States, Markets, and the Global Digital Divide

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Abstract

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Keywords: Global Digital Divide, Technology Diffusion, Policy Reform, Time-Series Cross-Sectional Analysis

Word Count: 10,388

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Abstract

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I. INTRODUCTION

On October 24, 1995, the Federal Networking Council formally defined the term "internet" as an information system that linked computers together by assigning them a unique address. That same year, the National Science Foundation defunded the "NSFNet," an early internet backbone, and effectively privatized the internet by redistributing funds to regional networks that could then buy internet connectivity from the private, long-haul communications networks that were emerging. These two events—formally defining the internet and opening up the infrastructure to private sector development via the private sector—helped launch the digital communication infrastructure that would foster a rapidly unfolding information society in the United

States. For many other countries, however, the emergence of an information society still remains in its nascent stages. Indeed, especially when one compares countries located at opposite ends of the economic development spectrum, the notion of a "digital divide" in access to digital communication technologies may sometimes be better described as a "digital chasm." While six out of every 10 people in the United States reported ever using the internet by 2005, only six out of every 100 people reported doing so in Indonesia, and only six out of every 10,000 people in Tajikistan reported doing so.[1]

A growing number of global development and international communication scholars are examining what causes this digital divide, assessing whether or not it is narrowing or widening, and determining what individual countries can do to improve their lot.. And while divergent findings occasionally emerge, it can be observed that a common approach has been adopted in order to quantify and thus evaluate the digital divide. Specifically, indices of the global *diffusion* of information and communication technologies (ICTs) have been utilized,[2] done so by looking at various aspects of a country's "network readiness," patterns of internet access and usage, or the costs of digital technologies for governments and consumers.[3] At the same time, with regards to the scope of existing approaches, most have examined wealthier countries or a regional

[1] See Van Dijk (2005) and Pohjola (2003).
[2] The ICT diffusion perspective often uses data about the rate at which new technologies are taken up in a country, compares these adoption rates with neighboring countries or previous points in time, and assumes that the pattern of technology adoption within a country will follow an S-curve pattern (see Rogers [2003]; UNCTAD [2006]). In contrast, the ICT distribution perspective often works with data about the relative share of global infrastructure available in a country, comparing changes in the proportional supply of global ICT infrastructure over time, and assumes that technology adoption patterns within non-OECD countries rarely, if ever, follow an S-curve pattern (see Barzilai-Nahon [2006]).
[3] Dutta and Lâopez-Claros (2005); World Economic Forum (2002).

subset of countries while constructing either static models or ones that comprise only a few years of data at best.[4]

Though significant insights have been generated from many of these studies, in this article we argue that for other approaches to examining the global digital divide. For one, time-series cross-sectional studies covering a broad range of cases and time periods that include many non-OECD countries can now be constructed in order to explore the determinants of the digital divide as it has changed over the last 15 years. In addition, an alternative to diffusion-based studies is also possible, such as one that focuses on the global *distribution* of ICTs which uses measures of the relative proportion of a particular global ICT infrastructure or usage that is available in a country. At the same time, more attention should be focused upon the impact of state policy reform on the digital divide. Finally, we argue that the global digital divide should be assessed not simply in terms of internet use, but through the various technologies that form the infrastructural basis of modern information societies: computers, internet hosts, secure servers and mobile phones.[5]

In these respects, we offer a new approach to studying the digital divide while adding to the valuable contributions that have already been made by many comparativists. In order to present our approach, we conduct a large-N analysis of a panel of 110 countries from 1990 to 2004 using a country's share of the global distribution of internet users, internet hosts, secure servers, personal computers, and mobile phones as our dependent variables. In terms of our statistically significant findings, we find that

[4] Notable exceptions in the literature exist and are discussed below.
[5] Though studies have been done on personal computers (such as Caselli and Coleman [2001], Chinn and Fairlie [2004], and Goolsbee and Klenow [2002]), few have addressed the spread of mobile phones. One

infrastructural and demographic variables are overall the best predictors of changes in a country's share of the global distribution of most ICTs. We find a negative relationship between the liberalization of retail communication markets and a country's share of internet users, internet hosts, personal computers, and mobile phones. We also find support for a positive relationship between the privatization of state-owned telecommunication infrastructure and a country's share of internet users as well as personal computers. De-politicizing the agency that provides regulatory oversight of the country's telecommunications sector has a negative impact on a country's share of global internet hosts. Separating this agency from control of the executive branch of government can positively contribute to a country's share of hosts, but this reform strategy has a negative impact on a country's share of the global supply of personal computers.

Our study begins by discussing the causes of the digital divide. We then consider the question of whether or not the digital divide is widening or narrowing, and present our approach to studying this process using measures of ICT distribution instead of ICT diffusion. Next, we move onto our data section and present our time-series analysis. Following this, we provide an interpretation of our results and briefly conclude. We advance the research in three respects: we analyze a larger panel of countries over a longer period than covered previous research; we analyze multiple indicators of the global digital divide; rather than using more limited regression models, we treat this data with time-series analysis.

II. WHAT CAUSES THE DIGITAL DIVIDE?

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important exception is Cartier, Castells, and Qui's (2005) analysis of mobile phones and other ICTs in

Understanding the causes and consequences of the digital divide has recently become a popular and highly contested area of research. Yet the stakes of properly understanding the digital divide are significant, since information technologies play an increasingly important role in social development around the world.[6] Indeed, some research has already pointed to a strong positive relationship between access to information and communication technologies and a country's level of income, as well as its prospects for democracy.[7] However, the causes of the digital divide are not yet clear as the scholarly debate often produces competing causal explanations, weight the effects of regime type and policy reform in different ways, and produce a veritable laundry list of potential predictors. During most of the 1990s, understanding the digital divide was much more straightforward as the divide was primarily one that was technical in nature: international connections to the internet were made through dial-up services, few countries had their own domain names, and few countries had the capacity to manufacture (much less maintain) computer technologies. But with the growth in numerous kinds of digital communication technologies over the last decade, it has become clear that studying the digital divide by comparing per capita measures of internet users or internet hosts can expose only part of the digital divide.[8]

Historically, most of the world's technologies were pooled through scientific exhibitions that allowed developing countries to compare technical systems and choose

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China.

[6] See Acemoglu and Robinson (2000), Boas, Dunning, and Bussell (2005), Cartier, Castells and Qiu (2005), Evans (2005), Parente and Prescott (1994), Saxenian (2005), and Weber and Bussell (2005).

