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The New Economy and Developing Countries

Assessing the Role of ICT Diffusion

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Abstract

Using data from developing countries, this paper explores the nature and direction of the links between ICT diffusion and per capita income, trade and financial indicators, education, and freedom indicators. Internet hosts, Internet users, personal computers and mobile phones represent indicators of ICT. The Gompertz model of technology diffusion is used to study ICT dissemination. The results show that income and government trade policies influence ICT diffusion. Depending on the ICT indicator, freedom indices may or may not affect ICT diffusion. Moreover, only personal computers and Internet hosts seem to have a positive influence on income. Contrary to expectations, ICT diffusion does not seem to enhance education.

Keywords: information technology, communication technology, Gompertz model, ICT diffusion, economic development, freedom indicators

JEL classification: F01, O1, O3

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Tables appear in Appendix II (page 13).

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1 Introduction

The global economy has been driven by a greater integration of world markets and a spectacular growth of information and communication technologies (ICTs). Country data, however, reveal a global digital divide. It is feared that the so-called New Economy will reinforce the gap between rich and poor nations, and increase income and spatial inequalities within countries. There is a growing body of literature focusing mainly on the effects of the New Economy on industrial countries. The empirical evidence (Oliner and Sichel 2000; Pohjola 2001; and Jalava and Pohjola 2002) indicates that ICT diffusion has a significant positive impact—albeit to varying degrees—on GDP growth. In addition, using neoclassical growth models, some studies have shown that IT investment has greatly contributed to economic growth in the United States (Sichel 1997) and in Finland (Niininen 2001).

Based on these findings it is plausible that the New Economy may offer a new channel for economic growth. Such channel may allow developing countries to catch the development train faster and perhaps ensure a more sustainable ride. Thus, it is important to explore what the structural changes associated with the New Economy imply for developing economies.

While there is a substantial literature on the possible determinants of globalization, much smaller work has been devoted to understanding the determinants of ICT diffusion, particularly in developing countries. In addition to focusing on developing nations, new research can add to the literature by addressing the following issues. First, the empirical literature on the impact of ICT diffusion assumes contemporaneous (simple) causality, while it is quite plausible that variables may be cointegrated or influenced through lagged effects. Second, the direction of causality has, in general, been assumed rather than formally ascertained. Third, some important variables have generally been omitted. In particular, policy variables and freedom indicators can be crucial to both accessibility and dissemination of ICT.

Many studies have emphasized that there is a leapfrogging element in the use of ICT (World Bank 1998; and Kenny 1995 and 2000). It is argued in these studies that the use of ICT leads to more effective economic reforms as it enhances public administration's efficiency and reduces bureaucracy. In turn, increased access to information and knowledge would result in higher people's participation and higher human development (Hadden 1996; and UNDP 1993 and 2001). This may seem rather intuitive; a reduction in information asymmetry that enhances efficiency and access to knowledge to all would prevent one party from monopolizing opportunities for profit (gain) and at the same time allow participation of previously excluded groups.

However, the role of ICT in enhancing income and human development through reduction of barriers to knowledge and information asymmetries is yet to be empirically tested using data from developing countries. Some studies caution against the assumption that such linkages would indeed occur in the case of developing countries. For example, Avgerou (1998) and Morales-Gomez and Melesse (1998) argue that the transfer of ICT to developing countries may not contribute to economic development the same way it did in industrial countries, and that it may be best to localize technology and focus on its use in education.

Thus, there are ambiguous conclusions concerning the link between ICT use and economic growth in developing countries. In addition, the issue of the direction of causality needs to be formally addressed. Did ICT-endowed countries reach high-income levels as a result of higher use of these technologies or was ICT diffusion caused by higher economic growth?

This paper examines the relationship between ICT diffusion and a set of macroeconomic and policy variables for a sample of 47 developing countries. More specifically, the paper explores the nature and direction of the links between ICT diffusion, and per capita income, trade and financial liberalization, literacy and education, and freedom indicators including economic freedom, civil liberties and political rights. The number of Internet hosts, Internet users, personal computers and mobile phones are used as alternate indicators of ICT. Following Kiiski and Pohjola (2002), estimates of the Gompertz model of technology diffusion are generated using data on these four indicators as well as the set of macroeconomic and policy variables mentioned above.

The remainder of the paper is organized as follows. Section 2 describes the data and outlines the methodology employed in this study. In section 3 the estimates of the determinants of ICT diffusion and the impact of ICT on selected economic and social development variables are discussed. Section 4 presents concluding comments.

2 Description of the data and methodology

Quah (2001) includes in the definition of the New Economy ICT, intellectual assets, electronic libraries and databases, and biotechnology (carbon-based libraries and databases). This paper focuses only on one aspect of the New Economy, namely ICT. Four ICT indicators are used: cellular mobile subscribers per 100 inhabitants, personal computers per 100 inhabitants, Internet hosts per 10,000 inhabitants, and Internet users per 10,000 inhabitants. The data on these variables are for the period 1998-2000 and are taken from the website of the International Telecommunication Union (ITU 2002). The first three variables may be viewed as indicators of the state of the ICT infrastructure, while the fourth indicator, Internet users, measures access to the Internet.

It is worth noting that the differences between communication technology and information technology have become blurry. For example, mobile phones are primarily tools of communication. But with the advent of wireless applications, consumers can access data and information via cellular phone. The Internet is mainly an indicator of information technology. Yet, many Internet users communicate with other users from their personal computers. Thus, all three information indicators (Internet hosts, Internet users and personal computers) have also become tools of communication.

Following Kiiski and Pohjola (2002), the Gompertz model of technology diffusion is used to study ICT dissemination. The model can be expressed in equation form as follows.

$$\ln T_{i00} - \ln T_{i98} = \delta\beta_0 + \delta\beta_1 \ln INCOME_i + \lambda'\mathbf{Z}_i - \delta \ln T_{i98} + \varepsilon \qquad (1)$$

where ε is a white noise.

