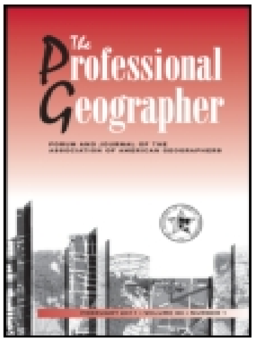

The Professional Geographer

ISSN: 0033-0124 (Print) 1467-9272 (Online) Journal homepage: https://www.tandfonline.com/loi/rtpg20

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To cite this article: Richard Perkins & Eric Neumayer (2011) Is the Internet Really New After All? The Determinants of Telecommunications Diffusion in Historical Perspective, The Professional Geographer, 63:1, 55-72, DOI: 10.1080/00330124.2010.500994

To link to this article: https://doi.org/10.1080/00330124.2010.500994

Published online: 11 Aug 2010.

Is the Internet Really New After All? The Determinants of Telecommunications Diffusion in Historical Perspective

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Recent anxieties over the digital divide have centered on the observation that uptake of the Internet is shaped by a number of identifiable, place-based factors. Yet is the Internet any more a product of material geography than previous communication technologies? Our contribution in this article seeks to address this question by deploying quantitative techniques to examine whether the country-level adoption of past communication networks—mail, telegrams, and telephone—was shaped by similar socioeconomic factors. Our results reveal striking similarities in the domestic attributes—income, education, and trade openness—influencing rates of uptake across all four technologies during their major periods of diffusion. **Key Words: digital divide, global, Internet, quantitative techniques, telecommunications.**

最近对数字鸿沟的忧虑集中于互联网吸收是由可识别的，地点为基础的多种因素形成的这一观察。然而，互联网更多的是材料地理还是以往的通信技术产品？我们在这篇文章中的贡献旨在解决这个问题。本文通过部署定量方法研究是否国家一级对过去的通信网络—邮件，电报，和电话—的采用受类似的社会经济因素的影响。我们的研究结果显示，国民属性—收入，教育，以及贸易开放度—在所有四个技术扩散的主要时期影响吸收率的惊人相似之处。**关键词：数字鸿沟，全球，互联网，定量技术，电信。**

Las ansiedades recientes en torno a la brecha digital están centradas en la observación de que el auge de la Internet está configurado por un número de factores identificables, basados en lugar. Pero, ¿es que acaso la Internet no es un producto de la geografía material como las anteriores tecnologías de la comunicación? Nuestra contribución en este artículo busca enfrentar esta cuestión mediante el despliegue de técnicas cuantitativas para examinar si la adopción de cadenas de comunicación del pasado a nivel de país—correo, telegramas y teléfono—estuvo determinada por factores socioeconómicos similares. Nuestros resultados revelan asombrosas similitudes en los atributos domésticos—ingreso, educación y apertura comercial—que influyen las tasas de auge en todas las cuatro tecnologías durante los períodos de mayor difusión. **Palabras clave: brecha digital, global, Internet, técnicas cuantitativas, telecomunicaciones.**

The emergence of the Internet has been greeted with a mix of optimism and pessimism ("Better Together" 2007). On the one hand, cyber-optimists have celebrated the potential ability of the Internet to free people from traditional place-based constraints and how the technology provides new opportunities for previously marginalized actors to engage in distanciated forms of communication, political mobilization, and economic exchange (Negroponte 1998; Friedman 2005; Tapscott and Williams 2007). On the other hand, cyber-pessimists have drawn attention to the Internet's divisive nature, pointing toward its tendency to reinforce existing and generate new socioeconomic inequalities across space (United Nations Development Programme [UNDP] 2001; Lucas and Sylla 2003; Stevens and O'Hara 2006).