[7] For example, see Quibria (2002).

[8] Indeed, it is also important to recognize that one important source of the digital divide is reflected in variation in the speed of internet access given that people living in advanced industrial economies have more affordable broadband access than those on the other side of the developmental spectrum. Unfortunately, high-quality comparative, long-term data on broadband access across multiple countries is as yet unavailable.

the best technologies to meet their national needs.[9] More recently, however, markets have driven international adoption and complex patterns of technology diffusion have emerged that are not simply explained by a country's level of modernization, policy reforms, or existing technological capabilities.[10] Often, individuals in a country adopt a particular technology but do a significant amount of work adapting and redesigning it to fit their own needs and capabilities. As one example of this phenomenon, consider the alternative kinds of digital technologies that people around the world use to communicate via the internet. Mobile phones have now become an important way of accessing the internet especially in poor countries where connectivity through mobile phone providers is relatively cheap and ownership of personal computers is relatively expensive. Indeed, the number of connected mobile phones has surpassed the number of computers, such that the primary form of digital communication is increasingly the mobile phone. Global differences in technical standards and capabilities, diverging market prices of various technologies, and the presence of local adaptations and innovations all make the process of technology diffusion both uneven and complex—and understanding the digital divide all the more difficult.

Whereas early research found that economic factors far outweigh others in determining a country's placement on the digital divide spectrum,[11] more recent studies suggest that political and social variables can also have significant explanatory traction.[12] Among the widely-cited large-N studies of late, the overall theme is that income, education, telecommunication infrastructure, and the state's regulatory system are all

[9] See Fischer (1992), Hughes (1983), and Rogers (2003).
[10] Political forces can obviously also be important in determining rates of technological diffusion. See Acemoglu and Robinson (2000) and Milner (2006).
[11] See Norris (2001).

important determinants of where a country sits on the digital divide.[13] Dedrick et al. finds similar results in their study of 31 countries between 1985 and 1995, concluding that a country's economic structure, income level, telecommunication infrastructure and human capital[14] best explain cross-national patterns of investment in ICTs.[15] At the same time, literacy rates, core-periphery status in the world economy, and level of "cultural cosmopolitanism" have also been found to be statistically significant predictors as well.[16]

Contributing to these findings, Pohjola analyzed 49 countries between 1993 and 2000 and concluded that not being an agricultural economy was important in predicting the amount of ICT investment in a country.[17] Kiiski and Pohjola also examine a panel of 60 countries over 1995 to 2000 and find relevance for the role of income, telephone access costs, and level of schooling on the number of internet hosts in a particular country.[18] Mann and Rosen further point out in their study of 21 APEC countries that, over time, high access charges and a lack of political freedom is negatively associated with rates of internet diffusion.[19] In addition, Goolsbee and Klenow as well as Kiiski and Pohjola both conclude that a dense urban population and extensive telecommunication network are key factors behind the adoption of new technologies as well as being placed

[12] See Milner (2006) and Norris (2001).
[13] Caselli and Coleman (2001) and Chinn and Fairlie (2004).
[14] Further exacerbating the digital divide is the fact that there is a great difference in skill sets between populations throughout the world. This can prevent many people from taking advantage of the internet given that some competence in English and computer skills is necessary. This aspect of the digital divide is sometimes labeled a "second order" digital divide.
[15] Dedrick et al (2003).
[16] Guillén and Suarez (2005).
[17] Pohjola (2003). Despite the salience of their findings, it might be noted that one limitation when applying Dedrick et al's (2003) and Pohjola's (2003) results to the current day is that they cover a time period before most of the digital infrastructure arrived in developing countries as well as before the dot-com crash.
[18] Kiiski and Pohjola (2002).
[19] Mann and Rosen (2002).

on the narrowing side of the digital divide spectrum.[20] Finally, several studies find that a country's degree of property rights protections and level of regulation of the telecommunication sector also matters.[21]

Democracies may be more likely than autocracies to promote the spread of internet users and internet-related ICTs, as Milner's study of approximately 190 countries over the time period 1991 to 2001 shows.[22] At the same time, it is important to observe the fact that both democracies as well as dictatorships top the list of rates of growth for internet users, internet hosts, mobile phones, personal computers, and secure servers. Indeed, both democracies and dictatorships are also at the bottom of this list. Moreover, Johnson and McGlinchey's close examination of several Central Asian countries reveals that unstable democracies may actually be *more* likely to restrict internet service providers than confident authoritarian regimes.[23] Similarly, Kalathil and Boas find that authoritarian regimes may significantly develop their digital communication infrastructure specifically as a means of extending the reach of the state.[24]

Understanding the impact of state telecommunications policy on national development is a relatively new area of inquiry. However, a debate has already emerged in regards to the role that privatization of the telecommunication sector can play in a country's adoption of new kinds of communication tools.[25] Guillén and Suarez, with

[20]Goolsbee and Klenow (2002) and Kiiski and Pohjola (2002). Indeed, this makes intuitive sense as countries with good social and economic infrastructure will be more likely to invest in other improvements, such as those of a technological nature.
[21] Chinn and Fairlie (2004) and Wallsten (2005). Also see Weber and Bussell (2005).
[22] See Milner (2006). Important case studies in the literature have also offered many hypothesized causal paths regarding the relationship between democratic institutions and internet usage. See Abbott (2001), Everett (1998), George (2006) and Hogan (1999).
[23] Johnson and McGlinchey (2005).
[24] Kalathil and Boas (2003). Also see the studies on China by Chase and Mulvenon (2002) and Zittrain and Edelman (2002).
[25] See Milner (2006).

evidence from 61 countries between 1997 and 2001, argue that a country's level of internet use is associated with its level of privatization and competition in the telecommunication sector.[26] In addition, Wallsten finds that certain characteristics of regulatory regimes—such as agency independence, transparency, and discretion—can explain the growth of internet users and internet hosts in 45 countries in 2001.[27] As a whole, however, scholars of world development have yet to provide a lengthy cross-national study of the role that various telecommunication policies can play in determining a country's placement on the digital divide spectrum.

Much insight has been gained from the existing literature on the digital divide. At the same time, there is a real need for more large-N studies to help explain the variation in global distribution of ICTs, and the comparative impact of policy reform on national development. Though using aggregated trends has been one approach to expand the range of focus across countries, relying on studies that utilize a single point in time[28] or comprise only a few years of transition[29] can only provide a certain degree of analytic purchase. Indeed, our study seeks to fill this need in the literature by offering a cross-national study that spans well over a decade, utilizes an alternative measure of the digital divide, and encompasses a suite of both internet- and non-internet-related ICTs. Next, we consider the question of whether or not the digital divide has been narrowing or widening, and present the measure of the digital divide that will be used to create our study's dependent variables.