As in Kiiski and Pohjola, equation (1) is based on the following assumptions. The spread between the value of the ICT indicator in 2000 and its value in 1998 is a function of the spread between a target value (or post-diffusion level) T^* and the value in 1998. This can be written as

$$\ln T_{i00} - \ln T_{i98} = \delta(\ln T_i^* - \ln T_{i98}) \quad (2)$$

where δ represents the speed of diffusion.

The post-diffusion level is a function of income and a vector $\mathbf{Z}_i$ which includes economic freedom, openness and the other variables described above. In contrast with the model in Kiiski and Pohjola's study, this paper does not include a price vector for at least two reasons. First, in general, prices are usually regulated by the government or by the fact that providers operate in imperfect markets, which would be reflected in the index of economic freedom. Second, reliable data on ICT prices are not available for all countries in the sample. Kiiski and Pohjola (2002) use telephone tariffs to proxy for ICT prices, but this may not be a good proxy for the access cost of the other three ICTs used in this study. For instance, according to data published by the World Bank (2002), in Germany it costs US$ 0.34 to make a three-minute call to the US, while in Finland it costs US$ 1.07 for the same call. The monthly Internet access fee through a service provider is US$ 28 and US$ 9, respectively. The Internet monthly access telephone charge is $23 in Germany and US$ 11 in Finland. Based on telephone tariffs, the access cost is higher in Finland, while the actual cost of Internet access shows that Finland has indeed lower fees. The telephone fee for Internet access is nil in some countries, for example the United States and the Russian Federation. Yet, ICT expenditure per capita in the US is 15 times that in Russia. Converting the figures to their purchasing power parity values will not eliminate these inconsistencies. The divergence clearly indicate that telephone access cost may not be an appropriate proxy for the cost of Internet access and, more importantly, will not adequately portray the link between ICT prices and demand for knowledge-based products.

The disparities are even sharper in the case of developing countries. Moreover, expenditure on ICT as a ratio of GDP or population could be a good indicator of ICT adoption, though it may not reflect diffusion. In this case, one would expect the ratio of ICT expenditure to GDP to be higher in countries that have low ICT access cost. Empirical data indicate that this is not necessarily the case when we use telephone tariffs as a proxy for the cost of Internet access. For example, in Japan ICT expenditure as a percentage of GDP is 9.6 per cent, whereas in Germany it is 7.9 per cent. ICT expenditure per capita is US$ 3,256 and US$ 1,880, respectively. This would not be consistent with the difference in telephone tariffs in Japan (US$ 1.67) and in Germany (US$ 0.34).

In the absence of an adequate ICT price, this paper assumes that per capita income, economic policy variables and freedom indicators are the main determinants of the equilibrium (target) level of ICT. The equation for the target level of ICT in log form can be expressed as

$$\ln T_i^* = \beta_0 + \beta_1 \ln INCOME_i + \lambda' \mathbf{Z}_i \quad (3)$$

Equation (1) represents the model to be estimated and is derived by substituting the RHS of equation (3) into (2). The assumption that per capita income is a major determinant of ICT diffusion is fairly standard and plausible on both theoretical and empirical grounds (see for example Hargittai 1999; Norris 2000; and Kiiski and Pohjola 2002). Historical data from developed nations indicate that adoption and diffusion of ICT are highly correlated with income. Countries with higher per capita income invest more in research and development, and hence are more able to discover and use advanced information technologies. Prior to the spread of the Internet, fixed telephones (Hardy 1980) and telephone infrastructure (Norton 1992) were used to model communication effects on economic growth. The issues of the direction of causality and endogeneity were, in general, ignored. Since mid-1990s, however, other indicators of ICT began to be emphasized and more robust econometric tests are being employed. In general, the association between ICT and income is expected to be strong. This seems to be the case given the significant correlations of 0.83 between the number of mobile phones and per capita income, and personal computers and per capita income; and 0.68 between Internet hosts and income (Table 1). The correlation between income and Internet users is lower (0.35) but statistically significant.

The first variable in vector Z is education. Low levels of education and literacy are expected to hinder both accessibility and dissemination of ICT. Since the use of knowledge-based products requires a basic level of literacy, we would expect to see higher education causing higher ICT use. Diffusion of ICT may require higher or tertiary education, and scientific research. Kiiski and Pohjola (2002) showed that, in a sample including developing and OECD countries, tertiary education had a positive and statistically significant influence on ICT diffusion. In contrast, Hargittai (1999), and Kiiski and Pohjola (2002) have found that in the case of industrial countries, education did not seem to influence ICT diffusion. Also, in a sample that included both developed and developing countries, Norris (2000) shows that education did not have a significant influence on ICT diffusion. Consistent data on tertiary education are not available for all countries in the sample. This study uses adult literacy in 1995[1] and the education index in 1999. This index is used by UNDP in generating the human development index (HDI). The correlation coefficients in Table 1 are positive but not very significant. However, this may be due to the existence of nonlinear relationships or poor quality of data on literacy and education.

This paper also uses three freedom indicators. The first indicator is the index of economic freedom published by the Heritage Foundation. This index is an average score of 10 indexes measured on a one-to-five scale, with 5 indicating the lowest level of economic freedom. The 10 indexes assess trade policy, monetary policy, capital flows and foreign investment, wage and price control, banking and finance regulations, intellectual property and black markets, property rights, regulation, transparency and bureaucracy, government intervention in the economy, and the fiscal burden of the government (taxes and government expenditure). At least in cross-sectional analyses, greater (lower index) economic freedom is expected to be associated with higher GDP, higher levels of education or literacy rates, and stronger ICT indicators.

1 This is in order to capture the effect of the existence of a literate population prior to the adoption of ICT which in most developing countries started in 1996-97. However, in estimating the effect of ICT on other variables, adult literacy in 1998 is used.

