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TESTING THE LEAP-FROG HYPOTHESIS

The impact of existing infrastructure and telecommunications policy on the global digital divide

This paper tests the 'leap-frog' hypothesis by modeling the impact of existing telecommunications infrastructure, controlling for economic, political and demographic factors, on changes in information communication technology (ICT) access for over 200 countries between 1995 and 2005. This study has significantly greater coverage than previous research, in terms of both time frame and country cases. First, the analysis demonstrates that in the first decade of the information society successful leap-frog countries are few and far between. Second, the relative distribution of personal computers, internet hosts and secure servers among the nations of the world has barely improved over the last decade. Third, contrary to received wisdom, most of the countries that might qualify as successful leap-frog countries are actually among the wealthiest in the world. Finally, while policy reform in the telecommunications sector can sometimes speed the diffusion of digital communication tools, the record of market reforms is mixed, and the overall effect of economic wealth is still paramount. In sum, a few poor countries have leapt ahead in the development of a few aspects of ICT infrastructure and use, but these relatively rare successes are more likely to be due to economic productivity than to privatization, regulatory separation and depoliticization, or market liberalization in the telecommunications sector.

Keywords Global digital divide; Gini coefficient; leap-frog; telecommunications policy; privatization

Introduction

Although the 'leap-frog' hypothesis is often referred to in popular accounts of information technology and economic development, it has rarely been tested. Can a poor country, with the right telecommunications policies, modernize

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its communications infrastructure and develop into an information society ahead of neighbors who invested heavily in older, analog communications systems? How far can a leap-frog country leap? This metaphor of leaping ahead in development is often used when we talk about information communication technologies (ICTs) and social development around the world. There are surprisingly few scholarly efforts, however, to test how applicable the metaphor is to the growth of information societies, and no systematic analysis of large datasets.

Whereas some scholars argue that new technologies diffuse when there is a strong underlying infrastructure and commitment to supportive technical standards, others argue that new information technologies can spread more quickly when this deep investment in a communications infrastructure has not been made. Information technologies spread in complex patterns and are not only shaped by engineers' assessments of technical advantage, but also by the needs of users and the design of underlying infrastructure (Hughes 1983; Fischer 1992; Rogers 2003). There is a growing amount of research into development communication and the role that ICTs play in improving the quality of life around the world. Evidence suggests that public health services, environmental impact assessments, agricultural research, distance education and micro-credit loan services are significantly more effective when ICTs are employed (Edejer 2000; Grant 2000; Jimba 2000). Aside from the specific goal of improving the logistics of development work, researchers often harbor a hope that ICTs will help developing countries leap-frog over some of the difficult political, cultural and economic problems that developed countries have had to wrestle with. Whereas developed countries have had to make significant infrastructure investments in wired telecommunications, for example, developing countries may be able to avoid this investment by building an infrastructure of wireless communication technologies (Butler 1999; James 2001).

But using Western technologies, often with policy conditionalities currently imposed on developing countries, has had complex political, economic and cultural implications (Canclini 1996; Arunachalam 1999). And beyond the obvious logistical benefits of observing elections, documenting crimes against humanity and providing disaster relief, these technologies are often used by challenger groups to project their political grievances onto the international stage (Cleaver 1998; Kalathil & Boas 2003). Moreover, not only is there a significant digital divide between member countries of the Organization for Economic Cooperation and Development (OECD) countries and the rest of the world, but within the developing world many communities are entirely off the grid (Persaud 2001; Kowalczykowski 2002).

The other great hope in development communication is that the small, indigenous development projects started within poor communities may benefit most from ICTs. Examples include the Indian company PicoPeta, which builds computing devices at price points accessible to the middle classes of developing countries (http://www.picopeta.com); the Tarahaat Project, which builds village-to-village linkages and records the progress of land reform (http://www.tarahaat.com); and Global Forest Watch, which allows indigenous communities to monitor sustainable development and logging practices (http://www.globalforestwatch.org). As technologies become less expensive and easier to use, the organizational capacity of local development projects may improve. It is particularly difficult, however, to test this hypothesis without systematically collected data that allow for comparison across countries and cultures (Loo & Beng 1998; Madon 2000).