III. IS THE DIGITAL DIVIDE NARROWING?

[26] Guillén and Suarez (2005).
[27] Wallsten (2005).
[28] Beilock and Dimitrova (2003); Guillén and Suarez (2001); Volken (2002).

When considering the question of whether or not the digital divide is narrowing or widening, Firebaugh makes the important point that we need to differentiate between *explaining a wide* (or narrow) digital divide and *observing a widening* (or narrowing) digital divide.[30] Much of the research cited above attempts to explain the wide global digital divide, but it is conceptually more useful to explain how and why the digital divide has been changing over time. Has it been narrowing or widening?

It is clear that the best ICTs arrive first in wealthy countries where considerable resources have been devoted to telecommunications infrastructure. Especially during the early days of the internet, most of the nodes of the world's digital communication networks physically resided in one country—the United States—with the rest being scattered among other wealthy countries. In addition, most of the internet's users were located at universities or worked for governments and militaries, lived in urban areas, and paid out-of-pocket for dial-up services. Wealthy countries have continued to develop new ICTs, and their populations have always been the ones to first gain access to the latest innovations. And as the technology to develop new ICTs is dependent on an existing level of technological advancement, a path-dependency argument might take the position that the global digital divide should only continue to widen over time.[31]

The argument that the digital divide is narrowing has been buttressed by statistics that point to the growing number of internet, personal computer, and mobile phone users around the world. Just recently, the "e-readiness rankings" of 60 countries published by *The Economist* found an overall increase between 2005 to 2006 in global access to ICTs

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[29] Bauer and Maitland (2002); Oxley and Yeung (2001).
[30] Firebaugh (1999).
[31] See Van Dijk (2005).

as well as a greater gain in "e-ready" scores for poorer countries.[32] While the e-ready score increased 2.6 percent for wealthiest tier of countries, it increased 6.5 percent for the middle tier, and 10 percent for the poorest tier of countries. Although this study leaves out many of the poorest countries in its analysis, its findings suggest a narrowing of the digital divide. In a similar fashion, Caselli and Coleman confirmed a narrowing of the digital divide with respect to personal computer diffusion in their analysis of 89 countries between 1970 and 1990.[33] Many studies have pointed to the narrowing of the digital divide *within* countries. As the digital divide undoubtedly manifests itself along race, gender, and class lines, Hoffman and Novak as well as Youngs have suggested that the digital divide within nation-states has narrowed.[34]

Whether or not the digital divide is found to be narrowing or widening, common among approaches in the literature is the utilization of diffusion-based measures of ICT infrastructure and usage. Although diffusion is obviously one way of getting at the digital divide, it should be pointed out that scholars have rarely examined the digital divide from the perspective of distribution—essentially as a form of global *inequality*.[35] An examination of the global distribution of ICTs can lead us to analyze the digital divide from a fresh angle; one that focuses on the change that has taken place in the proportion of the world's number of a particular ICT that is located in an individual country.

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[32] See Economist Intelligence Unit (2006).
[33] Caselli and Coleman (2001). While their findings are significant, it should also be noted that much of their study covers the period prior to the introduction of the internet, certainly a central feature of modern computing.
[34] Hoffman and Novak (1998) and Youngs (2002).
[35] While there are some studies which have looked closely at the distribution of such technologies within regions (See Bauer and Maitland [2002]; Estache et al [2002]; Mann and Rosen [2002]; Oyelaran-Oyeyinka and Lal [2005]; Quibria [2002]), the number of cross-national studies (especially those involving non-OECD countries) is only slowly improving (See Ono and Zavodny [2004]; Primrose [2003]; Singh [2004]; Warschauer [2003]).

As an example, consider the case of secure servers, which are used to encrypt data during the transfer of information between a browser and a secure server. Currently, most of the world's secure servers are located in just a handful of wealthy countries. Even if the overall number of secure servers in the world grows, as long as those few countries still possess most of the secure servers there has been no change in their relative distribution among countries. Ultimately, inequality in the global distribution of secure servers still exists and can lead to additional inequality in any new innovations that require an infrastructure of secure servers. Conceptually, there is a difference between studying the global diffusion of ICTs over time and studying the changes in the global distribution of ICTs over time: whereas the former is concerned with the extent to which individual countries increase their number of users or total number of a particular ICT, the latter is concerned with whether or not a more equitable distribution of ICTs is being fostered around the world. To be sure, both are critical to understanding the digital divide. We utilize measures of the global distribution of five ICTs over the last 15 years as our dependent variables and as one way of looking at the digital divide. Through this, we hope to examine whether or not the world's internet users, secure servers, internet hosts, personal computers, and mobile phones continue to remain concentrated in wealthy countries or has become more equitably distributed throughout the world.

Is the digital divide narrowing or widening with respect to the global distribution of ICTs? Elsewhere, it has been argued that Gini coefficients are a meaningful way of measuring how technology resources are distributed among nation-states, weighted by population.[36] Such coefficients range from a score of 0 (where all countries have the same access or usage of an ICT) to 1 (where all access or usage of an ICT is held by only

one country) and are weighted per capita. Figure 1 plots the global distributional trends for inequality in the digital divide for each of the five indicators of technology diffusion tracked by the World Bank, International Telecommunications Union, and World Resources Institute.

FIGURE 1 ABOUT HERE

As Figure 1 reveals, internet users, mobile phones, and personal computers have become much more evenly distributed among nation-states between 1995 and 2005. Mobile phones appear to be the most equitably distributed of all modern ICTs. However, secure servers and internet hosts remain highly concentrated among a small pool of nation-states over this period (although only four years of data exist for secure servers). Though personal computers were originally the most equitably distributed of all the ICTs, after ten years they are relatively more concentrated in a few countries than either mobile phones or internet users. This may mean that internet users in many countries accessing the internet from personal computers, but from libraries, cybercafés, and mobile phones. Indeed, this would support arguments laid out in recent studies by Wheeler and Cartier, Castells and Qui.[37]

All in all, Figure 1 provides important evidence that the digital divide is narrowing in terms of the global distribution of personal computers, internet user and mobile phones, but not in terms of internet hosts and secure servers. What factors can explain improvements in a country's share of the global distribution of a particular ICT?