The other freedom indicators are the index of political rights and the index of civil liberties. By including these indexes, the paper follows the work of Norris (2000) and tries to explore whether countries with higher levels of civil and political freedom would also have greater ICT diffusion. These two indexes are published by Freedom House and are measured on a one-to-seven scale, with 7 indicating the lowest degree of freedom. The correlation between these indexes and income is expected to be negative. This is confirmed by the correlation coefficients in Table 1. It is worth noting that, as expected, the correlation between civil liberties and political rights, and Internet use is statistically significant (although not very strong), while economic freedom is highly correlated (and statistically significant) with the other three ICT indicators. As anticipated, the signs on the coefficients are negative, implying that a fall in the index (an improvement) is associated with an increase in income, ICT indicators, education indicators, and the policy variables. The association among the three freedom indicators is, as anticipated, positive and statistically significant.

The vector Z also includes policy variables or outcomes such as financial liberalization and international trade variables. Financial deepening, commonly defined as the ratio of broad money (M2) to GDP, is used as a proxy for financial liberalization. The banking sector in many developing countries is among the first to adopt advanced information technologies. With increased financial deepening, banks strive to make information available to their customers and often use this service to generate additional source of income (service fees). At the same time, customers tend to value improved accessibility. With the advent of ICT customers are able to access information about their accounts, interest rates, and other bank services at any time, day or night, and from anywhere in the country (or the world). This implies that the use of mobile phones, and the number of Internet hosts and users would be expected to increase as financial deepening proceeds. The correlation coefficients in Table 1 show that there is a positive and significant correlation between financial liberalization and mobile phones, personal computers, and—to a lesser extent—Internet hosts. There seems to be no correlation between financial deepening and Internet users.

Openness to international trade is one of two trade policy indicators used in this study. It is measured as the ratio of the sum of exports and imports to GDP in world prices. The role of trade policy is important. For example, Jussawalla (1999) claims that East Asian nations fostered ICT production through openness and export-oriented investments. Both exports and imports may offer a channel for increased adoption and diffusion of ICT. Some imported goods and services require the existence of specific ICTs to be operational. In some cases, ICT may be embodied in the imported product. Similarly, to enhance their exports, firms find it increasingly necessary to make use of ICT. Mobile phones, Internet use, computerized operations are all tools used to improve the efficiency of conducting business in the global market. These tools tend to reduce the level of imperfect information and incomplete markets. As argued by Stiglitz (1989), imperfect information results in less trade. Thus, we would expect a positive and significant correlation between ICT and openness. The correlation coefficients in Table 1 indicate that, indeed, this is the case for mobile phones, Internet hosts and personal computers, but not for Internet users. This result is plausible, as in most developing countries e-commerce is still at its infancy.

The second international trade variable is foreign direct investment (FDI). Inward FDI usually allows recipient economies access to advanced technologies, managerial skills and higher level of know-how. Transnational corporations tend to standardize their

operations around the world and train workers in host countries according to their skill standards, including the use of ICT. Moreover, FDI may replace ICT as a medium for information and knowledge diffusion in cases where information and knowledge associated with ICTs have a proprietary feature. As emphasized by Bedi (1999), '...in such cases, the role of ICTs in enabling access is limited, and other measures such as trade and foreign direct investment may be appropriate conduits for disseminating information and knowledge'. Thus, it is reasonable to expect higher inward FDI to contribute to ICT diffusion. This, however, does not seem to be supported by the correlation coefficients shown in Table 1. The association, while positive, is statistically insignificant.

It is important to emphasize that ICT can, in turn, influence all other variables. Enhanced communication, and greater access to information and knowledge reduce information asymmetry and transaction costs, and increase the awareness of more effective institutional organizations (Krueger 1988). ICT also fosters the development of NGOs, and information and knowledge-based communities that are more capable (relative to individual citizens) to cause institutional changes. We would expect freedom indicators to improve as the stock of ICT increases in both breadth and depth. ICT diffusion may also affect the degree of competition or market structure of other industries. For example, because consumers can have access to product prices on the Internet and order products electronically, what might be a monopoly in a city or state becomes perfectly competitive on the World Wide Web. The evidence about changes in markets and communities in developing countries is ambiguous. While there are examples of significant benefits from the use of ICT on credit and trade markets in some countries (World Bank 1998: 61; and Bayes *et al*. 1999), there are studies that highlight the limited extent of the impact of these technologies (DuBoff 1980 and Avgerou 1998).

Other variables have been emphasized in the literature as potential determinants of ICT diffusion. These variables include English (Kiiski and Pohjola 2002), income distribution (Bedi 1999; Hargittai 1999 and Pohjola 2001), and competition in the telecommunication industry (Hargittai 1999; Jayakar 1999; and Kiiski and Pohjola 2002). The empirical evidence on the impact of these variables, particularly in developing countries, is ambiguous or more in support of their insignificance. For example, Hargittai (1999) has found that the presence of a monopoly in the telecommunication industry influences negatively the Internet connectivity in the industrial countries; Pohjola and Kiiski (2002) did not find evidence of such influence. It should be stressed that most developing countries maintain monopolies (or duopolies) in the telecommunication sector. Also, some studies (Norris 2000; and Kiiski and Pohjola 2002) show that English does not influence ICT diffusion.

Income distribution may not be a significant factor since the use of the Internet and other ICTs tends to be concentrated in urban areas (clusters) and spillover effects accruing to groups located in the same cluster (due to work, school or family ties) may offset some of the inequalities in income distribution. Perhaps spatial inequality would be a better predictor. It would be more interesting to explore whether spatial inequalities (for example rural versus urban, or coastal versus inland areas) hinder ICT diffusion. Unfortunately, data on spatial inequality for the group of countries used in this study are not available.

Finally, it is worth noting that the coefficients of correlation between mobile phones, and personal computers and Internet hosts are strong and highly significant, and have increased in 2000 relative to 1998 (Table 2). This may reflect increased integration of these three indicators. On the other hand, the correlation of the variable 'Internet users' with the other three indicators has decreased or became insignificant over time. The absence of correlation suggests that the use of the Internet may not be directly linked to business transactions or income.

