up enterprises that were able within years to topple established giants. Indeed, the power of the Internet appears to be bringing world economies closer together over time, so that firms in Indonesia can compete electronically with those in Indiana. By bringing down impediments to trade and communications and lowering entry barriers, information and communication technologies seem to be introducing a powerful force towards convergence of world incomes.

Although the potential benefits from advances in information and communication technologies appear to be clear, how they will be distributed is not. Well-founded fears exist that the poor are being left behind by the information revolution. Access to information and communications technologies (ICTs) requires education, infrastructure and institutions, three resources which many developing countries lack. Without them, it is increasingly likely that the poor may be on the losing side of this revolution.

3. Technology Across the World.

We define ICTs as the set of activities which facilitate by electronic means the processing, transmission and display of information[ii]. In order to measure and evaluate the reach of ICTs in different countries, we must look at both the outputs produced by those industries – those that directly contribute to the electronic processing, transmission and display of information – and the inputs that make those activities possible. In particular, we will look at how these inputs and outputs vary across countries and over time.

The information revolution started in today's developed countries, so it makes sense that these countries have higher levels of technological attainment and higher use of ICT products. Still, the magnitude of the differences is staggering. In Table 1 we show five indicators of technological outputs – the products of technology that actually benefit consumers – for different regions of the world: Personal Computers, Mobile Phones, Internet Hosts, Fax Machines and Televisions. Our data show that although the average OECD country has roughly eleven times the per capita income of a South Asian country, it has 40 times as many computers, 146 times as many mobile phones, and 1036 times as many Internet hosts. The differences are less marked with respect to the forms of technology that have been around longer - particularly television sets - but they are still there. There are important gaps in ICT inputs as well. If developing economies were investing more in technology than richer countries, one could anticipate that the 'first mover' advantages of the latter would be reversed over time. However, the evidence shows that technological investment is also much higher in developed economies. As shown in Table 2, several of the most important measures of technological inputs – the investment necessary to produce high-technology goods – are substantially higher in developed economies than in developing economies. OECD economies invest nine times as much of their income in Research and Development – that is, in creative, systematic activities intended to increase the stock of knowledge and on the use of this knowledge to devise new applications - and have roughly seventeen times as many technicians and eight times as many scientists per capita as the economies of sub-Saharan Africa.[iii] These 'soft infrastructures' are as essential for successful ICT diffusion as are the 'hard' technologies. Indeed, the OECD nations also have twenty one times as many telephone mainlines per capita - a measure of the infrastructure necessary to take advantage of communications technology advances – as sub-Saharan Africa.

Our indicators of technology – in particular our indicators of technological outputs, which measure the availability of appliances and applications to consumers – capture many aspects of technological change. But they also capture other characteristics of particular markets and nations. For example, Qatar has more TVs per capita than Sweden, but it would not be sensible to call Qatar a more technologically-advanced economy than Sweden, particularly because Qatar is far behind Sweden on all of our other indicators. Likewise, Japan has fewer Internet hosts per capita than Slovenia, but is far ahead of Slovenia on all other indicators. A country with a high number of televisions per capita but without high marks on other indicators of technology may be a country in which mass media communications has developed successfully despite lagging in other technology. Likewise, a high number of mobile phones per capita may just reflect a lack of fixed telephone infrastructure instead of technological progress.

How then can we say that one country has made more advances than another in terms of information technology? Our solution to this problem has been to construct an *Index of Technological Progress* in which we combine information on all five of our indicators of technological outputs. Through a statistical technique called *principal components analysis*, we capture the *common source of variation* that these five indicators have in common. In other words, our index measures to what extent the variations in its five components – personal computers, Internet hosts, fax machines, mobile phones and televisions – are due to a single common phenomenon that differs across countries. We will call this index the ITP, or Index of Technological Progress.

Our index is shown for 110 economies in Table 3. The level of the ITP ranges form 0 to 100, with the United States at the top of the scale and Mozambique at the bottom. Our sample size is not larger because we were forced to exclude almost one hundred economies for which there are insufficient data to calculate our index. Among the excluded observations are some of the world's poorest nations; therefore the ITP almost certainly exaggerates the technological progress of the poor. Even despite that upward bias, it is clear that the picture painted by the ITP is not an encouraging one for developing countries. The top 10 economies are all members of the OECD group; the only two non-OECD economies to make it into the top twenty places are Hong Kong, China (12) and Singapore (13). The bottom 10 economies are all in sub-Saharan Africa.

The lowest ranked OECD economy is Greece (38); the highest ranked sub-Saharan African economy is Mauritius (46)

Figure 1 brings home strongly how the differences in technological progress are related to differences in income: rich countries enjoy higher technological progress. As others have noted for years, the level of GDP per capita is strongly associated with the level of ICTs. However, the Figure also shows that being richer is no guarantee of superior technological progress. Belgium has a higher GDP per capita (PPP value) than Finland but lags far behind it in technological development. Figure 1 suggests that there are many things that governments can do to raise – or lower – their levels of technological progress. Thus, structural features like GDP/PC help shape ICT outcomes, but they are not perfectly determinative. Human volition, institutional arrangements and policy choices also play their part. We return to their contribution in Section Three.

i. Notes on the variables included in the ITP

The data appendix contains details on the statistical method used to calculate the ITP. In this section, we discuss several robustness tests to evaluate to what extent our results are sensible to the choice of variables that were included in the index. The choice of what variables to include in the Index is of course a difficult one. Our main consideration in choices of variables is that they represent industries that facilitate, by electronic means, the processing, transmission and display of information – that is, that are consistent with the definition of ICT that we provided earlier. Televisions, fax machines, internet hosts, personal computers and mobile phones are all devices designed for these purposes.

It should be emphasized that the statistical technique used to construct the index captures the *common source of variation* in the variables used. And, even though one may have qualms with the ability of any single variable to capture technological progress, it seems logical to infer that the factors that make these variables move together must be somehow related to what we think of as progress in the functions of ICT.

Our ITP has been conceived of as an index of *new* ICTs – these technologies that have emerged in the world economy during recent years and that have given sense to the idea that an "information revolution" is taking place. There are a variety of views as to what the information revolution actually consists of. On the one hand, those who hold a restricted notion of ICTs that defines it as a set of core technologies would argue that variables like televisions and fax machines are not new technologies and should not be included in the Index. On the other hand, those who believe in a broad definition of ICTs would argue that the information revolution is not as new as it is commonly made out to be and that more traditional means of communication such as radios and newspapers are also legitimate means of electronic data transmission. In order to calculate the Index, we have drawn the dividing line somewhere in the middle of these two polar views. For that reason we have included TVs and fax machines but excluded radios and newspapers.