Many geographers, but not all, have fallen into this latter camp (Torrens 2008). Hence, they have highlighted the existence of inequalities in Internet availability, access, and usage, widely dubbed the "digital divide" (M. Graham 2008). Moreover, calling into question cyber-optimists' claims about the uniquely emancipatory nature of the technology, they have suggested that these divides are mapped onto existing spatial inequalities (Warf 2001; Zook et al. 2004). Indeed, far from eliminating the significance of material geography, it is argued that the grounding of the global Internet network in particular territories is crucially

The Professional Geographer, 63(1) 2011, pages 55–72
Initial submission, November 2008; revised submissions, May and August 2009; final acceptance, September 2009.
Published by Taylor & Francis Group, LLC.

dependent on enabling place-based characteristics (Malecki 2002; Warf 2007).

All of this raises an important question: Is the Internet any different from previous technologies? We know from recent statistical research that uptake of the Internet has been governed by a number of identifiable place-based factors. Yet was the uptake of past communication technologies constrained by similar geographic attributes? Understanding this question is instructive about the extent to which uptake of the Internet is more a product of material geography and therefore likely to accentuate inequalities (Cutter, Golledge, and Graf 2002). More generally, it says a great deal about continuity in the geographic patterns of diffusion and whether we can make predictions about the future of the Internet on the basis of previous technologies (Perkins and Neumayer 2005).

Our contribution in this article tackles this question. Focusing on the digital divide at the global scale, we use large-sample econometric techniques to investigate whether the Internet is any different by examining the domestic determinants governing the spatio-temporal diffusion of two public mobilities (i.e., mail and telegrams) and two personal mobilities (i.e., telephones and the Internet) across countries (Kellerman 2006). Our results highlight a high degree of continuity, in that many of the same basic country socioeconomic characteristics—income, education, and trade openness—are found to shape the uptake of all four technologies constituting different mobilities during their major periods of diffusion.

The Global Digital Divide and Its Underlying Determinants

Although the digital divide is a complex construct that can be understood in many different ways, mainstream accounts have tended to define it in terms of variations in the spatial or social distribution of Internet infrastructure, access, or usage (Corrocher and Ordanini 2002; Selwyn 2004; Oyelaran-Oyeyinka and Lal 2005). Such divides have been identified at a number of different spatial scales (Warf 2001). Thus, digital divides have been documented at the national and subnational scale—for example, spatially between urban and rural areas (Whitacre and Mills 2007) and socially between different ethnic and racial groups (Gibson 2003)—macroregional scale—for example, between countries or cities in the same region (Chin 2005; Oyelaran-Oyeyinka and Lal 2005)—and at the global scale (Drori and Jang 2002; Dutta and Mia 2008).

At the latter scale, much of the existing literature has focused on aspects of the "global divide" (Norris 2001, 4) in Internet availability, access, or usage between developed economies on the one hand and developing economies on the other (UNDP 2001; Drori and Jang 2002; Dutta and Mia 2008). This reflects concern about the impact of the digital divide on poverty, economic growth, and other aspects of development in low-income countries and how the Internet might entrench existing sociospatial inequalities (Lucas and Sylla 2003; James 2007; Al-Fahad 2008). Indeed, a common theme of applied, and many academic, discourses surrounding the global digital divide is that narrowing the gap in Internet access will help low-income countries to modernize and develop (see M. Graham 2008). Yet, as shown in Figure 1, the digital divide exists not only between developed and developing countries. Within each of these generic country groupings, cross-national variations in Internet uptake can be found, pointing to a more complex geography of digital inequality.