[36] See Firebaugh (1999); Milanovic (2005).
[37] See Wheeler (2008); Cartier, Castells and Qui (2005).

What role can a state's telecommunication policy play in affecting this distribution? Below, we present our data and then offer an empirical model which seeks to answer these questions.

IV. DATA

To examine how a state's telecommunication policy and other key factors influence a country's share of global ICT, we constructed a panel of 110 countries with data covering the period from 1990 to 2004. The dependent variables employed are discrete measures of a country's share of the world's number of internet users, internet hosts, secure servers, personal computers, and mobile phones during a given year. We argue that a study which includes all of these ICTs offers a broader approach than is typically offered in the literature because it speaks to internet-related as well as non-internet related facets of the digital divide.

On the one hand, it is essential to examine a country's number of internet users because it provides a measure of the degree to which individuals are able to access and utilize the internet and other Web-based technologies.[38] Including a measure of secure servers is also important because this indicator reveals the degree to which a country possesses the capacity to encrypt data during the transfer of information between a Web browser and a server.[39] A measure of the number of internet hosts reveals the number of computers connected to the internet with a distinct national IP address and further speaks

[38] Estimates of internet users are from the subscription rates reported by in-country internet service providers, rates that might not reflect the actual number of people using each shared internet access point (Miller and Slater [2000]). Thus, the number of reported internet users may be underestimated in poor countries where multiple users will share computing resources belonging to friends and family, a library, or cybercafé.

[39] International Telecommunication Union (2006). The data for internet hosts in 2005 were adjusted by Zook (2006) to associate top–level domain names such as *.org and *.com with particular nation–states.

to the development of information societies.[40] At the same time, other digital technologies, such as personal computers and mobile phones, are useful indicators of the digital divide.[41] In the early years the bulk of ICTs were concentrated in a handful of wealthy countries, and there were many countries that simply had no ICTs, zero internet hosts or secure servers for example, so we decided to rank transform the measures prior to running the regressions.

With respect to the independent variables of an economic nature, we first control for the effect of a country's level of economic wealth by including a log transformed measure of GDP which is measured in current United States dollars. We expect that higher levels of GDP will be associated with higher shares of all ICTs. We then test for a country's level of integration into the global economy using two variables: (1) a measure of the percent of a country's GDP that comes from trade and (2) a measure of the percent of a country's GDP that comes from foreign direct investment. We expect that higher levels of trade as well as foreign direct investment will be associated with higher shares of all ICTs. The data for these variables were obtained from the World Bank's World Development Indicators dataset.

The effects of two infrastructural variables are also controlled for: (1) a log transformed per capita measure of a country's kilowatt hours of power consumption and (2) a log transformed measure of a country's number of telephone mainlines. We expect that more telephone mainlines will be associated with higher shares of a particular ICT

[40] Internet Software Consortium (2006).
[41] In many countries, the cost of a personal computer is higher than the average annual income for most citizens. The number of personal computers may underestimate the total use of computers, especially in poor countries where computers are a shared resource, and such a value does not reveal the great differences in the quality of computers. The number of personal computers underestimates the use of computers in countries where mainframe computers are prevalent and where computers are a collective, not

given that this indicator, along with power consumption, can serve as a proxy for the level of development of a country's communication infrastructure. The data for these variables were also obtained from the World Bank's World Development Indicators dataset.

The influence of demographic factors on a country's share of the world's number of a particular ICT are controlled for by including three additional independent variables: (1) a log transformed measure of a country's total population, (2) the percentage of a country's population living in an urban area and (3) the percentage of a country's adult literate population. We expect that higher levels of each of these variables will be associated with higher shares of ICTs. Total population data was taken from the World Bank's World Development Indicators dataset, urban population measures were taken from United Nations datasets,[42] and literacy measures were taken from UNESCO datasets and the CIA World Factbook.

The influence of political regimes is tested for by including a measure of regime type from the Polity IV dataset. This measure ranges from perfect democratic governance, scored at 10, and perfect autocratic governance, scored at -10. These measures are based on an assessment of the competitiveness and openness of the process for selecting the country's chief executive, the extent of constitutional limitations on executive power, the competitiveness of political participation generally, and the stability of the terms that govern public participation.[43]

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personal resource. A count of the number of personal computers may exclude networked gaming systems and other information technologies.

[42] United Nations (2004).

[43] See Jaggers (2004) and the Polity IV dataset at http://www.cidcm.umd.edu/polity.

To test the impact of different state telecommunication policies on a country's share of the world's number of a particular ICT, four independent variables were created that reflect some of the important telecommunication-specific policy tools that states have at their disposal. Firstly, we address the issue of privatization of the state-owned telecommunication provider by constructing a count measure of the years since a country has privatized this sector. Countries that are known to have not done so receive a score of zero, whereas those that have privatized receive a score that reflects the number of years the privatization has been in effect. Those whose status is unknown are judged as missing. For example, Chile effectively privatized its telecommunication sector in 1989, so in 1995 Chile receives a score of six. We feel that this is a more appropriate measure than a binary one that simply measures "privatized" or "not privatized" because we argue that privatization's impact on the digital divide is likely to be felt over time as the market adjusts and new institutional arrangements take shape after formal privatization is concluded.[44] The measures for the privatization variable were calculated from the year in which the government first sold a majority stake in the relevant state-owned telecommunication provider.

Similar logic is applied to the construction of the other three policy variables. For instance, we also include a variable of market liberalization which is a measure of the years since a country's retail telecommunications market has been open to competition between multiple service providers. This is calculated from the year in which competition in long-distance telephony first occurs.[45] We also include a variable of regulatory

[44] It should be noted that there were no cases in which the telecommunications provider was nationalized.
[45] These definitions and data from the period up to 1999 come from Henisz, Zelner and Guillén (2005). Data on additional countries covering the period 1999 to 2004 were collected by hand and are available from the authors.

separation which is a measure of the years since a country's telecommunication authority has been separated from direct supervision by elected officials. Finally, we include a variable of regulatory de-politicization which is a measure of the years since a regulatory authority is judged to have become effectively independent or autonomous from the executive branch. With respect to all variables, if a country had not yet done a particular policy reform in a given year they received a score of zero and those whose status are unknown are judged as missing. For the period 1960 to 1999, data was taken from Henisz et al. (2005), and for the period 2000-2004, data was taken from the World Information Access Project.[46]

To be sure, there are advantages and disadvantages to working with this kind of policy data. For example, it may be that the four types of policy reform are somewhat generalized as there are often important local variations in reform in particular countries. In some countries privatization has involved selling the publicly-developed infrastructure and opening up market competition in many parts of the telecommunication sector, leading to more affordable computers and mobile phones and thus greater internet use. In others, however, privatization has involved creating privately held monopolies, with owners that are indistinguishable from political elites. Countries also often combine policy tools, and there are certainly alternatives to the four that we analyze here. Still, the four policy reform types included in this study are the mostly commonly-used forms of policy intervention in the telecommunication sector and they are also the ones most promoted by multi-lateral lending institutions. None of these measures can capture aspects of the digital divide *within* countries. Across the globe, wealthy people always

[46] Henisz et al. (2005); World Information Access Project (2007)

have better access to ICTs than poor people. Unfortunately, comprehensive surveys of technology access within a host of countries are currently unavailable.