There is a significant body of literature regarding the impact of new media ICT in wealthy, Northern democracies (Hargittai 1999; Norris 2001; Howard 2006). But the current research on new media ICT and international development tends to be single-country case studies, studies of particular technologies, or cross-case comparisons that involve several countries selected for their similarity in culture, geography or stage in development (Coy & Moshavi 1994; Mitra 1996; Wheeler 2000; Lal 2001; Franda 2002). Currently, scholars are wrestling with a number of questions concerning the role of ICT in international development, questions that require comparative analysis to answer meaningfully (Barzilai-Nahon 2006). How has the distribution of information technology changed over the last decade? Are key technologies more equitably distributed or more concentrated? What economic, infrastructural and policy factors cause the digital divide? Does having a large infrastructure speed or slow the diffusion of new IT? The next step in this research agenda is to embrace more than a handful of country case studies, but this will be possible only with an appropriate archive of experience from development projects that employ new media ICT. More important, answers to these questions may be different across the common categories of social inequality, such as gender, age and ethnicity (Mitter & Rowbotham 1995; Mitra 1997; Mesch 2001). Most attempts to answer these basic questions have relied on penetration rates for personal computers, excluding other digital technologies that are important parts of the digital infrastructure (Borgman 2000; Groebel *et al.* 2006).

Many poor countries have computer and internet penetration rates that are a fraction of those found in wealthy countries, but some poor countries have rates of change higher than those rich countries. By 2005, six out of every 10,000 people in Tajikistan, six out of every 100 people in Indonesia, and six of every 10 people in the United States had ever used the internet. However, the proportion of countries with a tiny fraction of the world's internet users has not changed over the last decade. Since economic wealth is linked with access to innovative technologies, expressing internet use per dollar of GDP, rather than per capita, makes the divide much less dramatic (Fink & Kenny 2006). The digital divide is not simply between countries but within countries as well, though in rich countries the digital divide among race, gender and class is slowly closing (Hoffman & Novak 1998; Howard *et al*. 2001; Margolis & Fisher 2002; Youngs 2002). The term 'digital divide' has also been used to refer to the disparity in access between people with good search skills and those without, or between people with physical disabilities and those without (Dobransky & Hargittai 2006). Here the term will be used to refer to inequality in the distribution of technologies among the countries and populations of the world.

Even though the leap-frog metaphor is often used to describe the role of ICTs in developing countries, the list of countries that may actually be considered to have leapt ahead in ICT development holds several surprises. Table 1 identifies countries that have had a rise in the relative share of key ICTs. In other worlds, this list does not include countries that acquired proportionally more ICTs, but did so below the mean, or countries with a declining share of ICT over the 10-year period. As might be expected, a relatively small number of countries really do leap-frog ahead, by getting a larger and larger proportion of the world's ICTs over time. In terms of particular aspects of digital infrastructure and use, most of the countries that leaped ahead in a single metric were already wealthy. In the aggregate, there were only five countries that leaped ahead in four of the five available metrics of ICT infrastructure and use over the last decade: Spain, Russia, Turkey, China and India.

Research on telecommunications policy and the global digital divide

Inequalities in information access have long interested social scientists (Schramm 1964; Sussman & Lent 1991; Stevenson 1992; Schiller 1996). But to date, much of the quantitative research on the digital divide has focused on counts of personal computers and internet users, even though theorists of information supply often refer to multiple, diffusing ICT innovations, including internet hosts, mobile phones and secure servers, all of which form crucial parts of the digital infrastructure for an aspiring information society. There is no clear connection between privatizing public communications infrastructure and closing the digital divide. Initially, most internet nodes physically resided in the richest countries, and most of the internet users were at universities, working for governments and militaries, or living in urban areas and paying for dial-up services (Davison & Shelia 2003). After a few years of competition digital technologies were diffusing quickly, but unevenly. Diffusion rates varied by race, class, gender and age, such that different people had levels of online political sophistication (Kling 1996; Howard 2004).

Around the world, digital communication technologies often play a variable role in economic and political development (Mueller 1999).

From the perspective of those on the losing side of the digital divide, the benefits of fast, multimedia networks in today's communication-intensive world economy are accruing disproportionately to the wealthiest countries and peoples (Mossberger *et al*. 2003; Badshah *et al*. 2005). Most efforts to create indices for the development of information societies are closely focused on existing patterns of internet access over personal computers, or more speculative aspects of 'network readiness'. They emphasize the growing raw number of internet users around the world and the diminishing costs of digital technologies for both governments and individual consumers (World Economic Forum 2002; Dutta & Lâopez-Claros 2005). These reports provide little insight into the important cultural patters of ICT adoption – and adaptation – and offer few explanations for the consistently skewed distribution of information access (Press 1995; Persaud 2001). Such explanations are needed because of mounting evidence that the coercive effects of multilateral lending agencies on industries in many regimes may not produce ideal outcomes for consumers (Henisz *et al*. 2005).