One way of thinking about these cross-national variations in Internet uptake is as a case of spatio-temporal diffusion (Wood 1998; Comer and Wilke 2008). Briefly, diffusion can be understood as a process whereby a new innovation spreads through a social system over time, sometimes replacing (or partially substituting) existing innovations (O'Loughlin et al. 1998; Shiode et al. 2004; Perkins and Neumayer 2005). Two main mechanisms are identified in the literature to explain diffusion: (1) epidemic-type dynamics whereby contact with previous adopters stimulates uptake as potential adopters learn about a new innovation; and (2) economic-type mechanisms whereby potential users adopt a new innovation as it becomes more profitable, useful, or valuable, with uptake characteristically spreading as costs become lower, performance improves, or the potential uses of the innovation grow over time. For the former, spatio-temporal variations in uptake reflect differences in patterns of contact between adopters and potential adopters,

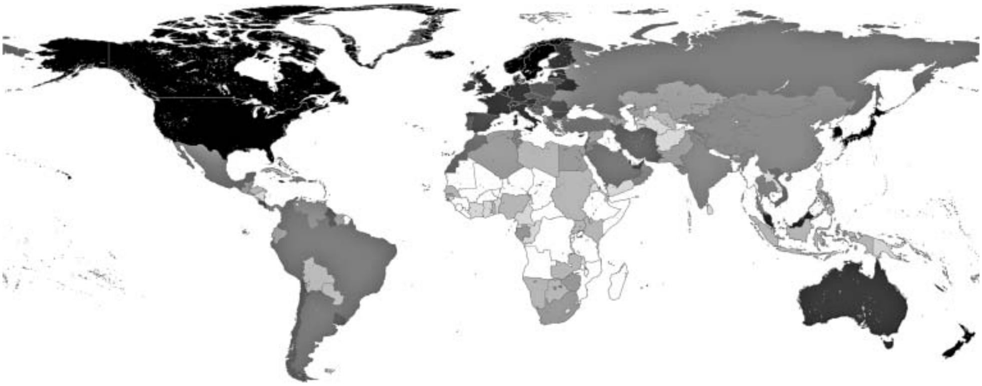

Figure 1 *The global digital divide. Note: Darker colors represent higher number of Internet users per capita (2005–2007 average). Source: World Bank (2009).*

whereas economic accounts emphasize variations in the characteristics of adopters, with some actors better able to afford the costs of an innovation or exploit its economic benefits (Rogers 1995).

Implicitly or explicitly, both of these explanations have been invoked in recent work concerned with the international diffusion of the Internet. Empirically, this work has identified a number of domestic, contextual factors underpinning cross-national differences in Internet penetration. The most important of these determinants, and one that resonates closely with broader concerns about the global digital divide discussed earlier, is income. In nearly all studies, per capita income emerges as a positive correlate of Internet hosts, users, or both, across both developed and developing country samples (Bauer, Berne, and Maitland 2002; Baliamoune-Lutz 2003; Guillén and Suárez 2005; Crenshaw and Robison 2006). The importance of income can readily be explained in terms of economic-type models: Connecting to the global Internet network requires large capital investments (e.g., in terms of hubs and lines) and users have to be able to afford access charges and interface hardware. Hence, effective demand for the Internet is likely to be greater in higher income countries, providing an incentive for private-sector investments in Internet infrastructure and services. At the same time, private and public actors in higher income countries are more likely to possess the financial capacity to fund these investments, or else raise finance from capital markets (Beilock and Dimitrova 2003; Lucas and Sylla 2003; Warf and Vincent 2007).

Income explains a large amount of cross-national inequalities, but the literature identifies three further determinants. One of the most widely studied is human capital, with a large number of studies showing that education exerts a positive influence on domestic uptake of the Internet (Kiiski and Pohjola 2002; Baliamoune-Lutz 2003; Quibria et al. 2003; Andonova 2006; Liu and Gee 2006; Vicente and López 2007). Most likely, this is explained by the importance of linguistic and computer literacy for Internet usage but also by the fact that an educated workforce makes it easier and cheaper to install, operate, and maintain the network infrastructure needed to connect to the global Internet network (Lucas and Sylla 2003; Chin 2005; Warf and Vincent 2007; Comer and Wilke 2008).