3 Empirical results

3.1 Determinants of ICT

The results from the model exploring the factors that influence ICT diffusion are reported in Tables 3a-d. To test the robustness of the model, four equations were estimated. Table3.a displays the statistical results from estimating the model with mobile phones as the relevant ICT variable. Tables 3.c-d report the results associated with Internet hosts, Internet users and personal computers, respectively. Equations (1)-(4) in each table differ in terms of the determinants (RHS variables) used. The same variables are used in the same equation for each ICT indicator. Equation (4) includes, instead of income and economic freedom, the ratio of income to economic freedom in order to capture the interaction between these two variables. In addition, this equation includes a dummy variable to account for the poor state (stock) of ICT in the country. South Korea and Singapore have higher ICT levels and are assigned zero while the other countries in the sample are assigned one. Equation (4) also adds the level of personal computers in 1998 as a potential explanatory variable for the first three ICT indicators. When the ICT indicator is mobile phones or Internet hosts, the estimates yield an insignificant model. Therefore, the coefficients are not reported.

The speed of diffusion δ is assumed to be constant. As suggested in Kiiski and Pohjola (2002), the speed of adjustment changes with time and it might be more appropriate to make δ time dependent. However, since the period 1998-2000 is rather short, the overall effect may not be significant. On the other hand, one might argue that in the late 1990s, the diffusion has increased at an increasing rate, implying that even within a three-year period, the speed of diffusion might have changed significantly, relative to the mid-1990s.

Table 3.a displays the estimates using mobile phones as the ICT indicator. The empirical results indicate that the model fails to capture the process of diffusion since the coefficient on the lagged value of this variable is not significant. However, the results suggest that political rights, civil liberties, and—to a lesser extent—openness are important determinant of the behaviour of mobile phones. Perhaps dissemination could not be properly modelled because many people in developing countries substitute mobile phones for fixed lines, as the combination of cost and mobility of the former makes them more attractive. Thus, the target level of mobile phones (Y^*) changes continuously and more likely faster than income. A more appropriate indicator, in such case, would be the sum of mobile and fixed telephones. The substitution from fixed to mobile phones could also explain the negative coefficient on the variable 'adult literacy'. The use of mobile phones does not require the user to be literate. For example, illiterate merchants in Africa, the Middle East and South Asia use cell phones to

conduct business. Yet, the finding of a negative effect from literacy to the diffusion of mobile phones suggests that there is a link. If the number of users who switch from fixed to mobile phones is large in countries with low literacy rates (in North Africa, it tends to be growing significantly) then there would be a negative link between literacy and mobile phones.

In the case of Internet hosts, the speed of adjustment is significant in all three equations, but the adjusted R-squared is low. Similar to mobile phones, Internet hosts appear to be influenced by civil and political freedom. In addition, the results indicate that income is an important factor, but fail to provide support for the influence of education or literacy on Internet host diffusion.

The estimates reported in Table 3.c indicate that equation (4) provides the best results. The adjusted R-squared is 0.79 and most RHS variables are significant at the 5-per cent level or lower. The coefficients on income and economic freedom (the interactive term), openness, adult literacy and, as expected, the coefficient on personal computers in 1998 are all strong and significant, and have the correct signs.

Table 3.d displays the results from estimating the model where ICT is represented by the number of personal computers per 100 people. All four equations capture the diffusion process as δ is highly significant. Income, openness, and political rights are all important determinants of personal computer diffusion. However, the variable 'Internet host' has the wrong sign and is only significant at the 1-per cent level. More Internet hosts in the country do not cause people to buy more personal computers. This implies that, at least for this indicator, diffusion is not a supply side phenomenon. In addition, education and literacy appear to have no impact on the dissemination of personal computers.

This is rather surprising, as we would expect education to have an impact on the number of personal computers in a country. Lee (2001) shows that secondary education is an important determinant of ICT diffusion. However, Lee uses a measure of technology gap between industrial and developing countries to proxy for ICT diffusion. Also, using data on imports of computer equipment, Caselli and Coleman (2001), find that secondary education influences technology adoption. Nonetheless, in both studies the focus was on adoption not diffusion of technology. Undoubtedly, education must have a role in the diffusion of computers but there are at least three possible reasons that may support the lack of empirical evidence to back up theory. First, there may be serious measurement errors in data on education and schooling for a number of developing countries included in the present sample. Second, the education index and education literacy rates are positively correlated with GDP, suggesting that there may be collinearity in the equations. Third, university students and faculty are usually major users of computers in developing countries. Perhaps the correlation between adult literacy and the education index, and tertiary education is weak.

Equally surprising is the finding that there is no support for the influence of FDI on ICT diffusion. As mentioned earlier, FDI is an important channel through which technology enters a country and gets disseminated. Perhaps, there is a threshold that most developing countries in the sample have not yet reached or that FDI in the countries under study (with the exception of South Korea and Singapore) targets labour-intensive sectors that require negligible levels of ICT. Similarly, financial liberalization does not seem to influence ICT diffusion. However, there may be an issue of multicollinearity as

financial liberalization is highly correlated with other RHS variables. In fact, since both financial liberalization and FDI are accounted for in the index of economic freedom, the findings do not necessarily imply that these variables have no impact on ICT diffusion.

In summary, the empirical results provide support for the role of income as a major determinant of ICT diffusion. This is consistent with the conclusions in Niininen (2001), Hargittai (1999), Quah (2001), Norris (2000), and Kiiski and Pohjola (2002). Similarly, openness of the economy, civil liberties, and political rights influence ICT diffusion. This confirms that restrictions to trade and censorship constitute high barriers to the adoption of ICT and its dissemination. It is important to emphasize that these are demand side effect as they pertain to the use, not production, of ICT. Moreover, the estimation yields values for the speed of adjustment (δ) that are consistent with the increased adoption of ICT. In a cross-sectional model including 75 developed and developing countries, Kiiski and Pohjola report values for the speed of diffusion that range from 0.186 to 0.527.[2] The present paper finds that the speed of diffusion can vary from 0.269 to 0.375 for Internet hosts, from 0.509 to 0.656 for Internet users, and from 0.529 to 0.579 for personal computers. However, given that the RHS variables are not the same, it is difficult to make a more meaningful comparison of the results derived in the two studies.