Contested causes of the global digital divide

The causes and consequences of the digital divide have become a contested area of research. Understanding the digital divide is crucial for understanding the role of ICTs in contemporary social development. There is a strong positive relationship among access to IT, economic wealth and democracy (Quibria 2002). There are arguments over what causes the global digital divide and whether it is getting better or worse. In the early 1990s the digital divide was clearly technical: international connections to the internet were made through problematic dial-up services, few countries had their own domain names, and few countries had the capacity to manufacture, much less maintain, computer technologies (Howard *et al*. 2001). Much of today's research assumes that the digital divide is reflected in measures of internet use or internet hosts per person. While a difference in the proportion of internet users in two countries may reveal a digital divide, a change in the digital divide occurs only if the proportions change over time.

Economics

There is some agreement about the primary causes of the digital divide, though there are competing explanations for the relative weight of secondary factors. Most statistical analyses find that, at any time over the last decade, the global digital divide is accounted for mainly by income differentials (Caselli & Coleman 2001). Most of the conventional statistical approaches have resulted in an intuitively sensible consensus: to be in the upper ranks of information

TABLE 1a Leap-frog countries with above-average rise in their share of global ICT between 1995 and 2005.

	mobile phones	*personal computers*	*internet users*	*internet hosts*	*secure servers*
countries sampled	214	173	209	245	174
countries with a declining share	107	113	63	42	82
countries with a rising share	107	60	146	203	92
average percentage rise in share	0.35	0.16	0.27	0.25	0.06
countries with above-average rise in share	20	20	27	12	8

TABLE 1b Countries with above-average rise in their share of global ICT, by income group.

mobile phones	*personal computers*	*internet users*	*internet hosts*	*secure servers*
		high income		
France, Saudi Arabia, Spain*	Australia, Austria, Israel, Japan, Saudi Arabia, South Korea, Spain*	France, Germany, Italy, Japan, South Korea, Spain*, United Kingdom	Cayman Islands, Germany, Italy, South Korea, United States	Canada, Denmark, Ireland, Japan, Netherlands, *Spain**, United Kingdom
		upper middle income		
Czech Republic, Mexico, Poland, Romania, Russia*, South Africa, Taiwan, Turkey*, Ukraine	Malaysia, Mexico, Poland, Romania, Russia*, Taiwan	Argentina, Chile, Malaysia, Mexico, Poland, Romania, Russia*, Taiwan, Turkey*, Ukraine	Argentina, Russia*, Turkey*	*Turkey**
		lower middle income		
Brazil*, China*, Egypt, Indonesia, Morocco, Philippines	Brazil*, China*, Egypt, Iran, Peru,	Brazil*, China*, Egypt, Indonesia, Morocco, Peru, Philippines, Thailand	China*, Brazil*, Western Samoa	None
		low income		
India*, Nigeria	Bangladesh, India*	India*, Vietnam	India*	None

Note: Secure servers covers the period 2001–2004. * Denotes countries with above-average rise in at least four of the five ICT categories.
Source: Author's calculations, based on data from the World Bank's *World Development Indicators* (2006), the ITU's *World Telecommunication Indicators* (2006) and the Internet Software Consortium (2006) with adjustments by Zook (2006).

societies, a country needs to have a rich and educated population, a reasonably modern telecommunications infrastructure, and a relatively transparent regulatory system that guarantees freedoms of speech for technology users and that provides minimal regulations for businesses offering information and communications services (Chinn & Fairlie 2004). Literacy rates, core status in the world economy and cultural cosmopolitanism are sometimes statistically significant (Guillén & Suarez 2005).

Infrastructure and demographics

There has been no global study of the contribution of different kinds of telecommunications policy toward improving information access. Most of the research suggests that economic growth and regime type are associated with rapid technology adoption, but there is a debate over what role privatization of telecommunications might have in the adoption of new communication tools (Milner 2006). Whereas early research into the digital divide found economic factors to outweigh others (Norris 2001), more recent research illustrates that political and social variables also contribute (Milner 2006). Wallsten (2005) found a role for the characteristics of regulatory regimes, such as agency independence, transparency and discretion, in explaining growth in the number of internet users and internet hosts in 45 countries in 2001. In contrast, for 1997–2001, internet use in 61 countries increased with privatization and competition in the telecommunications sector, democracy, cosmopolitanism and core status in the world system (Guillén & Suarez 2005). Unfortunately, this research lacks parsimony and concludes that a country's degree of modernization explains its degree of internet use, which is not helpful for either industry designers or policy-makers.