Institutional quality, in terms of how well the institutions of state function, make decisions, and exercise authority, is another attribute found to affect uptake (Hargittai 1999; Guillén and Suárez 2001; Andonova 2006; Crenshaw and Robison 2006; Liu and Gee 2006; Chinn and Fairlie 2007). Its significance is widely attributed to the influence of a country's legal, political, and regulatory environment over commercial investment decisions (Henisz and Zelner 2001). Investors are more likely to make large capital outlays in telecommunications infrastructure where the institutional environment provides stable, secure, and credible conditions for investment, such that investors are more likely to obtain economic returns from their outlays.

A third variable is trade (Baliamoune-Lutz 2003). Trade potentially lowers the costs of acquiring the technologies required to interface with the Internet, as well as increasing the economic incentives to adopt competitiveness-enhancing technologies, of which the Internet is a prime example. The influence of trade might also plausibly work via contagion as actors in one country learn about and emulate technological choices made in another country. Finally, a number of studies have identified a role for domestic telecommunications policy, with privatization, deregulation, and policies fostering greater price competition between service providers—for example, through mandatory unbundling and access to the local loop—identified as a positive correlate of Internet diffusion in samples of richer countries (Hargittai 1999; Bauer, Berne, and Maitland 2002; Guillén and Suárez 2005; Warf 2007).

Is the Internet Any Different?

The finding that Internet adoption has been constrained by fairly durable contextual factors would appear to support cyber-pessimists' arguments about the tendency of the technology to reproduce existing geographic inequalities. The question addressed in this article, however, is whether the Internet is any different. At a conceptual level, there are a number of compelling reasons to believe that similar socioeconomic attributes might have influenced the uneven geographic uptake and diffusion of past communication technologies.

As with the Internet, technologies such as mail, telegraphy, and telephony comprise complementary networks of physical artifacts, supporting infrastructures and users (Hugill 1999). Moreover, the grounding of these elements in place-based contexts is likely to have similarly depended on the hardware and software required to make the technology function, as well as the ability, willingness, and motivation of potential adopters to make use of communications services.

We therefore expect income to have played an equally pivotal role in the uptake of older communication technologies. As with the Internet, domestic demand for mail, telegraph, and telephone is likely to have risen with per capita income, in that individuals with higher incomes should have been better able to afford respective user charges and possibly have greater uses for these media. On the supply side, the ability of private or public actors to respond to this demand by making capital-intensive infrastructural investments is likely to have increased with income (Willmore 2002). In much the same way as the Internet, demand for past communication services is likely to have been influenced by the ability of actors to use them and, therefore, by basic levels of education. An educated population might have additionally supported the effective and cost-efficient installation, operation, and maintenance of communication systems, facilitating their expansion.

Investments in capital-intensive infrastructures such as the electric telegraph and telephone services are also likely to have been sensitive to the domestic regulatory, legal, and political environment. In much the same way as the Internet, the existence of weak, unstable, or corrupt political institutions would plausibly have hindered the willingness of profit-seeking private actors to invest, retarding the expansion of new communications infrastructure. Additionally, institutional instability will have made it less likely that governments would be able to commit to, raise financing for, and complete large public-sector communications projects, such as the construction of telegraphy networks.

Similarly, the commercial value of mail, telegraph, and telephones in facilitating international exchange, together with greater competitive pressures, means that demand for long-distance communications services is likely to have been greater in open economies. The geopolitical significance of trade for maintaining or extending economic and political power is also known to have led governments of major trading economies such as Britain to subsidize the development of public mobilities such as intercountry telegraphy networks (Hugill 1999). Additionally, trade is likely to have been instrumental in spreading awareness about new communication technologies, with domestic firms learning from their foreign counterparts (Standage 1998). As per contagion models, such knowledge might have subsequently spilled over into the wider population, stimulating uptake by private individuals.