However, our results are not sensitive to this assumption. In Table 4 we show the result of calculating two other versions of our index. One is a version that restricts it to the "core" components of new technologies: Personal Computers and the Internet. The other one expands it to include newspapers and radios –products of traditional ICT sectors. We call the former ITP-Core and the latter ITP-Broad. The indices are very similar. Indeed, they are strikingly so: the correlation between ITP and ITP core is .94, and between ITP and ITP-Broad is 0.99.

It is also worth pointing out that the ITP is an index of *products*: it measures the capacity of different countries to process information useful to consumers and firms. It does not take into account the other dimension of ICT functions – the hard and soft infrastructures necessary to provide them. Obviously, the dividing line between an ICT product and an ICT input is very difficult to pin down – is a telephone mainline an input into the ICT sector or an output of it? The choice of what to classify as an input or not is in the end somewhat arbitrary. But our choice is based on the desire to capture the *capacity* to process information electronically, and not the possibilities for its future development.

One particular reason for which we may be interested in inputs is the possible enabling capacities that they have for future generation of ICT products. In that sense, it is possible to think of telephone mainlines and televisions as potential enablers (telephone mainlines now, televisions in the future) of internet communications. An ICT index that includes information on these two factors, along with PCs and internet hosts, could be seen as an index of future possibilities for development of ICT. This is what we call the Forward Looking Core ITP, which we also present in Table 4 . Again, the correlation with the ITP is impressive (.97).

This set of alternative calculations point to the fact that, despite the wide differences that exist in how to measure ICT products, the ITP index is able to capture the main differences across countries in their capacity to process information by electronic means. Out ITP index is robust to the use of alternative methods for its calculation, regardless of whether they reflect more inclusive, exclusive, backward-looking or forward-looking definitions of ICT. The basic reason for this is that the common source of variation seems to be affecting all the defining variables in the same direction.[iv]

4. Catching Up or Falling Behind?

We have demonstrated that there is a very substantial gap between rich and poor nations in the current distribution of investment and production of IC products. We turn now from this static picture to review the dynamic aspects of ICTs in OECD and non-OECD countries.

For 40 countries, we have been able to calculate the ITP in 1994 and 1996. Although we can calculate the ITP for some countries going as far back as 1992 and as recently as 1998, we will use the endpoints 1994 and 1996 because they maximize the number of observations: we have a total of 40 comparable observations for 1994-1996, but only 24 for the 1992-97 period. These indicators of the evolution of the ITP over time allow us to examine what countries are catching up and what countries are falling behind in terms of technology. We show the ITPs for 1992-97 as well as the annual percentage growth rates for different subperiods in Table 8. In Table 6 we show the ITP growth rates by regions for the 1994-96 subperiod as well as for other subperiods (1992-96, 1994-97, 1993-96).

If the growth rate in ITP were higher for poor countries they would sooner or later come sufficiently close to rich countries so as to catch up or possibly overtake them. But if these and other poor countries manifest lower ITP growth rates than rich countries, then we would expect the distribution of technology over time to become more and more unequal. Figure 2 shows that indeed rich countries are concentrating more of the gains in technology through time. The average growth rate in the ITP of developed countries is 20%; that of poor countries is 16%. The result is a widening gap in the distribution of technology globally. In 1994, the average ITP of developed economies was 28.3; by 1996 it had risen to 43.3. During the same period, the ITP of developing economies went only from 10.3 to 14.8. Only one region of developing economies in the world seems to be keeping up with the rich, and that is East Asia. The growth in the ITPs of China, Hong Kong, Malaysia, Singapore , Thailand and Vietnam, have averaged 20.9%. However, its rate of technological change is barely enough to keep up with developed economies: at this rate, East Asia would only catch up with developed countries by the year 2040.[v]

Our conclusions are of course qualified by the lack of availability of data for a longer period of time. At the time of writing, data on the components of our ITP going back before 1994 or later than 1996 were extremely limited. However, recalculating the data using this more limited information did not alter our results. Table 6 shows the result of a number of alternative time ranges that we used for our study. We have chosen the 1994-96 range because it maximizes the number of observations (40). However, regardless of whether one chooses the longest possible time span (1992-97, 24 observations) or two intermediate ones (1994-96, 29 observations, or 1993-96, 34 observations) the same conclusions hold: developed countries are in general outstripping developing countries in technological progress, with the exception of East Asia.

Is this lack of convergence simply a statistical artifact generated by poor data? Could it be that it is simply by chance that developing regions have had an unlucky draw during the observed time period? One way to test for this is by attempting to identify whether the observed divergence is statistically significant or not. If it were due purely to random factors, then we would not expect it to be statistically significant. In order to test for the statistical significance of divergence/convergence, we borrow from existing methodology in the economic growth literature on convergence[vi], and test whether the growth rate (in ITP) of poor countries is significantly higher than that of rich countries. That is, we estimate the equation:

Growth of ITP = a + b*ln(Per Capita GDP) (1)

If b is estimated to be significantly negative, then we say that there is evidence for statistically significant convergence. If it is estimated to be significantly positive, then we say that there is evidence for statistically significant divergence. Otherwise, we would be unable to refute the hypothesis that there is no tendency to either converge or diverge.

Table 10 presents the result of these tests. Column 1 shows that estimating equation (1) gives evidence of statistically significant divergence. One can also test for the existence of *conditional convergence* by controlling for other possible determinants of ITP growth. The idea of conditional convergence is to test whether countries with the same given institutions and policies are converging among themselves – although perhaps diverging from countries with other institutions and policies. After we introduce these alternative controls (which we discuss more in depth below) we find that the evidence for statistically significant divergence disappears, and in some cases the point estimate even turns negative – although far from statistically significant. This indicates that, *given the appropriate institutions and policies*, developing countries need not diverge and may even converge – a point to which we will return in our next section, when we discuss the determinants of ITP growth.

Figure 2 illustrates to what extent other regions of the world are falling behind. Latin America seems to be the worst performing region in terms of *change* in its ITP[vii], which has grown by only 12% during the 94-96 period. Regrettably, we cannot say much about a region which may be doing even worse- sub Saharan Africa. The limited availability of data only allows us to calculate the levels and not the rates of change of ITP for all but one country in sub-Saharan Africa – the exception being South Africa. In terms of growth rates, South Africa's performance is actually impressive, although a number of case studies suggest that South Africa is an outlier in the region.[viii] The Middle East, despite its high levels of relative wealth, has had a very lackluster performance, and its percentage rate of growth in ITP (13.9%) is barely above that of Latin America. Eastern Europe puts in a similarly lackluster performance, with a percentage rates of ITP growth of 14.0%, still below what it needs to keep up with rich countries.