Regime type and telecommunications reform

Even though regime type is thought to be an important variable, it alone cannot meaningfully predict a country's place in the digital divide. Some dictatorships and democracies have high rates of ICT growth, and some dictatorships and democracies are at the bottom of the list of ICT access. Unstable democracies often restrict internet service providers more than do confident authoritarian regimes (Howard 2005; Johnson & McGlinchey 2005). There is a complex causality behind the interactions of democratic institutions and internet use (Everett 1998; Hogan 1999; Abbott 2001; George 2006). Authoritarian regimes may significantly develop their digital communications infrastructure to extend state reach (Kalathil & Boas 2003). To understand the dynamics of the digital divide around the world, it is important to situate economic variables in the social context of government policy for promoting field innovations.

The social aspects of the divide were firmly documented by research illustrating the degrees to which political parties and citizens in different countries use the internet for political participation (Norris 2001). Most analysts summed trends among a limited range of wealthy countries. Some focus on the distribution of internet access within the richer countries, either at single points in time or over a few years of transition, and find the rule of law to be positively related to the number of internet users in a country (Oxley & Yeung 2001; Bauer & Maitland 2002). The studies that have included observations from developing and developed countries have tended to examine data at a single point in time (Guillén & Suarez 2001; Volken 2002; Beilock & Dimitrova 2003).

The argument that the digital divide is closing is often presented through the numbers on growth in the number of computers and mobile phones around the world. Caselli and Coleman (2001) analyzed personal computer adoption in 89 countries from 1970 to 1990 with many explanatory variables, but this is before internet connectedness became such a prominent feature of the information society. Dedrick *et al.* (2003) analyzed 31 countries and highlight economic structure, income, telecommunications infrastructure and human capital as explaining patterns of investment in information and communication technologies from 1985 to 1995. Pohjola (2003) analyzed 49 countries between 1993 and 2000 and found that not being an agricultural economy was important in predicting the amount of ICT investment in a country, though this study covers a period before most of the digital infrastructure arrived in developing countries and before the dot-com crash occurred in developed countries. Kiiski and Pohjola (2002) examined 60 countries and measured the impact of income, telephone access costs and schooling on the number of country-specific internet hosts in the period 1995–2000. Not surprisingly, high access charges and the lack of political freedom were negatively associated with internet penetration among 21 Asian countries (Mann & Rosen 2001). None of these studies examines ICT adoption trends across the developing world, none incorporates adaptation patterns and all are centered on the personal computer.

There is an important difference between explaining a wide digital divide and observing a widening digital divide (Firebaugh 1999). While some look closely at the distribution of such technologies in regions (Mann & Rosen 2001; Bauer & Maitland 2002; Estache *et al.* 2002; Quibria 2002; Ho *et al.* 2003; Oyelaran-Oyeyinka & Lal 2005), analytical coverage of the digital divide outside the OECD is only slowly improving (Primrose 2003; Warschauer 2003; Ono & Zavodny 2004; Singh 2004). Interestingly, there is more research on the impact of ICT on diaspora communities living in rich countries than there is on the poor countries whence these diaspora came (Tufte 2002; Mallapragada 2004; Ignacio 2005). Researchers often conflate a comparison of the relative rise in the number of computers in countries with a change in the proportion of all the world's computers located in a country. If the overall number of computers in the world grows, and those few countries continue to get a large – but constant – proportion of those computers, then there has been no change in the relative distribution of computers among countries. But if the rate of change is constant – for example, if Cameroon's internet population grows at the same rate as Canada's – then the digital divide is not really growing.

In addition, most current quantitative research uses known categories of technology, such as the personal computer or the mobile phone, and does not consider the 'patchy' way technologies actually diffuse. Even people with little formal skill and limited access to parts and other technology can radically reconfigure ICTs (Akrich 1992; Wyatt 2003). From non-governmental agencies and ministries of infrastructure down to local fishermen and farmers, there is evidence that people in poor countries reengineer and repurpose technologies. In Tanzania a significant amount of innovation is occurring around mobile phone technologies: one international donor is delivering lessons in fish species identification by text messages to mobile phones; a rural community of rice growers has pooled funding to hire a programmer to build an open source application for automatically transmitting the daily market prices for rice (Nielinger 2003; Samuel *et al*. 2005). There is often a gulf between the income of small farmers and the urban customers they supply, and ICTs increasingly help close this gulf. These kinds of innovations significantly increase information access (von Hippel 1988), but are often left out of digital divide research. Users are a significant source of new innovations in technological systems; these innovations have the potential to propagate back throughout the entire user base (von Hippel 2005). Mobile phones are not simply a digital communications tool for carrying on conversations; they are increasingly used to deliver content and serve as internet portals.