As is common in any time-series study of international political economy, we were forced to deal with the issue of missing data with respect to the study's non-policy-related independent variables. Rather than use list-wise deletion, we decided to undertake a process of data imputation where we thought it was theoretically justified. For one, some country data on adult literacy was missing. Given the relatively static nature of this measure, we decided that if at least one year of data for a country could be found within the time period 1990 to 2004 we imputed this value for all the country's years. Fortunately, however, this situation occurred in less than 10 percent of the country cases used in this study. Additionally, if literacy data were obtained only for the years at the endpoints of the study we used linear interpolation to impute the missing values. With respect to all the other eight independent variables, the data were over 90 percent complete—quite good by any standards in the field. Data were imputed for the variables GDP, urban population, power consumption, and telephone mainlines, and the decisions as to which method to employ were informed by suggestions offered in Little and Rubin.[47] The data for all other variables were either complete or the missing values were left alone. Below, we introduce our empirical model and discuss the results generated.

V. EMPIRICAL MODEL

In order to construct a model of the determinants of a country's share of the world's number of a particular ICT infrastructure or usage over time, we sought

[47] Little and Rubin (1987). Missing values for GDP were mean imputed for a given country. Missing values for urban population were imputed using local interpolation and mean imputation. Also, four missing values were imputed via linear interpolation for power consumption.

inspiration from the methodological advancements made in time-series studies. The panel we created incorporates 110 countries and data were collected annually for each of the countries over the period 1990 to 2004. To begin, we first addressed unit heterogeneity, an important issue that must be dealt with prior to using any estimating method, but especially important in time-series analysis. For our study, we argue that a fixed effects model should be more appropriate than alternative specifications because there are features of the study's units (i.e., individual countries) that are either unobservable or impossible to capture during the estimations. In order to confirm the appropriateness of a fixed effects model, both a Breusch and Pagan Lagrange multiplier test and Hausman specification test were used.

We also confirmed the presence of first-order autocorrelation using a Woodridge test. In order to correct for this, we desired a time-series model that would account for dynamic specifications, and many have been presented in the methodological literature. Here, we chose to follow the route of using a lagged dependent variable and including a fixed effects specification to create the dynamic panel model that is addressed more thoughtfully in Wilson and Butler.[48] This model takes the following form

$$Y_{it} = \alpha_i + \beta X_{it} + \lambda Y_{it-1} + u_{it} \qquad i = 1,\ldots, N \quad t = 1,\ldots,T$$

[48] There is some initial concern in using this model because its least-squares estimates have been shown to be both biased and inconsistent.[48] While there are many available specifications that can correct for this bias, they necessitate an asymptotic N, which is not present in this study. Fortunately, Wilson and Butler report Monte Carlo analysis by Judson and Owen and unpublished work by Adolph, Butler and Wilson as well as Beck and Katz showing that the overall bias would be low for this type of study, though still high when estimating the coefficient for the lagged dependent variable (i.e., λ). Given that this value is of little concern here, we have chosen to adopt the dynamic panel model as the estimation model for this study—indeed, what Wilson and Butler deem "likely to be the best choice." See Judson and Owen (1999); Wilson and Butler (2007).

where Y is a country's rank among the world's distribution of a particular ICT, *i* is an individual country, *t* is a period of time (one year), α_i is the intercept, β is a scalar, X is the set of independent variables, λ is a scalar for the lagged dependent variable, and u_i is the unobservable unit effect.[49] Hence, the results of our time-series study emerge from a dynamic panel model that uses fixed effects to control for unit heterogeneity and a lagged dependent variable to adjust for autocorrelation.

VI. FINDINGS

Table 1 displays the results for the regressions that were ran on a country's share of the world's internet users, internet hosts, and secure servers. Consistent with other studies in the field, we initially find a strong positive, statistically significant relationship between GDP and a country's share of the world's internet users and internet hosts. Thus an increase in a country's economic wealth is associated with an increase in its share of internet users and internet hosts—narrowing the digital divide. This finding makes intuitive sense given that the more an economy grows the more its state is likely to invest in ICT infrastructure and the more the people may have the income to acquire new ICTs. Such a relationship is not confirmed for secure servers, however, though it should be noted that only four years of data are currently available for this variable.

TABLE 1 ABOUT HERE

But these findings suggest that increasing integration into the global economy may or may not lead to a narrowing of the digital divide. The results also indicate that

[49] Wilson and Butler (2007, 108).

neither a country's level of trade or foreign direct investment (measured as percentages of GDP) is a statistically significant predictor of a country's share of internet users or internet hosts. Increasing global economic ties or attracting more foreign investment may not create spillovers with respect to a country's level of ICT infrastructure, or spark the development of an information society

From a demographic standpoint, the results confirm the role of population size and level of urbanization in predicting a country's share of the world's internet users and internet hosts. Intuitively, these findings also make sense given that the overall number of internet users often increases alongside an increase in total population. Given that the bulk of ICT infrastructure is located in urban centers, as more individuals move to these centers it is logical to assume that more internet users will become born. The similar relationship found with respect to a country's share of internet hosts may also lend support to the idea that telecommunications providers further develop internet capabilities and infrastructure when the demand for internet access grows and the population becomes localized in an urban setting.

Levels of adult literacy, however, emerge as statistically insignificant predictors of a country's share of any internet-related ICT. One would presume that increases in literacy levels should lead to an increase in the number of internet users given that accessing and using the internet is contingent on being literate (as well as having some competence in English, it can be argued). Another indicator of human capital might be a better, though the other indicators we explored were less complete than that for adult literacy. Hence our finding here may complement other studies that suggest that investment in the development of libraries, higher education institutions are more

important than literacy programs in narrowing internet-related aspects of the digital divide. As universities played a critical role in the launch of the internet it would be appropriate that the further development of a country's higher educational institutions would be needed to assist the efforts to narrow the digital divide.