3.2 Impact of ICT diffusion on selected economic and social development indicators

Since high levels of ICT indicate that a certain level of diffusion has already taken place, the *stock* of ICT is used as a proxy for ICT diffusion. The influence of ICT diffusion on economic and social development indicators (*ESDI*) is examined using the following equation

$$ESDI_i = \alpha_0 + \alpha_1 \ln Y_i + \gamma' \Pi i + \varepsilon \qquad (4)$$

Where Y is an ICT indicator in 1999, the vector Π contains economic and social indicators, and ε is a white noise.

Table 4 reports estimates of the impact of ICT on income (log transformation of per capita income). While income figures are from 2000, ICT indicators are from 1999. The model uses a modified version of Granger causality in the sense that this does not explore contemporaneous causality but assumes that the effect originates from the explanatory variable occurring in the preceding period. Similarly, the variables in vector Π are from 1999. The use of explanatory variables from the previous year is justified by the fact that it takes time to make improved learning (education) and new technology contribute to income. While one might argue that a one-year lag is relatively short, the lack of reliable data for a more extended period of time limits the lag length. In addition, the model uses a dummy variable for low-income countries.

The statistical results displayed in Table 4 indicate that increases in the use of mobile phones, Internet hosts, and personal computers, lead to higher per capita income. The only ICT indicator that does not seem to influence income is the number of Internet

[2] See Kiiski and Pohjola (2002).

users per 10,000 people. As mentioned earlier, this is plausible as e-commerce is still at its early stages in most developing countries. In the Middle East, Africa and Southeast Asia, there are two phenomena in sales and marketing that are not expected to disappear any time soon. First, many sellers of produce (for example the floating market in Bangkok), clothing and small home appliances are mobile and even make house calls. Thus, 'when you cannot go to the market, the market comes to you'. Second, while in most developed economies products are processed and packaged, and consumers rarely get to inspect the quality thoroughly before buying, in most developing countries, not only do consumers get to inspect the product closely but they are also invited to taste the product (at least in the case of fruits and other edible products like candy) before buying. For example, one of the most delightful experiences in Morocco is to visit the *Souk* (weekly market) or the daily markets in imperial cities. This is in sharp contrast with the behaviour of consumers who use the Internet and e-commerce to save time and get access to information from different sources in the most efficient way. In many areas of the developing world, including those with high literacy rates, touching the product is a crucial step in the demand process. In addition to these two phenomena, sellers in developing countries usually do not accept returned merchandise. This makes e-buying unattractive.

At least in theory, ICT diffusion is expected to have a positive influence on education, as ICT users have access to means that would enhance learning and skills. However, the empirical literature presents ambiguous findings. In the case of developing countries, Schware and Jaramillo (1998) find that using computers in education did not enhance learning in Turkey. In countries where literacy and education levels are low, using computers in schools may not improve learning, and hence will not help keep students in school. Thus, the effect of ICT on education may be insignificant. On the other hand, having more personal computers may not necessarily mean they are used in schools. In many developing countries, the government is the largest buyer of computers mainly for use by civil servants (or for high-ranking government officials). The results reported in Table 5 seem to support this view. There is no empirical evidence in support of the influence of ICT diffusion on education (contemporaneous causality) except in the case of mobile phones. It is worth noting that income seems to be the main determinant of education.

Because ICT diffusion improves access to information and enhances idea-sharing, it is expected to foster civil and political freedom. This seems to be supported by the results reported in Tables 6 and 7. The difference between the (a) and (b) versions of these tables is the use of lagged values of ICT indicators in (a). While one would expect ICT diffusion to have a lagged effect on freedom indicators, the empirical results indicate that a contemporaneous causality is more likely. Perhaps this reflects the speed of changes resulting from higher exposure to globalization and enhanced integration of ICTs. The results displayed in Tables 6 and 7 suggest that ICT diffusion (except in the case of personal computers) has a strong impact on civil liberties and political rights.

4 Concluding comments

This paper examined the relationship between a major feature of the New Economy, namely ICT diffusion, and a set of macroeconomic and policy variables, for a group of developing countries. There are six important findings. First, income is a major

determinant of ICT diffusion. Income influences both ICT infrastructure (as it is shown to cause higher use of personal computers and Internet hosts) and –although the evidence is not very strong– access to ICT (since it has an effect on Internet use). Second, there is a positive impact of government trade policies on ICT. Openness fosters the adopting and adapting of technology. Third, at least in the case of two ICT indicators (mobile phones and Internet hosts) political rights and civil liberties have a strong influence. Fourth, at least in the case of one ICT indicator, there is some evidence supporting that education (literacy) has a positive impact on ICT diffusion. Fifth, the empirical results indicate that ICT dissemination fosters economic development, and enhances political rights and civil liberties. Finally, contrary to expectations, ICT diffusion does not seem to enhance education. These findings are, in general, consistent with the results in other studies (for example, Norris 2000; and Kiiski and Pohjola 2002). Moreover, the conclusions highlight the role of demand in the market for knowledge-based products, and are consistent with the propositions in Quah (2001).

It is important to note that for mobile phones and Internet hosts, civil liberties and political rights are important factors, while GDP does not seem to have an effect on these ICT indicators. In addition, the speed of diffusion in the case of Internet users is shown to be much higher than in the case of Internet hosts (an average of 0.6 versus 0.35). This finding may reflect the recent trend in large cities where *cyber cafés* are mushrooming. However, since the results indicate that ICT diffusion—as measured by dissemination of Internet use—does not cause higher income, it is feared that a faster diffusion of Internet users (relative to income and to Internet hosts) may lead to saturation and poor access to information.