In sum, digital divide research has been stymied in several respects. First, current research has a limited focus on economic wealth and regime type as explanatory variables: rarely are the interesting variations in national telecommunications policy considered. Second, digital divide research tends to be closely focused on computers and internet users, even though mobile phones are an increasingly important means by which people in poor countries share information and even though there are good data on other key equipment in digital infrastructure, such as hosts and secure servers. Third, previous studies have used an enormous battery of explanatory variables yet explained little of the observed variation; they have studied rich countries or a regional subset of countries, or analyzed a relatively short period of time before, during or after the dot-com boom.

This study remedies these deficiencies in several ways. First, it develops a metric of ICT distribution that more meaningfully captures change in the relative share of global ICTs within each country. Second, it moves beyond simple counts of internet users and incorporates multiple technologies of the digital infrastructure and usership that support modern information societies. Third, it analyzes changes in the distribution of these digital technologies over a longer period of time.

Measuring the leap-frog effect

Technology resources are not evenly distributed among countries and peoples. One common way of measuring how evenly a resource is distributed is through gini coefficients (Milanovic 2005). In a perfectly equal society 23 per cent of the population controls 23 per cent of the resources, and 90 per cent of the population controls 90 per cent of the resources. A more equal society will have a low gini coefficient, and a society in which resources are highly concentrated will have a high gini coefficient. Gini coefficients for internet hosts, mobile phones, personal computers, secure servers and internet users could reveal how equally they are distributed, and some summation could represent the overall inequality that is the digital divide. Gini coefficients could range from equal ICT distribution across a sample of countries (valued at 0.00) to a condition of complete inequality in which all ICT resources are held by one country (valued at 1.00). But there is a second way to adapt a gini index to help us understand the digital divide.

Since countries vary quite significantly in terms of population size, it would be more accurate to weight the gini coefficient for the distribution of mobile phones by the relative portion of the world's population residing in each country. This expression allows us to weight the relative contribution of countries with different populations and many mobile phones, such as the United States and Belgium (a large and a small country with many mobile phones), with Indonesia and Laos (a large and a small country with few mobile phones). In other words, this allows for a more reasonable fit between large and small countries on both sides of the global digital divide. Theoretically, it is possible to compute a gini coefficient for the distribution of information within a single country's population. Unfortunately, there are insufficient data on ICT distribution within poor countries to make this calculation.

This methodological approach allows for a comparison of the relative distribution of ICT infrastructure and use. Table 2 presents the changing coefficients for five information technologies over the last decade for the distribution of ICTs among countries and among population-weighted countries. Five indicators are used: mobile phones that use digital switches and are increasingly used for much more than just conversations; personal computers; internet users, as estimated by each country's internet service providers; internet hosts, revealed by the number of computers connected

TABLE 2 Gini index for ICT distribution around the world.

	1995	*2000*	*2005*	*change*
distribution among countries				
mobile phones	0.93	0.89	0.80	−0.14
personal computers	0.86	0.89	0.87	0.01
internet users	0.94	0.91	0.87	−0.06
internet hosts	0.89	0.92	0.92	0.03
secure servers		0.95[a]	0.95[b]	0.01
distribution among population-weighted countries				
mobile phones	0.67	0.37	0.13	−0.54
personal computers	0.62	0.50	0.37	−0.25
internet users	0.82	0.50	0.25	−0.57
internet hosts	0.86	0.75	0.77	−0.09
secure servers	–	0.87[a]	0.87[b]	0.00

Note: [a]Data for this year actually 2001. [b]Data for this year actually 2004.

Source: Author's calculations, based on data from the World Bank's *World Development Indicators* (2006), the ITU's *World Telecommunication Indicators* (2006) and the Internet Software Consortium (2006) with adjustments by Zook (2006).

to the internet with a distinct national IP address (in 2005 these values were adjusted to associate top-level domain names such as *.org and *.com with particular nation-states); secure servers that encrypt data during the transfer of information between a Web browser and a server (Internet Software Consortium 2006; ITU 2006; World Bank 2006; Zook 2006).

Surprisingly, internet hosts and computers were actually concentrated among fewer nations over the period between 1995 and 2005 (internet hosts from 0.89 to 0.92; personal computers from 0.86 to 0.87). In contrast, internet users and mobile phones have become much more evenly distributed among the nations of the world (internet users from 0.94 to 0.87; mobile phones from 0.93 to 0.80). Overall, these metrics of the international digital divide changed by only a few points over the last 10 years. Measuring the digital divide among country populations reveals more dramatic change. While hosts and secure servers remain concentrated among country populations, computers and internet users became more evenly distributed around the world (internet hosts from 0.86 to 0.77; secure servers constant at 0.87; personal computers from 0.62 to 0.37; internet users from 0.82 to 0.25). Indeed, mobile phones are the most equitably distributed of those assessed (mobile phones from 0.67 to 0.13). It is clear just from this initial examination of the data that personal computers alone are not a suitable measure of a country's access to information technologies. In terms of country populations, computers are slightly more equitably distributed but internet users are significantly more equitably distributed. This suggests that internet users in many countries are not using 'personal' computers for internet access. The prevalence of shared internet access points, in libraries and cybercafés, or access via mobile phones, may explain this trend.