Our results are similar if we restrict ourselves to the Core ITP – the ITP that only measures differences in internet hosts and personal computers. In absolute terms, developed countries are still widening the gap with developing countries. One difference is that when we use only the Core ITP Eastern Europe seems to also be catching up with the developed world – at a faster pace than Asia. When this index is used, the average rate of growth of developing countries' ITP is higher than that of developed countries, indicating evidence of relative convergence. However, the estimated rate of convergence is so slow that developing countries would catch up with developed countries only by the year 2291! (see Figure 3 and Table 7)

The data sources used in our ITP are taken from an annual questionnaire sent to member countries by the International Telecommunications Union (ITU) – a special agency of the United Nations. One way to check the consistency of our results, and to obtain data for a longer time span, is to use data collected by the World Information Technology and Services Alliance (WITSA) - a consortium of information industry representatives from around the world - which has used market surveys to estimate several indicators related to ICT. This alternative data set allows us to have observations for 30 countries from 1992 to 1997.

We can calculate an analog of the ICT core with the WITSA data. Figure 4 shows the results of doing this. The absolute differences between developed countries' levels of access to new technologies and that of developing countries is still widening over time. Only Asia had reached by 1997 the levels of information and communication technologies that developed countries had in 1992. Again there is evidence of a *slow* convergence between the developing world and the developed world: that is, the *rates* of growth of developing countries' ITPs is greater than that of developed countries. The rate of convergence is somewhat faster than with the ITU data, but we must remember that one key difference between the WITSA data and the ITU data is that the former has a considerably smaller number of observations in the sample. *Therefore it is probable that the slow convergence captured by the WITSA data reveals no more than the fact that the poorest, worst performing countries are being dropped from the sample.*

An interesting illustrative device for seeing how the distribution of technology across countries is worsening is to calculate the World Gini coefficients for Technology. Gini coefficients are commonly used to capture the distribution of income. Figure 5 shows the evolution of the Gini in ITPs among countries. The Gini has strongly deteriorated, from .67 to .78 between 1992 and 1997. This type of changes are uncommonly large among income distributions; they suggest that the deterioration in the distribution of technology across the world is occurring very rapidly.

Figure 6 shows that there is a wide dispersion in the technological performances of developing nations. It plots the growth in ITP against initial levels of GDP per capita. It shows that some developing economies are doing just as well as developed economies in terms of growth in their ITPs. In particular, Tunisia, Malaysia and Thailand have rates of improvement in their technological standing to parallel those of the best performing developed economies. However, there are a number of failures in the developing world which more than offset these success stories. Among the particularly poor performances are those of Algeria, Colombia, Russia and Egypt.

This performance mirrors what has occurred over the postwar period in terms of GDP per capita. It is well-known that per capita GDP growth rates are not higher in developing countries than in developed economies. As Lant Pritchett of the World Bank and Robert Barro of Harvard University – among many others - demonstrated in their own work, through the early l990s convergence was not occurring between North and South. However, the growth rates of some developing economies, such as those of the so-called East Asian tigers have by far outstripped those of developed countries. This is shown in Figure 7. Despite the fact that some economies with very high per capita GDP growth rates are developing economies, on average poor countries are not catching up with rich countries. This is because the growth performance of some poor economies is far below the lower end of the range for rich economies. In other words, some developing countries can converge to the level of income of rich countries, but they need not.

The moral of this story is that catching up to developed countries is very difficult for most poor developing countries, in either their GDP/PC or their ICT performance. Most are not converging in either their ICT inputs or outputs. On the other hand, along most ICT dimensions, the substantial majority of LDCs in 1999 are certainly well beyond where they were five years ago. LDCs are making progress in technological development. But what progress there has been is far from enough to keep up with the breakneck speed that the race for technological progress has taken. Indeed, the story might be far worse than what we are telling, as our evidence is based on the behavior of ITP for the set of countries for which we have been able to gather sufficient data to study the behavior of technology over time. It is quite likely that the countries we omitted from the sample because of lack of data availability are predominantly very poor countries which have fallen even further behind.

Our data indicates that catching up is possible, but that it does not happen easily or automatically. As we pointed out, there is a small number of developing economies which have kept up with and even surpassed the rate of technological progress of rich economies. The relevant policy question then becomes: what must developing countries do to maintain and accelerate their technological advances? Stated differently, what do the developing economies which have shown high rates of technological progress have in common? Our review of the empirical materials and the work of other scholars, which we discuss in the next section, suggests that the main requirement for technological advance is a national 'enabling environment' which promotes sustainable innovation and ICT diffusion.

5. Getting Policies and Institutions Right.

Our empirical investigation shows that economies which have technologically progressed differ from those which have stayed behind in two fundamental ways: an economic environment conducive to investment, and a climate of civil liberties conducive to research and expansion of communications. The interaction with other factors, such as education and investment in human capital or foreign direct investment is more complex and varied.

We have reached these conclusions through a systematic statistical analysis of the links between growth in technology (as measured by the ITP) and several potential determinants. In what follows, we discuss our findings with respect to each of these causes of technological progress.

i. Investment

Our first hypothesis is that growth in technology requires the set of conditions which are necessary to ensure high rates of investment in an economy. Without these propitious conditions, technological advance cannot occur. Technological innovation results from investment, so it must benefit from the same characteristics which lead to high rates of investment generally. And there are particular synergies between technology and domestic investment. Technological improvements raise the return to capital and stimulate further investment. Likewise, a desire for high levels of capital accumulation stimulates technology as a way to counteract the force of diminishing returns.

Do our data bear out this relationship? We do find strong evidence in the data that technological progress is associated with investment rates. Figure 8 shows this particularly strong association. An increase in the investment rate in 10 percentage points is associated with a 5.8% higher rate of improvement in technological progress.

ii. A detour: The causes of investment

It is useful to learn that investment is associated with technological progress. But what good is it to policymakers who want to raise their rates of technological progress? Most likely they are also interested in raising their investment rates, and are looking for a way to do this. Telling them that investment is good for technological progress is unlikely to be useful unless they can learn what causes investment.

There is indeed an extensive literature on the determinants of investment. In particular, work by Robert Barro at Harvard University[ix] has found that the main factors conducive to higher investment rates are investment in human capital, low levels of government distortions, security of property rights and basic political freedoms. High levels of human capital are conducive to investment because better workers raise the productivity of capital and potential profits. Low levels of government distortions – and in particular low levels of unproductive government expenditure – are associated with a safer climate for investors and lower tax burdens. A basic climate of security of property rights and low levels of expropriation risk are paramount in order to lead investors to expect to be able to reap the rewards from their efforts. And political freedoms are necessary for citizens to ensure that policymakers are acting in the public interest through actions conducive to greater economic growth.