With regards to infrastructure, the findings indicate that while a country's number of telephone mainlines is a positive, statistically significant predictor of internet users and internet hosts, a country's per capita power consumption is a negative, statistically significant predictor. For the former, this finding suggests that increasing the number of a country's hardwire telephone infrastructure is associated with an increase in a country's share of the world's internet users and internet hosts. This makes sense given that internet usage is predicated on well-developed telephone infrastructure and it is in this way that a country's infrastructural investments can pay off with respect to a continued narrowing of the digital divide.

However, the relationship between power consumption and internet users as well as internet hosts is negative. Whereas power consumption levels for advanced countries remained relatively constant or increased slightly throughout the period of this study, developing countries experienced far more significant increases in their power consumption levels over the 15 years. Yet these countries were also those that had a lower share of the world's internet users or internet hosts, while those that already possessed a well-developed energy infrastructure—among other industries—by the 1990s were those that have adopted a higher share of the world's supply of both these ICTs. This finding may actually speak to the notion that a certain level of industrialization is a

prerequisite for further development of an information society; countries that are still under-industrialized are those that are experiencing a widening of the digital divide.

In terms of governance, a country's regime type is not found to have a statistically significant effect on its share of the world's internet users or internet hosts. Recent findings by Milner indicating a positive relationship between democracy and per capita internet users as well as internet hosts may not extend to studies of the global distribution of either internet users or hosts. Moreover, this positive relationship does not appear when analyzed through time-series regressions. This could lend credence to the observation that the world's most vibrant blogging and internet-savvy communities are located in both the most authoritarian and most democratic regimes. However, in the case of secure servers a country's political regime does have a statistically significant effect—although negative. Here, the finding would suggest that an increase in democratic governance leads to a decrease in a country's share of secure servers. This may support the idea that authoritarian regimes are acting upon their greater (hypothesized) incentive to foster data encryption technologies for the purposes of government security, a finding suggested by Kalathil and Boas as well as in studies on China by Chase and Mulvenon and Zittrain and Edelman. Given the limited data available for this variable, further research would certainly be needed to confirm this cross-national finding.

The regression results are quite interesting and here we discuss only the statistically significant results. First, we find that ongoing market liberalization by opening a country's consumer communications markets to multiple service providers is associated with a *decrease* in the country's share of internet users, and internet hosts Second, we find that ongoing privatization of the telecommunications sector is only

associated with an increase in the country's share of the world's internet users and personal computers. This suggests that the market can actually exacerbate the digital divide in several respects, while surrendering state control of the national telecommunications provider can help close the digital divide in a few respects. Thus it appears that while the lack of public policy oversight in the consumer market for communications services can make to the digital divide widen, privatization of the national telecommunications provider can help the digital divide close.

We also find that ongoing regulatory separation of a country's telecommunication authority from direct supervision by elected officials is associated with an increase in the country's share of internet hosts. However, de-politicizing the regulatory authority itself is associated with a decrease in a country's share of internet hosts. Hence it appears that the particular way in which regulation of the telecommunication sector is structured has an effect on the extent to which a country fosters the growth of national IP addresses. Perhaps a public regulatory authority that is housed within the state, but comprised of professional technocrats and policy experts, rather than politicians or business leaders, is the best policy approach for narrowing the global digital divide in internet hosts.

The digital divide is also reflected in the distribution of other tools such as personal computers and mobile phones. Table 2 reveals the time-series regression models that explain the variation in each country's share of the world's supply of personal computers and mobile phones.

TABLE 2 ABOUT HERE

Much like the findings with respect to internet-related ICTs, many of the economic, demographic, and infrastructural variables are found to be statistically significant and with the same directionality. There are, however, some interesting differences. To begin, the role of economic wealth is also confirmed with regards to computers and mobile phones, as an increase in a country's economic wealth is associated with an increase in its share of personal computers and mobile phones.

Unlike the findings reported in Table 1, however, here we find that foreign direct investment has a slight negative, statistically significant effect on a country's share of the world's personal computers while trade has a positive, statistically significant effect on its share of mobile phones. In some way, foreign direct investment drives down a country's share of the global supply of personal computers. With regards to the effect of trade, however, it can be argued that increasing integration into the global economy leads individuals to become increasingly exposed to modern communication technologies, such as mobile phones, which are brought inside the country alongside many other goods.

From a demographic standpoint, population size is still found to be positive and statistically significant. However, a country's level of urbanization appears to be unrelated to its share of the world's personal computers or mobile phones. This makes sense given that usage of a mobile phone is not contingent on proximity to an urban center. Yet it is surprising that levels of urbanization are not related to a country's share of personal computers. Given a basic level of electrical infrastructure throughout a country, however, one may argue that it is irrelevant whether an individual is in a rural or an urban center with regards to usage of a personal computer. Adult literacy rates are also found to be positive and statistically significant for a country's share of mobile phones.

Although full literacy in one's native language is not necessarily a prerequisite for mobile phone use, some basic literacy skills are needed to purchase and operate one.

A country's number of telephone mainlines is also found to be a positive, statistically significant predictor of both personal computers and mobile phones. Perhaps most intriguing, the effect of having an extensive landline telephone infrastructure is consistently larger than the effect of economic wealth. Much as in the case of internet-related ICTs, an increase in the development of telephone infrastructure is associated with a narrowing of the digital divide in these realms. In addition, this finding may also allow us to reject "leap-frog hypothesis" whereby countries that have already invested heavily in landline telecommunications systems are argued to have a tougher time developing a suite of digital communication tools. It appears that countries that have already invested in a national, public telecommunications infrastructure are mostly likely to benefit from new information technologies. Clearly, an increase in telephone landlines leads to an increase in internet-related as well as non-internet-related ICTs. At the same time, the relationship between power consumption and mobile phones is negative, exactly what was found with respect to internet users and internet hosts. Here as well, perhaps the driving force is that power consumption is operating as a proxy for overall level of industrialization.