On its own, however, the metric of information access demonstrated above does not identify the relative impact of telecommunication policy options and other social variables on changes in ICT access. Ordinary least squares (OLS) regressions will robustly test factors, such as existing infrastructure, often cited in the literature on changes in the proportional distribution of ICT. Table 3 reveals the basic descriptive statistics on the dependent and independent variables that are most useful for testing the leap-frog hypothesis.

Dependent variables

To help restrict the inherent problems of time-series data, cases were constructed as country-years at three points in time over the last decade: 1995, 2000 and 2005. The inclusion of country-years at five-year increments allows for a pooling of data points without creating a dataset that suffers from the known problem of time-series effects in data from sequential years.[1]

Independent variables

Control variables include demography, economics, preexisting ICT infrastructure and the telecommunications policy environment, and these were lagged one year prior to each country-year observation. GDP (purchasing power parity) per capita was included because wealthier countries with larger populations can be expected to have greater demand for new information technologies. Since core–periphery status in the world may also help explain the digital divide, trade, as a percentage of GDP, is included as a measure of integration with the world economy. Measures of preexisting infrastructure were included since the adoption of new technology often depends on the condition of current technology. The number of telephone mainlines is a good indicator of the health of a country's overall ICT infrastructure. The cost of a local three-minute phone call at peak hours is a good proxy for how affordable this infrastructure actually is for a country's population.

Five indicators of both the political environment for policy-making and the types of policy options chosen are recorded for the three sample years 1995, 2000 and 2005. First, a general measure of regime type from the Polity IV dataset ranks perfect democracies a 10 on a 21-point scale and perfect autocracies a −10. This measure of regime type is taken annually and is based on an assessment of the competitiveness and openness of the process for selecting the country's chief executive, the extent of

TABLE 3 Leap-frog descriptive statistics.

variables	*n*	*minimum*	*maximum*	*mean*	*sd*
distribution of information technologies					
portion of world's mobile phones	582	0.000	0.372	0.005	0.022
portion of world's personal computers	438	0.000	0.412	0.007	0.031
portion of world's internet users	542	0.000	0.632	0.006	0.033
portion of world's internet hosts	567	0.000	0.356	0.005	0.022
portion of world's secure servers	309	0.000	0.647	0.006	0.051
economics					
gross domestic product, purchasing power parity, in current international dollars (millions)	546	0.314	55,938.190	1,177.634	4,710.653
trade as percentage of gross domestic product	495	3.425	270.143	80.356	42.149
foreign direct investment, net inflows as percentage of gross domestic product	396	−5.874	184.439	3.924	10.655
infrastructure					
electric power consumption, kilowatt hours per capita (millions)	284	15.837	24,499.330	3,037.373	3,923.356
telephone mainlines (thousands)	628	0.697	1,040.302	197.027	213.310

(*Table continued*)

Table 3 Continued.

variables	n	minimum	maximum	mean	sd
cost of a local three-minute call, peak rate	504	0.000	1.042	0.085	0.095
demographics					
population (millions)	632	9150.000	1,313.309	28.389	114,534.553
secondary school enrollment, percentage of gross	359	5.819	178.510	71.647	33.155
percentage of population in urban areas	666	6.280	100.000	54.538	23.971
regime type and telecommunications policy					
democracy score	317	−10.000	10.000	2.587	6.747
years of privatization	582	0.000	45.000	3.869	9.605
years of regulatory separation	582	0.000	45.000	3.294	5.526
years of regulatory depoliticization	582	0.000	45.000	2.101	5.709
years of market liberalization	582	0.000	43.000	2.344	6.690

Source: Author's calculations, based on data from the World Bank's *World Development Indicators* (2006), the ITU's *World Telecommunication Indicators* (2006), the Internet Software Consortium (2006) with adjustments by Zook (2006), the *Polity IV* dataset (Jaggers 2004), and the author's updates to data on telecommunication policy collected by Henisz *et al*. (2005).

constitutional limitations on executive power, the competitiveness of political participation generally, and the stability of the terms governing that public participation (Jaggers 2004). Since the telecommunications policy environment probably has a role in shaping technology adoption and information access, four variables describing different types of policy reform are used: privatization of the telecommunications provider, regulatory separation, regulatory de-politicization, and market liberalization. Of course, there are many forms of policy intervention possible but these four are the most commonly chosen and the most often promoted by multilateral lending agencies.