The present findings seem to provide elements for hope and concern at the same time. On the one hand, there is evidence that ICT enhances income, and hence, it can provide an additional source of economic growth. Due to its pervasive nature, ICT diffusion may allow a *leapfrogging* process to occur. On the other hand, the finding that trade policies and social development variables are important determinants of ICT diffusion, as well as economic development, implies that countries with poor performance in these variables may sink even further in the *information-poor* and *non-communicating* side of the digital divide.

Appendix I: List of countries

Algeria
Botswana
Egypt, Arab Rep.
Gabon
Madagascar
Mauritius
Morocco
Niger
Nigeria
Senegal
South Africa
Tanzania
Tunisia

Argentina
Bolivia
Brazil
Chile
Colombia
Costa Rica
Dominican Republic
Ecuador
El Salvador
Honduras
Jamaica
Mexico
Panama
Peru
Uruguay
Venezuela, RB

Bangladesh
China
India
Indonesia
Iran, Islamic Rep.
Korea, Rep.
Kuwait
Malaysia
Myanmar
Nepal
Pakistan
Philippines
Saudi Arabia
Singapore
Sri Lanka
Thailand
Vietnam
Turkey

Table 1
Correlation between ICT indicators and selected indicators of economic and social development [(a)]

	ECF	CL	PR	FL	FDI	OPEN	INCOME	LITERACY	EDU
ECF	1.00								
CL	0.52 (0.000)	1.00							
PR	0.37 (0.009)	0.89 (0.000)	1.00						
FL	-0.38 (0.009)	0.14 (0.356)	0.11 (0.468)	1.00					
FDI	0.04 (0.768)	0.18 (0.222)	0.12 (0.42)	0.36 (0.013)	1.00				
OPEN	-0.53 (0.000)	-0.09 (0.528)	-0.17 (0.258)	0.49 (0.000)	-0.14 (0.349)	1.00			
INCOME	-0.61 (0.000)	-0.25 (0.078)	-0.16 (0.283)	0.47 (0.000	0.13 (0.405)	0.46 (0.001)	1.00		
LITERACY	-0.41 (0.004)	-0.38 (0.009)	-0.38 (0.009)	0.09 (0.552)	0.04 (0.783)	0.26 (0.07)	0.48 (0.000)	1.00	
EDU	-0.43 (0.002)	-0.30 (0.040)	-0.32 (0.027)	0.23 (0.122)	0.22 (0.134)	0.26 (0.079)	0.52 (0.000)	0.93 (0.000)	1.00
CELL	-0.64 (0.000)	-0.29 (0.044)	-0.23 (0.123)	0.43 (0.002)	0.13 (0.374)	0.54 (0.000)	0.83 (0.000)	0.41 (0.004)	0.45 (0.001)
IH	-0.53 (0.000)	-0.13 (0.398)	-0.11 (0.481)	0.38 (0.008)	0.11 (0.448)	0.54 (0.000)	0.68 (0.000)	0.29 (0.045)	0.31 (0.034)
IU	-0.23 (0.110)	-0.36 (0.014)	-0.26 (0.073)	0.11 (0.471)	0.08 (0.588)	0.035 (0.981)	0.35 (0.014)	0.37 (0.011)	0.37 (0.009)
PC	-0.55 (0.000)	-0.164 (0.270)	-0.11 (0.463)	0.47 (0.001)	0.06 (0.668)	0.60 (0.000)	0.83 (0.000)	0.36 (0.014)	0.37 (0.010)

p-values are in parentheses.

Note: [(a)] ECF=Index of economic freedom; CL=Index of civil liberties; PR=Index of political rights; F =Financial liberalization indicator; FDI=Foreign direct investment in US dollars; OPEN=Openness to international trade; INCOME=GNI per capita (PPP international dollars); LITERACY=Adult literacy in 1998; EDU=Index of education (UNDP) in 1999; CELL=Mobile phone subscribers per 100 inhabitants; IH=Internet hosts per 10,000 inhabitants; IU=Internet users per 10,000 inhabitants, and PC = personal computers per 100 inhabitants.

Table 2
Correlation among ICT indicators [(a)]

	CELL1998	CELL2000	IH1998	IH2000	USER1998	USER2000	PC1998	PC2000
CELL1998	1.00							
CELL2000	0.89 (0.000)	1.00						
IH1998	0.73 (0.000)	0.82 (0.000)	1.00					
IH2000	0.65 (0.000)	0.76 (0.000)	0.96 (0.000)	1.00				
USER1998	0.46 (0.001)	0.45 (0.001)	0.27 (0.062)	0.23 (0.119)	1.00			
USER2000	0.11 (0.437)	0.12 (0.421)	-0.01 (0.939)	-0.044 (0.770)	0.27 (0.064)	1.00		
PC1998	0.81 (0.000)	0.88 (0.000)	0.94 (0.000)	0.90 (0.000)	0.37 (0.009)	0.10 (0.498)	1.00	
PC2000	0.81 (0.000)	0.88 (0.000)	0.93 (0.000)	0.88 (0.000)	0.39 (0.006)	0.10 (0.496)	0.993 (0.000	1.00

p-values are in parentheses.

Note: [(a)] CELL=Mobile phone subscribers per 100 inhabitants; IH=Internet hosts per 10,000 inhabitants; IU=Internet users per 10,000 inhabitants, and PC=personal computers per 100 inhabitants.