In terms of governance, a country's regime type is not found to have a statistically significant effect on its share of personal computers, similar to the findings above with regards to internet users and internet hosts. However, regime type is found to be a positive, statistically significant predictor of mobile phones, and that increases in democratic governance lead to an increase in a country's share of mobile phones. This

finding would speak to the desire of authoritarian regimes to repress modes of personal communication that cannot be easily controlled by the state. There may be blatant restrictions on the purchase of mobile phones in authoritarian states, or the state may simply tax mobile phone service providers to the point of making owning one a luxury. For certain, the incentive of an authoritarian state to prevent increasing mobile phone usage from the population would be significant as it could contribute to enhancing regime stability. Contrary to previous findings, time-series analysis reveals that economic wealth is not the strongest predictors of a country's share of ICT, and regime type is only useful in explaining the global distribution of mobile phones.

Market liberalization again comes up negative and statistically significant for both of the non-internet-related ICTs. Keeping a country's retail communications markets open to multiple service providers is associated with a *decrease* in the country's share of personal computers and mobile phones—and a consequent widening of the digital divide. Ongoing privatization of the telecommunication sector is found to be associated with an *increase* in the country's share of personal computers. A country's share of mobile phones, it appears, may or may not be affected by whether or not the state controls the country's telecommunication sector.

From a perspective of public policy reform, the only statistically significant finding is that ongoing regulatory separation is negatively associated with a country's share of personal computers. Hence an ongoing separation of a country's telecommunication authority from direct supervision by elected officials is associated with a *decrease* in the country's share of personal computers. While keeping the regulatory authority itself independent from the executive branch is an insignificant

factor, some public policy leadership of the telecommunications sector actually contributes to a rise in computer use. Here, we might think of the ways in which a country's political representatives may seek to benefit its constituencies of ICT consumers in ways that business leaders in the telecommunication sector care far less about. In one sense, given that the computer is viewed as the most "basic" of all ICTs that are available, the establishment of minimal ICT infrastructure and facilitation of individual ownership of a computer is one way that politicians can satisfy some of the primary technological demands of a population. The findings suggest that for some public supervision of the telecommunications sector—perhaps by a professional bureaucracy rather than elected politicians—may be a positive step towards narrowing the digital divide.

In the final analysis, the most consistent results are that market liberalization has a *negative* effect on four dependent variables and that privatization has a *positive* effect on two dependent variables. Thus while privatization may reduce inequality in the digital divide, market liberalization of the consumer market for telecommunications services may exacerbate it. Regulatory separation or regulatory de-politicization produces varying, though often statistically significant, results that depend on the ICT infrastructure or ICT usage in question. These findings underscore an interesting notion that neither blanket state-directed or private sector-directed approaches to help the spread of digital ICTs among countries will work. Instead, a role for the state alongside the private sector appears to be the best recommendation that emerges from this study. Although subsequent analysis of the influence that these policy-related factors have on a country's share of all ICTs certainly needs to be undertaken, what we have presented in

this article is an important step towards understanding how policy reform can impact inequality in the global distribution of digital telecommunications.

VII. CONCLUSION

Instead of taking the traditional diffusion perspective on the world-wide spread of information and communication technologies, usually measured by rates of technology access per capita, we take a *distributional* perspective and offer a way of measuring each country's relative portion of the global supply of ICTs. One important contribution of this study is its utilization of an alternative measure of the global digital divide that focuses on distribution rather than diffusion. This approach offers another window into an examination of the global digital divide—one that centers directly on changes in the distribution of ICT infrastructure and usage that has occurred throughout countries both rich and poor over the last 15 years. Though it is clear that the digital divide has narrowed in most respects, any optimism must be tempered with recognition of the fact that there are still tremendous differences between countries on either side of the global digital divide.

This analysis advances our understanding of the causes of the global digital divide. First, liberalization of the consumer market for telecommunications services has a consistently negative impact on a country's share of the world's information infrastructure, while privatizing the state-owned telephone company can positively impact a country's share of some aspects of the world's information infrastructure. Second, several factors thought to be important in explaining the digital divide appear less relevant when treated by time-series analysis, including literacy, democratization,

foreign direct investment, international trade, and the policy reforms of separating and depoliticizing the regulatory agency. Finally, having an extant, information infrastructure is a strong positive indicator, and exceeds the explanatory power of economic wealth.

This disparity among information societies is distressing. Yet our findings suggest that some of the policy reform tools that states have at their disposal may help to bring about a further narrowing of the global digital divide. We confirmed that the digital divide is slowly closing, and controlling for economic, demographic, political and infrastructural factors, we found that countries with more years of market liberalization in this sector have comparatively smaller shares of the global ICT infrastructure, while privatization in this sector have comparatively larger shares of a few aspects of global ICT infrastructure. Other policy reforms of a regulatory nature appear to have either a nuanced or uneven impact on the digital divide. Indeed, the mix of reforms needed by states to maximize a narrowing of the digital divide is likely to be both complex as well as contingent on the particular way that these reforms are implemented..

It is possible that the effects of these policy reforms take more than 15 years to become positive. But this time-series analysis finds consistently negative medium-term results for market liberalization, some positive results for privatization, and mixed results for the other types of policy reform. To build an information society, the state should not completely withdraw from leadership in the development of a public information infrastructure.