These measures are not simply the condition – privatized or not privatized – in a given year; they measure the number of years in which each type of policy reform was successfully implemented. For example, the year of privatization was noted for each country so that the years of effective privatization could be counted at three points in time. For example, Chile effectively privatized its telecommunications sector in 1989, so in 1995, 2000 and 2005 Chile's telecommunication sector had been privatized for six, 11 and 16 years, respectively. If privatization has a positive impact on the digital divide, then this impact will be felt over time as the market adjusts and new institutional arrangements take shape. If privatization helps a country leap-frog into the information age, then in 2005 Chile should have a well-developed information society, having benefited from 16 years of privatization. It follows that Chile's information society in 2005 should be more evolved after 16 years than it was in 2000, after only 11 years of privatization. Moreover, in 2005 information access in Chile would be better than in Nigeria, where similar sector reform had occurred only six years earlier.

Findings and analysis

Table 4 provides several models for assessing the contribution of different factors to a country's share of the world's ICT in the three years sampled. Economic wealth is consistently one of the largest effects across all models predicting the distribution of mobile phones, personal computers, internet users, internet hosts and secure servers. International trade, measured as the proportion of a country's GDP coming from imports and exports, has a small negative impact on these five digital divide indicators. In contrast, having foreign investment is a slight positive effect. This may be because many developing countries generate wealth by exporting unprocessed natural resources, a relatively low-tech venture. Similarly, it may be that foreign investment occurs in efficient, IT-enabled industries, driving up overall ICT adoption.

In terms of infrastructure, having an energy-intensive economy is a strong positive predictor of whether a country is a growing information society. Having a large and costly-to-use mainline telecommunications infrastructure

TABLE 4 Leap-frog OLS regression models.

portion of world's ICT technology and users (standardized β Coefficients)	*mobile phones*	*personal computers*	*internet users*	*internet hosts*	*secure servers*
economics					
gross domestic product, purchasing power parity, in current international dollars (millions)	0.891***	1.091***	0.984***	0.877***	1.138***
trade as percentage of gross domestic product	−0.063	−0.127***	−0.097**	−0.148**	−0.057
foreign direct investment, net inflows as percentage of gross domestic product	0.017	0.081*	0.093	0.062	0.089*
infrastructure					
electric power consumption, kilowatt hours per capita (millions)	0.314***	0.223***	0.328***	0.631***	0.335***
telephone mainlines (thousands)	−0.257**	−0.132*	−0.326**	−0.451***	−0.331***
cost of a local three-minute call, peak rate	0.009	−0.066*	−0.056	0.010	−0.071
demographics					
population (millions)	−0.055	−0.381***	−0.304***	−0.357***	−0.509***
secondary school enrollment, percentage of gross	0.187**	0.110**	0.228**	0.074	0.091
percentage of population in urban areas	−0.052	−0.041	−0.101	−0.030	−0.049
regime type and telecommunications policy					
democracy score	0.058	0.012	0.033	0.278**	0.021
years of privatization	−0.050	0.081*	0.050	0.027	0.047
years of regulatory separation	0.014	−0.063*	−0.037	−0.045	−0.038
years of regulatory depoliticization	−0.088*	−0.052*	−0.057	−0.092*	−0.049
years of market liberalization	−0.053	−0.121***	−0.129*	−0.076	−0.060
n of country-years	582	438	542	567	309
adjusted R^2	0.687	0.886	0.671	0.706	0.833

Note: In all models, the standard error for the effect of the cost of a local three-minute call at peak rate is less than 0.03, and all other effects have a standard error less than 0.01.

Source: Author's calculations, based on data from the World Bank's *World Development Indicators* (2006), the ITU's *World Telecommunication Indicators* (2006), the Internet Software Consortium (2006) with adjustments by Zook (2006), the *Polity IV* dataset (Jaggers 2004), and the author's updates to data on telecommunication policy collected by Henisz *et al.* (2005).

comprises two of the strongest effects predicting a relatively small share of the world's ICT users and infrastructure. The (negative) effect of having a large extant landline communications infrastructure is almost as large as the (positive) effects of being a strong democracy with several years of privatized infrastructure. This finding supports the leap-frog hypothesis because it quantifies the effect, controlling for other factors, of how extant infrastructure can prevent a leap ahead. The other factors, however, are evidence of what helps a technological advancement.