By establishing that investment is a necessary condition for technological progress, our research has also established that all of the above named factors are also important for technological progress. They are important because they generate an overall climate conducive to investment; since technological innovation and imitation are forms of investment, they also benefit from improvements in human capital accumulation, low levels of government distortions, security of property rights and basic political freedoms

iii. Foreign Direct Investment

It may seem that a particular type of investment is likely to be highly conducive to technological progress, and that is foreign direct investment. To the extent that countries can benefit from technologies which are invented in developed economies, it may seem that the more that foreign firms invest in a country, the greater will be their ability to transmit information in the form of new technologies for production and new technology-intensive products.

However, we find little evidence for this. Figure 9 shows the association between gross foreign direct investment as a percent of GDP and technological progress. There is actually a negative relationship! Indeed, some countries that have fared quite well in terms of technological progress (such as Tunisia and South Africa) have some of the lowest rates of FDI of our sample.

We stress, however, that this result must be viewed with utmost caution. In particular, recall that we have shown above that investment is associated with technological progress. In particular, this means that both foreign and domestic investment are conducive to technological progress. What our result on FDI shows is that there is nothing special about FDI as opposed to domestic investment in terms of capacity for generating technological progress. It does *not* show that FDI fails to generate technological progress; what it does show is that there is no evidence to support the claim that FDI generates *more* technological progress than investment by domestic entrepeneurs.

Our evidence adds to other empirical work in economics that has found weaknesses in the channel of technology transfer of FDI. For example, a recent study of Venezuelan manufacturing by Brian Aitken of the IMF and Ann Harrison of Columbia University[x] found that even though foreign owned firms had higher levels of productivity, FDI actually diminished the productivity of domestic firms, with a net overall effect on the economy which was, overall, quite small. However, other authors do claim to have found a robust effect of FDI on economic growth[xi]. To borrow from the terminology of Joseph Schumpeter, foreign direct investment can be creative under the right institutional and policy conditions, but it can also be destructive.

iv. Investments in Education and Health

We have pointed out that investments in human capital – in particular investments in health and education – can be conducive to technological progress because they are conducive to higher levels of investment. However, we also would like to know whether these also have a direct effect on technological progress – that is, an effect above and beyond their effect through the inducement to higher levels of investment. Again, there are particular synergies between technology and human capital. In particular, more educated workers make more productive firms. And high levels of education may be a necessary condition for the use, imitation and innovation of new technologies.

On the other hand, there could be a trade-off between investing in technology and investing in human capital. Resources spent building hospitals and schools are resources not spent in communications infrastructure. Furthermore, someone must pay for higher investment in human capital, and to the extent that this spending is financed by taxation on producers of wealth then it may lead for lower incentives to investments in technology.

Indeed, we do find evidence of such a trade-off. It is not present in the relationship between public spending on education and technological progress which is strongly positive, as shown in Figure 10. But in the relationship between public health spending and technological progress (shown in Figure 11) we do find a negative association between public health spending and technological progress, indicative of such a trade-off.

A plausible explanation for this phenomenon is that, as we have suggested, there are synergies between technological progress and human capital accumulation but there are also trade-offs. In the case of public spending on education, which is directly associated with the quality of workers, the synergies appear to be stronger than the trade-offs. But in the case of health spending, where the links to the ability of workers to work with technology are weaker, the trade-offs seem to outweigh the synergies.

It is important to point out that this does not mean that public spending on health is harmful for technological progress. When trying to estimate the effect of public health spending on technology, we must remember that there is a direct effect – that shown in Figure 2-8 – and an indirect effect, which works through the impact of health on investment, which has been found to be strongly positive.

It is important to bear in mind that the balance between these trade-offs and synergies depend on the institutional environment within which the interaction between technological progress and human capital accumulation takes place. In principle, one can argue there are few trade-offs between ICTs and other values because in the medium term ICT will be complementary to and accelerate other investments. Furthermore, if both ICT and human capital investments make economic sense, there is no reason in a world of well-functioning international capital markets not to carry them both out. In reality, however, there have been enormous short-term pressures on LDC decision-makers to get by with limited resources. Public officials have been confronted with difficult trade-offs in the here-and-now -- as between Pentiums and Penicillin. Pressure to reduce budget deficits at all costs often means pressure not to carry out the investments – in human capital accumulation and in the generation of knowledge – that make the most long-run sense.

The general lesson that we draw from the above results is that we should be wary of the simple links between ICTs and human capital accumulation that are often formulated in the policy debate. ICTs may complement investment in human capital accumulation but may also substitute for them; we should not expect to see a simple relation between them.

v. Civil Liberties and Freedoms

Developing countries that successfully innovate and diffuse ICTs are able to open their political systems as well as their investment and commercial institutions. The evidence suggests that civil liberties go hand in hand with the conditions to innovate and generate technological progress. Technological imitation of the advances of other countries requires relatively free transmission of information across countries. The poor economies that are likely to be more successful in technological progress are not those that choose to reinvent technology but rather those that learn to imitate it and adapt it to their local needs.

A body of existing research has shown that ICT diffusion rates may influence and be influenced by a nation's legal, institutional and political environment.[xii] Central to such an enabling environment are civil liberties, including freedom of expression, transparency of institutions and protection of property rights.

ICT diffusion and civil liberties could be related in a variety of ways, through commercial and economic as well as political channels. We hypothesize that the presence of protected civil liberties (see the Appendix for a complete definition) will be more favorable to ICT use and diffusion than fewer and vulnerable civil liberties. The reason is that a government committed to low levels of interference with the market mechanism is more likely to have a legal and institutional framework where the rule of law and civil liberties are the guiding principles.[xiii] These governments recognize that the flow of economic goods and services – including information - requires intensive coordination and communications among many parties. In contrast, governments that restrict the market mechanism may at the same time restrict civil liberties, impeding the flow of news and other information. ICT restrictions therefore will reduce the incentives and opportunities for mutually beneficial exchanges.

Many analysts have also pointed to the link between innovation and generation of technological progress and the ability of social actors to share information across groups of inventors, investors, industrialists and customers. Restrictions on freedom of speech and communications may impose heavy burdens on technological innovation and diffusion.[xiv]

At the same time, ICTs are powerful instruments for the transmission of knowledge and political opinions, as well as data and information. As such, they may severely threaten powerful groups in societies who hold a monopoly over information transmission. Some national elites restrict access to ICTs for ideological and political reasons: they fear 'contamination' of the national culture, or seek to close alternative information channels about regime performance, fearing threats to regime stability. Furthermore, the Internet can be used to circumvent limits to the freedom of association - interconnected, networked computers offer the capacity to hide and store information far out of the reach of a repressive state apparatus. Therefore repressive governments are unlikely to grant their citizens full freedom to use ICTs. Whether the motives are political, cultural or economic, when regimes restrict ICT they may also unwittingly be restricting investment in the sector, closing off opportunities for technological innovation.