Of course, the ultimate arbiter of whether the geographic determinants of the Internet and earlier communication technologies are similar is empirical study. There is some existing evidence that points to continuity. Quibria et al. (2003) and Torero, Chowdhury, and Bedi (2006), for example, found a positive relationship between gross domestic product (GDP) per capita and the number of telephone mainlines. Henisz and Zelner (2001) showed that institutional quality has a negative influence on the uptake of digital telephone infrastructure. Similarly, Quibria et al. (2003) found that more educated countries have more telephone mainlines, whereas Perkins and Neumayer (2005) estimated a positive relationship between levels of trade openness and the uptake of digital telephony. More generally, Arnum and Conti (1998) found a positive, bivariate correlation between the wired ratio (the sum of electricity usage, phone lines, and televisions per capita) and the Internet ratio (the sum of Internet hosts, domains, and Web pages per capita).

Yet these studies hardly constitute a robust empirical test of continuity. They are far from comprehensive, examining only a scattering of communication technologies and determinants, and they use different definitions, methodologies, and samples. What this suggests is the need for a more comprehensive and methodologically consistent analysis. We seek to undertake such an analysis using econometric estimation techniques and panel data on mail, telegram, telephone, and Internet uptake. We test the following four hypotheses: Income, education, institutional quality, and trade openness, respectively, have a positive influence on per capita uptake of the Internet, mail, telegram, and telephone.

Method

Our scalar unit of analysis in this study is the state. We readily admit that analyzing technological diffusion at the country level potentially masks a great deal of subnational geographic variability (e.g., between urban and rural areas) in levels of availability, access, and usage over time (Standage 1998; S. Graham 2002). Yet we maintain that our "methodologically nationalist" approach nevertheless remains a useful one for understanding the factors that shape telecommunications connectivity over time.

Dependent Variable

Our dependent variables for this study are the respective annual growth rates in a country's per capita uptake of mail, electric telegraph, telephones, and the Internet.[1] The first two of these, mail and telegraph, are examples of what Kellerman (2006) labels "public mobilities." Telephones and the Internet, on the other hand, are "personal mobilities." As their name suggests, public mobilities involve the use of communication technologies designed for the public at large, access to which is mediated through operating agents that might lie outside the user's private sphere (Milne 2009). Conversely, personal mobilities involve "self-propelled" communications through media, often characterized by greater accessibility and convenience to private users. Whereas the mediated nature of public mobilities implies temporally lagged communications among participants, the individual character of personal mobilities allows near instantaneous communication, reception, and transmission between geographically distanciated actors (see Kellerman 2006).

We use a flow measure of usage for mail and telegrams, for which we have data on the number of mail items and telegrams sent, both on a per capita basis. We also deploy a usage metric for the Internet, albeit one that measures the share of the population with Internet access as given by the number of Internet users per 1,000 people, rather than actual levels of usage (e.g., number of hours online). For telephones, on the other hand, we are forced to use a stock measure of infrastructure, in the form of numbers of telephones per capita. We would have preferred to use exactly the same type of measure across the four technologies, but data limitations mean that this was simply not possible.

Data for our dependent variables for mail, telegram, and telephone are taken from Mitchell (2003). In the case of mail and telegraph, the data stretch as far back as 1830 and 1850, respectively, but comprehensive trade data are unavailable before 1870, so our panel starts with this year for these variables. For telephones, our panel starts in 1890. The telegraph panel ends before 1970.[2] For mail and telephones, the panel stops in 1992 due to unavailability of the historical trade measure variable beyond this point. Lack of data for the dependent or the explanatory variables mean that the sample covers 68, 64, and 101 countries for mail, telegram, and telephone uptake, respectively. This is short of universal coverage, but all samples cover not only high-income countries but also a wide range of low-income ones. (Details of countries and the relevant time periods included in each of the estimations can be found in the Appendix.) Our dependent variable for the Internet uses data from World Bank (2005). These data begin in 1991, but the sample ends in 2003, owing to lack of data on some of the explanatory variables.