Only a few of the demographic factors are statistically significant, and this is consistent with most other digital divide regressions. A country's education, urbanization or youth bulge rarely has a strong, statistically significant effect in regression models.[2] Of the four kinds of initiatives often taken by governments, having many years of effective privatization within a country's telecommunications sector is only a statistically significant predictor of a county's share of personal computers, controlling for other factors. In comparison, whenever policies of regulatory separation, de-politicization or liberalization have statistically significant effects, these effects are negative. In other words, the privatization of state-owned telecommunications firms may do more to improve access to ICT than other policies of economic liberalization, such as separating regulatory authority from the executive branch, eliminating political influence over regulators, or opening up retail communications markets to multiple service providers.

As might be expected, democratic countries with a relatively high GDP, significant foreign direct investment, an energy-intensive economy with an educated population and several years of privatization in the telecommunications sector are most likely to have well-developed information societies. Countries with a significant telephone mainline infrastructure are likely to have a smaller share of the world's digital technologies and users, though a strong modern economy easily overcomes this effect.

This analysis yields two surprises. Perhaps most surprising is the size of the negative effect of being deeply invested in telephone mainline infrastructure. Indeed, in explaining the digital divide in mobile phones, personal computers, internet users, internet hosts and secure servers, the positive impact of being a democratic country with a privatized telecommunication system may be entirely negated by the weight of investment in obsolete and expensive infrastructure (holding other factors constant). Privatizing the national telecommunications provider had a slight positive impact on a country's share of the world's personal computers but regulatory separation, de-politicization and market liberalization have small negative impacts. In addition, regulatory depoliticization has a negative impact on predicting a rise in internet hosts and mobile phones. Controlling for other factors, countries with many years of market liberalization are likely to have proportionally fewer internet users and personal computers. In the aggregate, it is not clear that these types of policy reforms help close the digital divide by boosting a country's share of the world's ICT users or infrastructure.

Conclusion

Many developing countries have become locked into obsolete technologies, and this analysis reveals that it can take many years for a reformed telecommunications sector to overcome the weight of heavy investment in landlines and analogue telecommunications systems. Indeed, the regression models suggest that the more landlines a country had in 1995, 2000 and 2005, the smaller was its portion of key digital technologies relative to the other countries in the world.

This analysis also demonstrates that it takes significant economic wealth, several years of democratic policy-making and several years of a privatized infrastructure for a country to actually leap ahead. Having a large landline infrastructure actually decreases the likelihood that a poor country has a large share of the world's digital information technologies or internet users. Countries that have not invested in mainline telephone systems are more likely to be on the positive side of the digital divide, and this statistical effect is second only to the effects of economic wealth.

This study improves on previous research through a digital divide metric that more closely reflects relative changes in the distribution of ICT, not simply the number of internet users or computers per capita. This study demonstrates a useful way of measuring the distance that a leap-frog country can leap, and uses this metric to calculate changes in the distribution of ICT and ICT users. These findings are based on a larger sampling of countries over a greater time span. Surprisingly, the distribution of computers, hosts and secure servers among the nations of the world has not really improved over time. When weighted by population, ICT access has improved overall but most dramatically for mobile phones. Some countries have dramatically crossed the digital divide by raising their share of global ICT, but these tend to be the economically wealthy, high-growth economies anyway.

This latter process is what we casually refer to as the leap-frog hypothesis: if a poor country avoids investment in expensive landline analog communications technologies, then it can speed its economic development ahead of its neighbors by purchasing the best-of-breed technologies that emerge over time, often at lower price points. Even though we often use this term, there are few countries for which the term sensibly applies. The countries on the winning side of the digital divide, the ones with strong information societies, are countries that did invest heavily in an early communications infrastructure and reaped economic benefits that propelled them forward in development. In terms of telecommunications infrastructure, this analysis proves that it is quite easy to become locked into a development path, whereby significant expenditure on an early analog, landline system limited the options for future digital communications technologies, even with an aggressive public policy to promote ICT. While it is true that the countries that invested deeply in a telephone mainline infrastructure had lower shares of the world's digital communications infrastructure, there are surprisingly few countries that deserve the label of leap-frog countries. Moreover, the commonly touted policies for becoming an information society – market liberalization and separating the ICT regulator from political oversight – seem to have done little to bring equity to the distribution of the world's digital infrastructure.

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Notes

1 In addition, it is assumed that the data obey a first-order Markov process in that the values of a given year depend only on the values during the preceding year, but not beyond. These OLS tests make assumptions about homoscedasticity and normality.

2 Additional variables, including literacy rates, were tested but were dropped from the models if the effects were negligible, statistically insignificant, contributed little to explained variation, and the literature reviewed above did not recommend their use.

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