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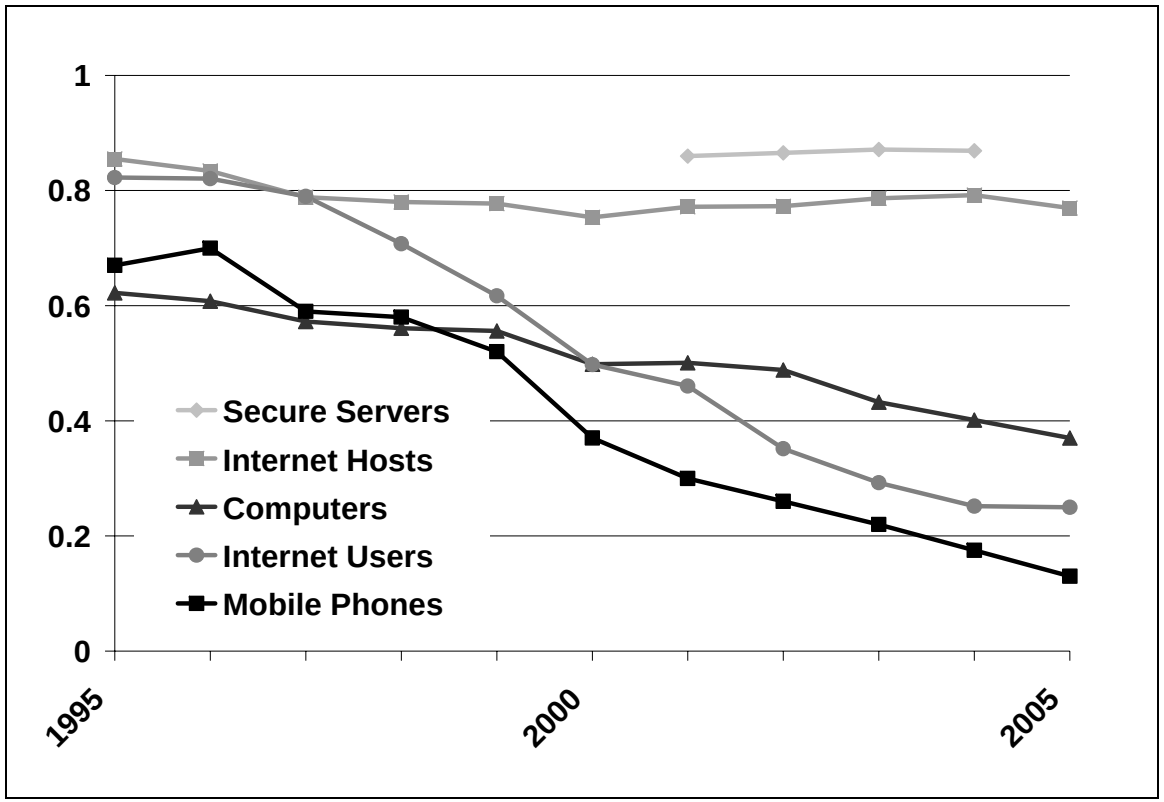
FIGURE 1: Gini Coefficients for 5 Indicators of the Global Digital Divide



Note: The number of countries covered in each year ranges from a low of 150 in 1995 to 210 in 2005.

TABLE 1: Determinants of the Global Digital Divide in Internet Users, Internet Hosts, and Secure Servers, 1990-2004

	Dependent Variables (country's share of the world's total supply of a particular ICT)					
	Internet Users		**Internet Hosts**		**Secure Servers**	
Independent Variables	*Coefficient*	*Standard Error*	*Coefficient*	*Standard Error*	*Coefficient*	*Standard Error*
Economic						
GDP[(a)]	282.253 **	55.592	302.982 **	46.905	-40.380	22.789
FDI	-1.124 e-04	0.001	0.001	0.001	-4.308 e-04	4.037 e-04
Trade	0.761	0.835	1.328	0.699	-0.018	0.401
Demographic						
Urban Population	15.360 **	3.419	15.523 **	2.879	0.056	1.348
Population[(a)]	1,153.968 **	226.425	772.935 **	191.879	97.937	90.073
Literacy	1.788	7.633	-5.641	6.411	-0.896	5.813
Infrastructural						
Power Consumption[(a)]	-444.364 **	89.058	-356.325 **	75.613	7.253	51.549
Telephone Mainlines[(a)]	629.512 **	50.218	503.983 **	41.670	14.109	27.365
Political						
Democracy Index	2.660	5.065	2.630	4.261	-29.118 **	10.114
Telecom Policy						
Privatization	17.562 *	7.906	12.866	6.778	-0.934	4.887
Market Liberalization	-23.230 **	7.861	-22.680 **	6.821	-3.617	5.455
Regulatory Separation	-0.308	7.221	27.348 **	6.250	7.554	6.090
Regulatory De-politicization	-15.833	8.120	-16.232 *	6.956	10.102	5.217
Lagged DV	0.343 **	0.021	0.430 **	0.018	0.153 *	0.072
Constant	-31,490 **	3,501	-24,223 **	2,957	-253.625	1,510.344
N	1,184		1,166		243	
R^2	0.68		0.78		0.21	

Note: ** $p < 0.01$, * $p < 0.05$. [(a)] indicates the variable was logged in analysis.

TABLE 2: Determinants of the Global Digital Divide in Personal Computers and Mobile Phones, 1990-2004

	Dependent Variables (country's share of the world's total supply of a particular ICT)			
	Personal Computers		**Mobile Phones**	
Independent Variables	*Coefficient*	*Standard Error*	*Coefficient*	*Standard Error*
Economic				
GDP[(a)]	103.182 *	45.395	205.931 **	44.389
FDI	-0.002 *	0.001	-0.001	9.316 e-04
Trade	0.594	0.682	2.674 **	0.662
Demographic				
Urban Population	4.827	2.790	2.174	2.712
Population[(a)]	820.881 **	184.930	393.484 *	179.762
Literacy	2.510	6.235	17.261 **	6.051
Infrastructural				
Power Consumption[(a)]	-136.685	72.445	-386.966 **	70.864
Telephone Mainlines[(a)]	222.221 **	39.584	362.139 **	39.176
Political				
Democracy Index	6.445	4.142	9.821 *	4.014
Telecom Policy				
Privatization	16.146 *	6.459	-2.726	6.266
Market Liberalization	-19.376 **	6.420	-27.266 **	6.244
Regulatory Separation	-12.312 *	5.861	4.100	5.734
Regulatory De-politicization	7.798	6.627	8.110	6.432
Lagged DV	0.439 **	0.022	0.415 **	0.021
Constant	-17,669 **	2,852	-14,540 **	2,769
N	1,184		1,184	
R^2	0.53		0.64	

Note: ** $p < 0.01$, * $p < 0.05$. [(a)] indicates the variable was logged in analysis.

Appendix: Descriptive Statistics

Variable	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*
Dependent Variables				
Share of Internet Users	1,425.5	810.75	439.5	2,850
Share of Internet Hosts	1,416.5	805.94	433	2,832
Share of Secure Servers	382.5	219.21	91	764
Share of Personal Computers	1,425.5	804.24	506.5	2,850
Share of Mobile Phones	1,433	822.15	330	2,865
Independent Variables				
Economic				
GDP	22.94	2.36	17.16	30.09
FDI	3,384.34	15,334.71	-34,903.3	321,274
Trade	84.77	47.18	11	433
Demographic				
Urban Population	53.14	24.04	5.3	100
Total Population	15.30	2.12	10.04	21
Literacy	78.89	22.97	11.40	100
Infrastructural				
Power Consumption	7.26	1.58	2.94	10.25
Telephone Mainlines	12.52	2.48	5.03	19.56
Political				
Democratize	2.68	6.79	-10	10
Telecom Policy				
Privatization	4.65	11.17	0	79
Market Liberalization	2.58	6.78	0	42
Regulatory Separation	2.71	4.84	0	44
Regulatory De-politicization	1.76	5.22	0	44