Our data confirm these hypotheses by showing a strong association between civil liberties and technological progress. We measure civil liberties through an index which combines information on freedom of expression and belief, association and organizational rights, rule of law and human rights, personal autonomy and economic rights. This index is produced by a non-profit American organization called Freedom House[xv]. Figure 12 shows the association between civil liberties and changes in the ITP. According to our estimates, a transition from the most repressive state to the higher state of civil liberties in our index would raise the annual growth rate of technology by 18 percentage points.[xvi]

6. Poor Nations and Poor People.

To this point, we have discussed the ways in which the information revolution is affecting poor countries, and in particular how poor countries can catch up through technology. But the reason that we consider the economic development of poor countries important is because the majority of the population in these countries is poor and we consider their economic plight particularly urgent. Even if developing countries gain from technology, can we be sure that the poor in these developing economies will benefit? Or will the gains be captured exclusively by those already better off?

There is ample literature on poverty rates, both cross national and intra-national. For example, Joan Nelson and others have shown that absolute poverty rates have been declining for some years now so that there are proportionately fewer poor people in the world than a decade ago[xvii]. However, recent work shows that countries are on average become more unequal during the past two decades[xviii].

However, as far as ICT and domestic income distribution are concerned, there is little to guide us, especially in LDCs. There are far too few studies that address this issue directly, and what we have is not encouraging. Research on the United States and some other developed economies has consistently found that information technology has contributed to substantial increases in the level of inequality. Indeed, a recent debate on the causes of the increase in wage inequality in the United States appears to have been settled decisively on the side of the proponents of information technology as the driving cause. And the other competing explanations – such as greater openness to international trade – are also among the expected effects of technological integration.

The reason that computers raise inequality appears to be two-fold. First, workers with greater levels of education are precisely the workers who are best able to use information technology. Therefore the introduction of information technology widens the gap in opportunities: it allows college graduates to earn higher wages while it reduces the demand for – and the wages of – unskilled workers with a high school diploma or less. Second, the introduction of a new technology allows firms to substitute machines for people. The people who are displaced by machines create a new mass of unemployed that depresses existing wages.

In general, the logic of ICT-inequality linkages is that when a new technology is introduced into a social setting where scarce resources and opportunities are distributed asymmetrically, the greater likelihood is that those with more resources will employ them to gain additional ones, including ICTs. Francisco Freire of the World Bank, for example, has argued that even if we assume ICT to be a free good, when diffused across a normal distribution where individual skills and capabilities differ markedly it will tend to reinforce existing patterns[xix].

Given this powerful logic and the strong empirical evidence that information technology has worsened inequality in some rich countries like the U.S. and the U.K., what can poorer countries expect? On the one hand, poor countries have much lower levels of human capital. They therefore have fewer people with the capacity to work with and benefit from computers. These few are likely to benefit disproportionately from the information revolution. Meanwhile, the groups of disadvantaged individuals that have not had access even to basic levels of education are likely to be out of the race from the start.

On the other hand, to the extent that the information revolution allows rich countries to specialize in technology-intensive goods and brings forth more flexible production processes in poor countries, poor countries may be better able to specialize in what they can produce at low cost – goods intensive in the use of labor, with low technological components. The effect of this specialization may be to raise wages in poor countries.

Regrettably, the cross-country data is simply too sparse to give us a definite answer to this question based on comparisons of changes in inequality and levels of technological development across economies. Much of the data on Gini coefficients is riddled by inconsistencies across countries in survey methodologies which make cross-country comparisons extremely difficult. And even though there is probably enough data to answer general questions about the behavior of inequality over the postwar period, the data necessary to confirm or reject hypotheses about the role of technology in changes in inequality over the past fifteen years is much more limited. What there is, however, does show a recent increase in Gini coefficients in most economies[xx]. The fact that this increase coincides with the spread of information technology may be no more than a coincidence, but it is at least a suggestive one.

Country and region specific case studies are also hard to find, but some recent studies[xxi] suggest that technological change biased in favor of skilled workers has been behind recent increases in income inequality in a number of Latin American countries. Much more research of this nature is necessary to identify the linkages that may exist between information technology and inequality.

In any case, analysts and policy makers need to be careful about easy claims regarding the putative relationships between information and communications technologies on the one hand, and other societal outcomes like productivity, investment and inequality on the other. Our evidence shows that the picture appears much more muddled. Some countries with large recent observed increases in inequality – such as the U.S., the U.K., China and Hungary – are also countries which, according to our data in Table 8, have experienced rapid technological development. But inequality has been stable over the past few years in economies like Sweden and Finland, which have also had high rates of technological development. Therefore the data do not seem to support the existence of an unequivocal relationship between changes in inequality and technological progress. If anything, it suggests a much more complex pattern, likely to be mediated by country-specific characteristics and institutions.

Much more research is needed on the effect of information technology on inequality in developing countries. It is hard to think of other questions which have such staggering potential implications but yet are so understudied. Only if we are able to accurately measure and understand how new technologies are affecting the poor *inside* developing countries will we know whether this is a force for the reduction of global inequality or for its increase.

7. Technological Progress and Economic Growth

Given the relevance of information technology in today's policy discussions, one would expect the link between technological and economic progress to be a well-established fact. It seems intuitively clear that the unprecedented technological innovations that we have seen over the past two decades ought to usher in a new era of economic growth. However, it has proven remarkably hard to establish such a link in the empirical evidence. Nobel Laureate Robert

Solow has remarked that one can see computers everywhere but in the productivity statistics. And the rate of per capita GDP growth in the US during 1990-1996 – the period of major growth in use of new technologies - has been substantially *lower*, not higher than during the earlier 1973-1990 period (and much lower than between 1948 and 1973). Study after study has thus far failed to find a positive impact of information technology on productivity. If anything, these studies have found that we use technology instead of other capital goods to produce roughly the same goods and services that were previously produced[xxii]. This remains a highly controversial area of research, where existing findings disconfirm not only conventional wisdom but well-grounded theoretical thinking.

Our ITP index can help shed some light on this issue from a cross-national perspective. The U.S. evidence is suggestive, but it is just one example. Its poor productivity growth could be due to many factors; a more striking finding would be one that established that growth was completely unrelated to technological progress over a broad cross-section of countries.

Our results do indeed confirm this: technology and growth seem not to be associated for a broad sample of developing and developed economies. Figure 13 shows the association between growth and the ITP index in our sample arising from a regression analysis that also controls for many of the traditional determinants suggested by the recent empirical literature on economic growth. The evidence shows that relationship is basically non-existent. There appears therefore to be a wide variance of outcomes. For example, China, Thailand, Chile and Lebanon are among the best performing economies in the world over the 1988-1997 period. However, somewhat counter intuitively they are all in the lower half of the distribution of ITPs. They are well below countries like Qatar and Estonia in terms of ITP, but Qatar and Estonia have had negative per capita GDP growth rates over that period. Similar results emerged when we carried out this analysis using ICT-Core.