Countries enter and—occasionally—exit (e.g., during times of war) the data set according to the availability of data. Our panel is therefore "unbalanced," but the panel estimators used in this study are able to accommodate such data. In cases where territorial changes have occurred during the period of study (e.g., Germany), the data refer to the country in the borders during the year in question. All our variables are normalized by either GDP or population, which also vary with territory, such that boundary changes do not represent a major problem for the analysis.

We chose to focus on postal mail, the electric telegraph, and the telephone because of their historic role in communication. All three technologies have—to a greater or lesser extent and for longer or shorter periods of time—assumed central importance in allowing actors to communicate over space. The chronology of the technologies runs as follows. Modern, prepaid, and publicly accessible postal services began to operate in the first half of the nineteenth century, many of them as public monopolies (John 1986; Willmore 2002). Postal mail was joined in the second half of the nineteenth century by the electric telegraph (Standage 1998). The electric telephone first emerged in the late 1870s, although it was not until the second half of the twentieth century that telephones became more widely used outside the core of high-income, industrialized economies (Hugill 1999; Guillén and Suárez 2005). The Internet dates back to the late 1960s and 1970s in university and military settings but only began to be adopted by a wider range of consumer, business, and governmental actors in the early 1990s (Warf 2001; Shiode et al. 2004). Still, despite becoming one of the fastest diffusing technologies ever, the density of hosts, connections, and users remains highly uneven (S. Graham 2002).

Independent Variables

The four main explanatory variables included in the study—GDP per capita, education, institutional quality, and trade openness—were selected because they have all been identified in recent empirical studies as correlates of national Internet availability, access, or usage. We do not explore the role of telecommunications regulatory policy or prices, simply because there are no comparable historical data for competition (and other) policies or user prices for mail, telegram, and telephone markets. Still, to the extent that no previous studies have analyzed the role of income, education, institutional quality, and trade in the uptake of our four different communication technologies, we believe that our study makes an important contribution to the literature.

Data for GDP per capita is taken from Maddison (2003). For education, we use data on primary schooling because, strictly speaking, not much more than basic education is necessary for the use of communication technologies. In the case of the Internet, we take the primary enrollment ratio, using data from World Bank (2005). These data only cover the period from the 1960s onward and we therefore use Mitchell's (2003) data on the number of primary school students per capita for mail, telegrams, and telephone.

To capture institutional quality, we use Henisz's (2000) metric of political constraints, which is the only available measure that reaches far enough back into the past. It measures the extent to which political actors are constrained in their future policy choices by the existence of other political actors with veto power and by the distribution of political preferences across and within these branches of the political system. That is, it captures the degree to which governments are able to credibly commit to maintaining an existing regulatory regime and therefore the degree of investment risk. Henisz's data have been used to measure institutional quality in previous studies investigating the uneven diffusion of telecommunication

Table 1 *Dependent and explanatory variables summary*

Variable	Underlying concept	Proxy variable	Source
Internet users per 1,000 people	Technology uptake usage	No	World Bank (2005)
Mail items sent per capita	Technology uptake flow	No	Mitchell (2003)
Telegrams sent per capita	Technology uptake flow	No	Mitchell (2003)
Telephones per capita	Technology uptake stock	Yes	Mitchell (2003)
ln GDP per capita	Income	No	Maddison (2003); World Bank (2005)
Primary enrollment ratio	Human capital	No	World Bank (2005)
Primary students per capita	Human capital	No	Mitchell (2003)
Political constraints	Institutional quality	Yes	Henisz (2000)
Trade/GDP	Trade openness	No	Barbieri (1998); Mitchell (2003); World Bank (2005)

Note: GDP = gross domestic product.

technologies (Henisz and Zelner 2001; Andonova 2006), but it is an admittedly crude proxy variable for institutional quality. See Henisz (n.d.) for a detailed description of how political constraints are measured. Our trade measure—trade openness—is given by the sum of exports and imports divided by GDP. For the Internet, we use data from the World Bank (2005). However, because these data do not stretch far back in time, we construct a measure of trade openness for our three historical technologies using data from Barbieri (1998) and Maddison (2003). Table 1 lists the variables, the underlying concept measured, and whether the variable represents a proxy for this concept, together with respective data sources.