Table 3.a
Determinants of mobile telephone (Y) diffusion
Dependent variable: ln Y_{2000} – ln Y_{1998}

	(1)	(2)	(3)	(4)
No. of observations	47	47	47	47
Adjusted R^2	0.182	0.165	0.210	0.079
F-test	2.43**	2.27**	2.39**	1.54
Constant	0.707	0.402	2.131	
	(1.891)	(1.918)	(2.121)	
lnY_{1998}	-0.127	-0.149	-0.047	
	(0.105)	(0.108)	(0.234)	
Income	0.053	0.106	0.147	
	(0.215)	(0.218)	(0.234)	
Economic freedom	0.101	-0.002	-0.208	
	(0.238)	(0.228)	(0.217)	
Openness	0.413*	0.388*		
	(0.234)	(0.235)		
Adult literacy [(a)]	-0.051	-0.045**	-0.033	
	(0.021)**	(0.021)	(0.022)	
Education	5.333*	4.547*	2.737	
	(2.644)	(2.6530)	(2.910)	
Political rights	-0.177**			
	(0.075)			
Civil liberties		-0.115	-0.047	
		(0.053)**	(0.629)	
FDI			-0.114*	
			(0.059)	
Financial liberalization			-0.539	
			(0.470)	
Dummy for ICT stock				
Income/economic freedom				
PC_{1998}				

* indicates significance at 0.1; ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.
Note: [(a)] Refers to literacy in 1995, used as an indicator of the initial level of education or literacy.

Table 3.b
Determinants of Internet host (Y) diffusion
Dependent variable: $\ln Y_{2000} - \ln Y_{1998}$

	(1)	(2)	(3)	(4)
No. of observations	47	47	47	47
Adjusted R^2	0.128	0.168	0.226	0.080
F-test	1.95*	2.30**	2.53**	0.515
Constant	0.156 (3.045)	-0.118 (0.968)	-1.992 (2.924)	
$\ln Y_{1998}$	-0.269** (0.127)	-0.292** (0.125)	(-0.375)*** (0.125)	
Income	0.472 (0.345)	0.551 (0.341)	0.740** (0.347)	
Economic freedom	-0.323 (0.453)	-0.445 (0.429)	-0.158 (0.376)	
Openness	0.437 (0.436)	0.417 (0.426)		
Adult literacy	-0.003 (0.035)	0.007 (0.035)	-0.011 (0.035)	
Education	-1.600 (4.485)	-3.134 (4.433)	-0.844 (4.668)	
Political rights	-0.309** (0.141)			
Civil liberties		-0.252** (0.096)	-0.303*** (0.107)	
FDI			0.116 (0.096)	
Financial liberalization			0.054 (0.732)	
Dummy for ICT stock				
Income/economic freedom				
PC_{1998}				

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 3.c
Determinants of Internet users (*Y*) diffusion
Dependent variable: ln Y_{2000} – ln Y_{1998}

	(1)	(2)	(3)	(4)
No. of observations	47	47	47	47
Adjusted R^2	0.280	0.282	0.216	0.795
F-test	3.44***	3.48***	2.41**	25.42***
Constant	-0.555	-0.543	-0.311	-2.069
	(3.867)	(3.859)	(4.196)	(1.493)
ln Y_{1998}	-0.509**	-0.514***	-0.511**	-0.656***
	(0.189)	(0.183)	(0.207)	(0.099)
Income	-0.021	-0.039	0.007	
	(0.189)	(0.436)	(0.493)	
Economic freedom	0.622	0.689	0.666	
	(0.619)	(0.597)	(0.589)	
Openness	0.054	0.065		0.884***
	(0.586)	(0.585)		(0.315)
Adult literacy	0.027	0.024	0.0315	0.020**
	(0.045)	(0.044)	(0.051)	(0.009)
Education	-1.519	-0.875	-2.759	
	(5.774)	(5.727)	(6.773)	
Political rights	0.162			-0.165
	(0.212)			(0.113)
Civil liberties		0.119	0.135	
		(0.140)	(0.172)	
FDI			0.051	
			(0.147)	
Financial liberalization			-0.126	
			(1.091)	
Dummy for ICT stock				2.223***
				(0.579)
Income/economic freedom				0.389*
				(0.210)
PC_{1998}				1.235***
				(0.164)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 3.d
Determinants of personal computer (Y) diffusion
Dependent variable: ln Y_{2000} – ln Y_{1998}

	(1)	(2)	(3)	(4)
No. of observations	47	47	47	47
Adjusted R^2	0.610	0.581	0.531	0.611
F-test	10.85***	9.90***	6.95***	10.89***
Constant	-5.692*** (1.502)	-5.709*** (1.548)	-4.879*** (1.719)	-4.457*** (1.195)
ln Y_{1998}	-0.529*** (0.076)	-0.537*** (0.079)	-0.579*** (0.088)	-0.561*** (0.089)
Income	0.589*** (0.175)	0.593*** (0.181)	0.637*** (0.212)	
Economic freedom	0.006 (0.212)	0.102 (0.209)	-0.112 (0.224)	
Openness	0.679*** (0.207)	0.720*** (0.047)		0.608*** (0.201)
Adult literacy	0.003 (0.016)	0.000 (0.017)	0.019 (0.197)	0.007 (0.006)
Education	0.081 (2.130)	0.439 (2.190)	-1.817 (2.679)	
Political rights	0.114 (0.067)			0.152** (0.067)
Civil liberties		0.034 (0.047)	0.074 (0.061)	
FDI			-0.032 (0.058)	
Financial liberalization			0.704 (0.434)	
Dummy for ICT stock				-0.022 (0.428)
Income/economic freedom				0.508*** (0.171)
$Host_{1998}$				-0.028 (0.097)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01. Standard errors are in parentheses.