In standard models of economic growth, the rate of growth of the economy is related to the level of ICT.[xxiii] It is for that reason that the above exercise uses levels of ICT as the explanatory variable. However, there are models in which the *change* in technological progress is the correct explanatory variable.[xxiv] To examine that hypothesis, we redid the above analysis using the change in ITP as the independent variable. Figure 14 shows this association, which is actually slightly negative – although not significantly so. Similar results were obtained when the experiment was redone using different time spans for the dependent and explanatory variable.

It is important to emphasize that our results, although consistent with the existing country-based empirical literature on the relationship between economic growth and information technology, is at odds not only with conventional wisdom but also with existing theoretical thinking on this subject. It is our view that a relationship between economic growth and ICTs does exist but is masked by problems in the quality and precision of the existing data. However, we must confess that such a belief is based on our priors about the benefits of ICT and not on the existing empirical evidence. At the least, this evidence should lead us to be very careful when passing judgments about the link between economic progress and ICTs.

8. Policy Implications and Conclusions

The policy implications of this mixed bag are not conclusive. It would be audacious on our part to prescribe in detail what governments and donors should do, given the limited and exploratory nature of the knowledge that exists on the subject. Instead, we sketch out several issues that can help officials think about program and policy support. Whether support for ICT is warranted hinges on the answers to a number of questions about the trends in global and local ICT diffusion, and the importance that one assigns to that diffusion. We argue that structural shifts, the importance of ICTs' contribution to development, absolute access and evidence of the global gap are all indicators that must be considered in order to evaluate the desirability of further investment.

The first question that must be tackled regards the **global trend** toward greater or less distributional equity cross nationally. We have shown in this report that the gap between the ICT haves and have-nots appears to be growing substantially. The need to reverse this growing gap in access to the benefits of new technologies should be a primary consideration in a decision to assign resources to ICT development. However, the question of **absolute access** is also relevant**.** This refers to whether or not ICT access in poor countries is growing in absolute terms. Do more people in LDCs have access to these technologies this year than last? Is the increase substantial or modest? If absolute access is growing fast and worldwide, then this may well moderate the demand for additional actions by donors. If on the other hand such access is moving slowly, then more support may be warranted by donors. This may also be the case if the domestic gaps in access are growing, or if there are substantial bottlenecks that are visible, and can be effectively reduced.

Ultimately, of course, the answer to donor support probably hinges on how important they judge ICTs to be for sustainable development. If donors think ICT is very important for the future of development, then support for ICT programs is warranted. But if they believe it is unimportant, resources may be better spent in investments which have been shown to be conducive to economic growth – such as education and health. As we have shown, the evidence on the efficiency effects of ICT is mixed. Our research found that investment and use of ICT alone is not automatically associated with economic growth. This finding, which contrasts with the conventional public wisdom, is nevertheless consistent with a large number of economic studies carried out mainly in industrialized countries. On the other hand, it does seem intuitively important that countries that have high and sustainable rates of growth are able to diffuse and use ICT efficiently and effectively. Our findings may reflect the fact that ICTs require a sophisticated enabling environment of hardware and policies before they contribute efficiently to economic growth.

There is an additional important consideration. It appears that the economic structure of some countries is shifting away from agriculture and industry, toward information services. If LDCs are to begin a shift in this direction, then they may need substantial assistance for such a restructuring of their economies and societies.

9. Conclusions

We believe our findings have stark implications for multilateral and bilateral support for ICT activities in developing countries. **Since the gap between OECD and non-OECD nations is indeed growing, then we believe substantial support for diffusion of these technologies to poor countries is warranted**.

Our conclusion is based on several assumptions. First, we believe that these new technologies are **very important**. Like electricity and advances in manufacturing a century and a half ago, these new innovations have the potential for transforming societies internally, and transforming their relationships to the global economy. Therefore, they open up enormous possibilities for development in the world's poor countries.

Second, we believe the current diffusion patterns suggest **market or social failures** that are limiting the diffusion of ICTs in LDCs, and that these failures of private markets can be overcome through targeted and selective government interventions.

Third, we believe there are **negative economic, social and political consequences of growing ICT disparities** between have and have not nations.

To consider more fully the policy implications of these findings and assumptions, there are two other critically important observations to be addressed.

First, we found that at all levels of development there have been tremendous increases in ICT availability and access. In Africa, for example, the number of Internet subscribers has gone from under 15,000 to over 400,000 between 1996 and 1999[xxv]. Anecdotal evidence suggests that for African and South Asian Non-Governmental Organizations, universities and research sites, and private companies, these information resources have enhanced performance and reduced costs substantially. It appears that even in the poorest areas of Africa and South Asia, for example, new ICTs are diffusing rapidly and are contributing to local well-being.

Second, the empirical evidence shows that among countries at roughly the same level of economic development with roughly similar economic structures, there are significant differences in ICT availability and utilization. When we investigate the reasons for those intra-category differences, we find that there are consistent causes. Our research has shown that advances in ICTs like Internet are most associated with a climate of democratic rights and civil liberties that is conducive to innovation and adaptation of ICTs, respect for the rule of law and security of property rights, investment in human capital, and low levels of government distortions. Other research has also pointed to the importance of encouragement of capital investment in the ICT sectors, absence of price controls, low or no tariffs on technology imports, pro-competitive and transparent regulatory structures, aggressive support for science and technology training and active support for private sector involvement in all markets.[xxvi] Together, these findings give us a menu of policy alternatives for reducing the ICT gap between poor and rich countries.

We began this Report asking several questions we have uncovered in this Research project. The questions and answers to them follow.

Question: *Is there evidence of convergence or divergence between Less Developed Countries (LDCs) and Developed Countries (DCs) in their use of ICT* *__products?__* In other words, is there gap between the use of ICTs like computers, faxes, mobile telephones between North and South, and if so is it growing or diminishing?

Answer: The evidence shows a gap between rich and poor countries' access to ICT that is staggering. While the average OECD country has about eleven times the per capita income of a South Asian country, it possesses 40 times as many computers, 146 times the mobile phones, and 1036 times the Internet hosts. We constructed a new indicator to measure ICT diffusion through a basket of applications, which we call the Index of Technological Progress (ITP). The ITP shows staggering differences in technological progress across countries.

In dynamic terms, our research concluded that rich countries are concentrating more of the gains in technology through time (as shown in figure 2-1). The average growth rate in the ITP of developed countries is 23% between 1994 and 1996; that of poor countries averages only 18% over the same period. The result is a widening gap in the distribution of ICT globally. In 1994, the average ITP of developed economies was 34.7; by 1996 it had risen to 56. During the same period, the ITP of developing economies went only from 10.3 to 15.3. Only one developing region – East Asia -- seems to be keeping up with the rich.