Dealing with Statistical Problems

An important statistical challenge is how to deal with the fact that uptake of new technological innovations characteristically accelerates over time, as they benefit from increasing returns to adoption (Rogers 1995). Such dynamics have been observed empirically in the historic spread of communication technologies such as the electric telegraph and telephones (Shiode et al. 2004), as well as the Internet (Chinn and Fairlie 2007). Within this study, we control for these temporal dynamics by including year-specific time dummies. What these variables do is to generate separate intercepts for each year, thus capturing and controlling for global changes in the availability, cost, and functionality of any one technology that affect all countries equally.

We additionally include the natural log of the technology uptake per capita, lagged by one year. This controls for conditional convergence. The rate of diffusion of many technologies is influenced by the existing levels of penetration, in that countries with higher levels of uptake characteristically experience slower uptake growth (Henisz and Zelner 2001; Perkins and Neumayer 2005). We also include the lagged log of technology uptake to control for autocorrelation in the error term (Beck and Katz 1996). The growth rate is equivalent to the natural log of a variable minus its natural log one previous period. Hence, regressing the growth rate on the log-level lagged by one period is equivalent to regressing the log-level on the lagged log-level. The only difference is that the estimated coefficient of the growth rate equation is that of the log-level equation minus one. What is important here is that the inclusion of what is effectively a lagged dependent variable (LDV) allows us to indirectly control for autocorrelation. We employ standard errors that are robust to arbitrary heteroscedasticity to deal with the other common problem of statistical inference.

Another statistical issue is reverse causality, which causes problems because the variable that is subject to reverse causality is also correlated with the error term. The one variable that is likely to be most affected by reverse causality is trade openness. Higher levels of trade openness might well be instrumental in accelerating the domestic uptake of new communication technologies. Yet uptake of new communication technologies might also stimulate higher levels of trade by, for example, enabling the functioning of regional and international production systems (Lew and Cater 2006; Clarke and Wallsten 2007). We deal with this problem by using a dynamic panel data estimator in which trade openness is treated as an endogenous variable (see later).

Estimation Technique

Panel data—of the sort used here—are typically estimated with either a random- or a fixed-effects estimator.[3] The advantage of the random-effects estimator, which treats country effects as a random part of the error term, is that it is more efficient because estimation is based on variation over time within countries, as well as on variation across countries. The country fixed-effects estimator, on the other hand, introduces separate intercepts for each country included in the sample and thus exclusively uses the within- or over-time variation in countries. Fixed-effects estimation is particularly inefficient for explanatory variables that change little over time. The disadvantage of a random-effects estimator is that it produces inconsistent estimates if the country-specific fixed effects are systematically correlated with one of the explanatory variables.

In the next section, we first report random-effects estimation results. Formally, this is modeled as follows:

$$\begin{aligned}(\ln y_{it} - \ln y_{it-1}) &= \beta_0 + \beta_1 \ln y_{it-1} + \beta_2 \ln GDPpc_{it} \\ &\quad + \beta_3 primedu_{it} + \beta_4 instqual_{it} \\ &\quad + \beta_5 \% trade_{it} + \delta_t + (\alpha_i + u_{it}) \qquad (1)\end{aligned}$$

where i denotes each country and t each year, y is technology uptake per capita, and the random effects assumption is that the unobserved random effects α_i have zero mean and are uncorrelated with each of the explanatory variables. We additionally report results from a fixed-effects estimation, which models the α_i no longer as a random part of the error process but as country-specific fixed effects. Lastly, because (1) fixed-effects estimations are slightly biased in the presence of the LDV (Nickell 1981) and (2) we wish to explicitly declare trade openness as an endogenous variable, we also use Arellano and Bond's (1991) dynamic generalized method of moments (GMM) estimator.[4] This estimator removes country fixed effects by first differencing the data. The first difference of the LDV and of the endogenous variable is instrumented for by the levels of each variable lagged by at least two periods. Our T, the total time period, is relatively large, which would give a very large number of potential instruments. However, because using too many instruments can bias the estimation results (Roodman 2007), we restrict the use of lagged instruments to a total maximum of eleven.