Table 4
ICT and income
Dependent variable = ln (per capita income)

	(1) *Y*=Mobile phones, 1999	(2) *Y*=Internet hosts, 1999	(3) *Y*=Internet users, 1999	(4) *Y* = Personal computers, 1999
No. of observations	43	43	43	43
Adjusted R^2	0.759	0.785	0.706	0.756***
F-test	34.95***	40.23***	26.77***	34.25
Constant	8.197***	7.673***	8.013***	8.388***
	(0.617)	(0.590)	(0.695)	(0.632)
ln *Y*	0.192***	0.136***	0.012	0.165***
	(0.064)	(0.035)	(0.053)	(0.058)
Economic freedom	-0.137	-0.070	-0.331**	-0.295**
	(0.144)	(0.139)	(0.144)	(0.129)
Education	0.703	1.239***	1.896***	1.146**
	(0.620)	(0.471)	(0.556)	(0.540)
Dummy for low-income countries	-1.048***	-1.098***	-1.313***	-1.162***
	(0.243)	(0.220)	(0.251	(0.233)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 5
ICT and education
Dependent variable = Education (1999)

	(1) *Y*=Mobile phones, 1999	(2) *Y*=Internet hosts, 1999	(3) *Y*=Internet users, 1999	(4) *Y* = Personal computers, 1999
No. of observations	47	47	47	47
Adjusted R^2	0.527	0.419	0.422	0.439
F-test	13.80***	9.29***	9.39***	10.00***
Constant	0.475	-0.088	-0.206	0.043
	(0.298)	(0.284)	(0.223)	(0.288)
ln *Y*	0.056***	0.011	0.012	0.028
	(0.017)	(0.013)	(0.013)	(0.018)
Income	0.025	0.101***	0.109**	0.087**
	(0.037)	(0.015)	(0.028)	(0.034)
Political rights	0.006	-0.005	-0.006	-0.010
	(0.013)	(0.015)	(0.014)	(0.013)
Openness	-0.019	-0.038	0.001	0.013
	(0.038)	(0.042)	(0.042)	(0.042)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 6.a
ICT (1998 indicators) and civil liberties
Dependent variable = Index of civil liberties (1999)

	(1) *Y*=Mobile phones, 1998	(2) *Y*=Internet hosts, 1998	(3) *Y*=Internet users, 1998	(4) *Y* = Personal computers, 1998
No. of observations	47	47	47	47
Adjusted R^2	0.151	0.170	0.258	0.090
F-test	2.99**	3.304**	4.84***	2.12*
Constant	1.551	1.526	1.471	4.858
	(4.906)	(3.758)	(2.908)	(4.280)
ln *Y*	-0.461*	-0.334*	-0.449**	-0.108
	(0.272)	(0.178)	(0.183)	(0.246)
Income	0.507	0.515	0.752*	0.224
	(0.578)	(0.465)	(0.421)	(0.549)
Adult literacy	-0.027	-0.028	-0.033*	-0.042**
	(0.019)	(0.019)	(0.018)	(0.018)
Openness	0.268	0.076	-0.134	0.297
	(0.620)	(0.601)	(0.564)	(0.626)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 6.b
ICT (1999 indicators) and civil liberties
Dependent variable = Index of civil liberties (1999)

	(1) *Y*=Mobile phones, 1999	(2) *Y*=Internet hosts, 1999	(3) *Y*=Internet users, 1999	(4) *Y* = Personal computers, 1999
No. of observations	47	47	47	47
Adjusted R^2	0.220	0.312	0.157	0.069
F-test	4.44***	6.22***	3.14**	1.85
Constant	-3.801	-3.086	5.386*	6.120
	(4.742)	(3.706)	(2.903)	(4.163)
Ln *Y*	-0.778***	-0.599***	-0.384**	-0.155
	(0.267)	(0.153)	(0.177)	(0.294)
Income	1.041*	0.991**	0.234*	0.013
	(0.564)	(0.467)	(0.439)	(0.536)
Adult literacy	-0.011	-0.018	-0.027*	-0.033*
	(0.018)	(0.016)	(0.017)	(0.018)
Openness	0.339	0.268	0.019	0.155
	(0.589)	(0.549)	(0.607)	(0.649)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 7.a
ICT (1998 indicators) and political rights
Dependent variable = Index of political rights (1999)

	(1) *Y*=Mobile phones, 1998	(2) *Y*=Internet hosts, 1998	(3) *Y*=Internet users, 1998	(4) *Y* = Personal computers, 1998
No. of observations	47	47	47	47
Adjusted R^2	0.147	0.215	0.308	0.112
F-test	2.95**	4.08***	5.901***	2.42*
Constant	4.071	2.954	3.069	4.778
	(3.694)	(2.710)	(2.052)	(3.136)
ln *Y*	-0.306	-0.288**	-0.389***	-0.182
	(0.204)	(0.128)	(0.129)	(0.180)
Income	0.152	0.278	0.455	0.139
	(0.435)	(0.335)	(0.297)	(0.402)
Adult literacy	-0.015	-0.014	-0.018	-0.024*
	(0.014)	(0.013)	(0.013)	(0.014)
Openness	0.013	-0.105	-0.306	0.075
	(0.467)	(0.433)	(0.398)	(0.459)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

Table 7.b
ICT (1999 indicators) and political rights
Dependent variable = Index of political rights (1999)

	(1) *Y*=Mobile phones, 1999	(2) *Y*=Internet hosts, 1999	(3) *Y*=Internet users, 1999	(4) *Y* = Personal computers, 1999
No. of observations	47	47	47	47
Adjusted R^2	0.211	0.310	0.216	0.085
F-test	4.06***	6.17***	4.17***	2.07
Constant	0.500	0.514	6.164***	7.750***
	(3.502)	(2.785)	(2.121)	(3.097)
ln *Y*	-0.522**	-0.428***	-0.340**	-0.046
	(0.201)	(0.115)	(0.128)	(0.218)
Income	0.153	0.529	0.056	-0.241
	(0.426)	(0.350)	(0.318)	(0.398)
Adult literacy	-0.005	-0.008	-0.014	-0.020
	(0.013)	(0.012)	(0.012)	(0.014)
Openness	0.065	0.026	-0.164	-0.082
	(0.445)	(0.413)	(0.439)	(0.483)

* indicates significance at 0.1, ** indicates significance at 0.05 and *** indicates significance at 0.01.
Standard errors are in parentheses.

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