Question: *Is there evidence of convergence or divergence between Less Developed Countries (LDCs) and Developed Countries (DCs) in their use of ICT inputs?*

Answer: Once again, we found substantial gaps in static comparisons across the two groups of countries, with investments much higher among developed countries. OECD economies invest nine times as much of their income in research and development - and have about seventeen times as many technicians and eight times as many scientists per capita as the economies of sub-Saharan Africa. Still, somewhat contrary to our expectations, the differences in input measures were substantially lower than the differences in output measures. Lack of data availability has precluded an evaluation of the behavior of these gaps over time, so that we cannot give a decisive answer to the dynamic question of convergence. But the extent of the gaps is quite suggestive.

Question: Is there convergence or divergence between LDCs and DCs in their GDP growth and other indicators of economic performance? Is the gap in the wealth of the richer and poorer countries growing or shrinking?

Answer: Here the evidence is rather straightforward: despite the fact that some economies with very high per capita GDP growth rates are developing economies, on average poor countries are not catching up with rich countries. The DC - LDC gap continues to grow for most countries, despite the introduction of information and communication technologies.

Question: Is there convergence or divergence within countries in the availability of these new technologies? Is there convergence or divergence of incomes domestically?

Answer: At present, data is simply not available to ascertain the trends in the distribution of access to ICTs within countries. In terms of income inequality, most research has suggested that domestic inequality rates are rather stable through time. However, some recent work has found an upsurge in average inequality indicators in the world. Gini coefficients have risen substantially for some large and important countries like the UK, the U.S. as well as China and some other post communist societies. Many of these are countries in which ICTs have been rapidly introduced in recent years.

Question: What is the link between ICT and trends in inequality across economies? Does higher exposure to technological progress contribute to lessening the gaps between the rich and the poor?

Answer: The link between introduction of ICTs and upsurges in inequality in the world is suggestive. Yet we cannot say unequivocally that ICTs automatically create greater equality or cause greater inequality. The picture is much more complicated, and requires careful country level studies to be addressed.

As far as ICT and domestic income distribution are concerned, there is little to guide us, especially in LDCs. There are far too few studies that address this issue directly; but what we have is not very encouraging. Research on the United States and some other developed economies has consistently found that information technology has contributed to substantial increases in the level of domestic inequality. Indeed, the ongoing debate on the determinants of spreading wage inequality gaps in the United States appears to have been answered decisively on the side of information technology as the driving cause. The emerging logic in much of the literature suggests that, at least in the short to medium term, when a new technology is introduced into a social setting where scarce resources and opportunities are already distributed asymmetrically, it is more likely that those with more resources will employ them to gain additional ones, including ICTs.

Question: What explains differences in technological progress across countries? What countries have been in a better position to take advantage of the information revolution, and what have they done right?

Answer: There are substantial differences in ICT performance, even for countries that have very similar levels of initial development and economic structure. We show that advances in ICTs like Internet are associated with a climate of democratic rights and civil liberties that is conducive to innovation and adaptation of ICTs, respect for the rule of law and security of property rights, investment in human capital, and low levels of government distortions.

Information technologies appear not to have contributed to lessening the gaps between the rich and the poor, neither within economies nor across them. Indeed, they may well have significantly contributed to worsening it. Given this evidence, it appears that, absent dramatic policy interventions, most poor countries can expect to fall further behind in technology and in outputs. But while these facts are striking, they should not allow us to overlook the dramatic improvement in levels of access to ICT that have occurred over the past decade in the world. The overwhelming majority of developing countries are well beyond where they were five years ago. The information revolution is spreading to the developing world, and it is spreading rapidly. Furthermore, increased productivity in rich countries benefits the poor because it allows the goods produced by rich countries to be sold at lower prices. Increased *absolute* levels of well being are ultimately, the most important base line measurement.

However, the spread of the information revolution *can be* accelerated. In this Report we suggested several possible alternative policy responses to the ways in which trends in ICT access and performance may play themselves out. We conclude that the guiding rule of thumb should be for policy makers, donors and others to pursue ICT policies with substantial equity components, appropriate to local needs and resources.

Much more research is needed on the effect of information technology on inequality in developing countries. It is hard to think of other questions that have such staggering potential implications but yet are so understudied and misunderstood. Only if we are able to accurately measure and understand how new technologies are affecting the poor *inside* developing countries will we know whether they are a force for the reduction of global inequality or for its increase, as well as how to harness their considerable powers to pursue greater equity.

10. Data Appendix

Variable Sources and Definitions:

1. **Personal Computers**: Personal computers are of the estimated number of self-contained computers designed to be used by a single individual, per 1,000 people. Source: ITU. Alternative data from WITSA, *Digital Planet* is used.
2. **Internet Hosts:** Internet hosts are the number of computers with active Internet Protocol (IP) addresses connected to the Internet, per 10,000 people. All hosts without a country code identification are assumed to be located in the United States. Source: ITU. Alternative data from WITSA, *Digital Planet* is used.
3. **Televisions**: Television sets are the estimated number of television sets in use, per 1,000 people. Source: ITU.
4. **Mobile Phones:** Mobile phones refers to users of portable telephones subscribing to an automatic public mobile telephone service using cellular technology that provides access to the public switched telephone network, per 1,000 people. Source: ITU.
5. **Fax Machines:** Fax machines are the estimated number of facsimile machines connected to the public switched telephone network, per 1,000 people Source: ITU.

6. **ITP:** First principal component of the average values of **1-5** for 1992-1997. The variable is scaled to be between 0 and 100.
7. **ITP94, ITP96**: First principal component of the values of **1-5** for 1994 and 1996 respectively. The coefficient estimates were based on the pooled 1994 and 1996 annual data. The variable is scaled to be between 0 and 100.
8. **Per Capita GDP:** GDP per capita based on purchasing power parity (PPP). GDP PPP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar in the United States. GDP measures the total output of goods and services for final use occurring within the domestic territory of a given country, regardless of the allocation to domestic and foreign claims. Gross domestic product at purchaser values (market prices) is the sum of gross value added by all resident and nonresident producers in the economy plus any taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current international dollars. Source: World Development Indicators 1999, World Bank.
9. **Civil Liberties**: Indicator of Civil Liberties constructed by Freedom House. See Freedom House (various years), *Freedom in the World*, Washington, DC: Freedom House. The indicator rates countries on a scale of 1-7 from most free to least free. For representational clarity, these scales were inverted for purposes of our study, so that higher values represent freer countries. Civil liberties are defined as the freedoms to develop views, institutions, and personal autonomy apart from the state.

Freedom House researchers rate countries based on their assessment of the state of the following civil liberties: freedom and expression of belief, association and organizational rights, rule of law and human rights, and personal autonomy and human rights. Five year averages for the most recent time period are used, taken from Wacziarg, Romain (1999), "Human Capital and Democracy," *mimeo*, Stanford University.

10. **Domestic Investment:** Gross domestic investment consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including commercial and industrial buildings, offices, schools, hospitals, and private residential dwellings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales. Source: World Development Indicators 1999, World Bank.

11. **Foreign Direct Investment:** Gross foreign direct investment is the sum of the absolute values of inflows and outflows of foreign direct investment recorded in the balance of payments financial account. It includes equity capital, reinvestment of earnings, other long-term capital, and short-term capital. The indicator is calculated as a ratio to GDP converted to international dollars using purchasing power parities. Source: World Development Indicators 1999, World Bank.

12. **Public Education Spending:** Public expenditure on education (total) is the percentage of GNP accounted for by public spending on public education plus

subsidies to private education at the primary, secondary, and tertiary levels. Source: World Development Indicators 1999, World Bank.

13. **Public Health Expenditure:** Public health expenditure consists of recurrent and capital spending from government (central and local) budgets, external borrowings and grants (including donations from international agencies and non-governmental organizations), and social (or compulsory) health insurance funds. Source: World Development Indicators 1999, World Bank.

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[i] Therefore we can speak about *absolute convergence* – when the gap in absolute terms is growing – and *relative divergence* – when the gap is growing as a fraction of countries' present levels of technology. Within a context of growth in the use of ICTs, relative divergence implies absolute divergence, but the converse is not true.

[ii] This is the definition adopted by the OECD's ICCP panel of statistical experts. See http://www.oecd.org/dsti/sti/it/stats/.

[iii] There is one relevant dimension of inputs in which developing countries are not diverging from developed countries:investment in telecoms. Investment in telecoms as a percentage of total investment is generally higher for developing countries than for developed countries, and highest in very small economies such as Barbados and Fiji. Although this could be taken to be contradictory with the hypothesis of divergence, we view it as most likely reflecting the increasing returns to scale inherent to telecom investment. Very small economies must pay high fixed costs in order to set up and maintain even a minimal telecom infrastructure. Indeed, despite the fact that small economies tend to have high rates of investment in telecom, the correlation between telecom investment and growth in telephone mainlines is practically zero.

[iv] Indeed, the factor loadings for each of the indices were remarkably similar and in none of our experiments was a second factor close to significant.

[v] Our statistical technique, principal components analysis, may affect rates of growth of the indices because it requires that all variables be made to have the same variance. To check that our result is not an artifice of our construction of the index, we constructed an alternative index by simply dividing each subcomponent by the maximum level attained in its dimension and summing all the indicators together. Our results are basically identical and the correlation between our two indexes is extremely high.

[vi] See Barro, Robert and Xavier Sala-i-Martin, *Economic Growth* New York: McGraw Hill, 1995.

[vii] This finding is especially time-sensitive since Latin America has been the best performing region in the last three years or so.

[viii] See Daly, John "A Conceptual Framework for the Study of Impacts of the Internet" mimeo, University of Maryland

[ix] See in particular *Determinants of Economic Growth: A Cross-Country Empirical Study* MIT Press, 1997.

[x] "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela." *American Economic Review* June 1999.

[xi] See in particular Borenztein, de Gregorio and Lee, "How Does Foreign Direct Investment Affect Economic Growth?" National Bureau of Economic Research, Working Paper: 5057, March 1995

[xii] See in particular Christopher R. Kedzie, "The Third Waves", *in Borders in Cyberspace Information Policy and the Global Information Infrastructure.* Brian Kahin and Charles Nesson. Cambridge, Mass: MIT, 1997, pp. 106-128, and Skolnikoff, Eugene B. *The Elusive Transformation: Science, Technology and the Evolution of International Politics*. Princeton, NJ: Princeton University Press, 1993

[xiii] This connection between economic and political freedom was first pointed out in the classic work of Milton Friedman, *Capitalism and Freedom,* University of Chicago Press, 1962.

[xiv] See the insightful comments on the links between authoritarian governments and the diffusion of innovation in Diamond, Jared, *Guns, germs and Steel*: *The Fates of Human Societies*, New York:Norton, 1997.
[xv] Freedom House, *Freedom in the World*, various years.
[xvi] Kedzie, C. "The Third Waves" in Brian Kahin and Charles Nesson, *Borders in Cyberspace*, Cambridge: MIT Press, 1997.
[xvii] Nelson, Joan M. "Poverty, Inequality and Conflict in Developing Countries." Project on World Security, Rockefeller Brothers Fund, 1998.
[xviii] See in particular Cornia, G. A. with Sampsa Kiiski, "Trends in Income Distribution in the Post-World War II period: Evidence and Interpretation." Presented at the Wider Meeting *Rising Income Inequality and Poverty Reduction: Are they Compatible?* July 1999, Helsinki.
[xix] Freire, Francisco "Inequality and Information Technology: A Preliminary Assessment," *mimeo*, World Bank, February 1999.
[xx] Cornia, G. A., *Op Cit*.
[xxi] See in particular the paper by Donald Robbins, "HOS Hits Facts: Facts Winn. Evidence on Trade and Wages in the Developing World," Cambridge, HIID, 1996.
[xxii] Indeed the only reason that it can be claimed - as it has - that one sixth of recent US economic growth is due to computers is that investment in other capital goods has been so low. See the work by Dale Jorgenson and Kevin Stiroh, "Information Technology and Growth," American Economic Review, May 1999.

[xxiii] See Barro and Sala-I-Marin, 1995, *Economic Growth*, chapters 2 and 11. This is because changes in levels of variables that affect the productive capacity of an economy lead for it to have a greater sustainable level of output in the long run. In the medium run, output needs to adjust to that new higher permanent level, generating transitional economic growth
[xxiv] Strictly speaking, one would need there to be no diminishing returns to capital asymptotically. In this case the economy would adjust immediately to its long-run path of growth and the rate of growth would be related to the rate of technological change. However, such a formulation requires a pure endogenous growth model without diminishing returns to capital, a specification which several empirical papers have found to be implausible. See in particular Jones, Charles "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics* May 1995.
[xxv] Wong, Kelly, *Database on African Internet Users*, Data File, Center for International Dveleopment and Conflict Management, University of Maryland.
[xxvi] See World Bank, *World Development Report 1999*, Washington: The World Bank,1999 and R. Mansell and U. Wehn, *Knowledge Societies : Information Technology for Sustainable Development*, Oxford: Oxford University Press, 1998.