Results

Table 2 reports random-effects estimation results. Consistent with past empirical research, GDP per capita, education, trade openness, and institutional quality are found to be positive and statistically significant correlates of domestic growth in number of Internet users. Across all four technologies, we also find that countries with a higher level of penetration in the previous year experience lower growth rates, a phenomenon well documented in the innovation diffusion literature (Perkins and Neumayer 2005).[5]

Of greater interest is the question of whether the determinants of uptake growth for our three historic communication technologies match the Internet's. In the case of income, we find such similarity, with GDP per capita positively and statistically significantly correlated with the uptake of telegrams and telephones. This is entirely plausible. Like the Internet, previous communication technologies involved large, up-front capital investments, and their expansion is likely to have depended on the ability of consumers to afford user charges. GDP per capita is insignificant for mail but becomes statistically significant in the fixed-effects estimation (see later).

Turning to education, we find that the number of primary-schooled students is positively and statistically significantly correlated with telegrams sent and telephones per capita. This is consistent with the idea that uptake depends on people's ability to use communications media and therefore some basic level of schooling. Again, the education variable is statistically insignificant for mail in the random-effects estimation but becomes significant in the fixed-effects estimation (see later).

Table 2 *Random-effects estimation results*

	Internet	**Mail**	**Telegram**	**Telephones**
ln (Internet users per 1,000 people)$_{t-1}$	−0.231***			
	(0.0182)			
ln (mail items per capita)$_{t-1}$		−0.0104***		
		(0.00402)		
ln (telegrams per capita)$_{t-1}$			−0.0765***	
			(0.0126)	
ln (telephones per capita)$_{t-1}$				−0.0463***
				(0.00624)
ln GDP per capita	0.171***	0.0109	0.0524***	0.0834***
	(0.0214)	(0.00749)	(0.0153)	(0.0112)
Primary enrollment ratio	0.00180*			
	(0.000965)			
Primary students per capita		0.0506	0.928**	0.296*
		(0.157)	(0.397)	(0.172)
Institutional quality	0.103*	0.00288	−0.0189	−0.00488
	(0.0615)	(0.0137)	(0.0250)	(0.0128)
Trade/GDP	0.143***	0.00790**	0.00709**	0.0295***
	(0.0357)	(0.00366)	(0.00319)	(0.0104)
R^2 (overall)	0.444	0.078	0.154	0.163
Observations	1,213	2,690	1,723	3,774
Time period	1991–2003	1870–1992	1870–1969	1880–1992
Countries	148	68	64	101

Note: The dependent variable is the annual growth rate in technology uptake. Absolute z values in parentheses. Regional dummies and year-specific time dummies included but not reported. GDP = gross domestic product.
** Significant at 0.1. ** Significant at 0.05. *** Significant at 0.01.*

Table 3 *Fixed-effects estimation results*

	Internet	**Mail**	**Telegram**	**Telephones**
ln (Internet users per 1,000 people)$_{t-1}$	−0.393***			
	(0.0305)			
ln (mail items per capita)$_{t-1}$		−0.0931***		
		(0.0159)		
ln (telegrams per capita)$_{t-1}$			−0.104***	
			(0.0168)	
ln (telephones per capita)$_{t-1}$				−0.0643***
				(0.00745)
ln GDP per capita	0.375	0.144***	0.0822**	0.111***
	(0.331)	(0.0314)	(0.0365)	(0.0147)
Primary enrollment ratio	0.00534			
	(0.00391)			
Primary students per capita		0.571**	1.252***	0.553**
		0.(0.277)	(0.274)	(0.234)
Institutional quality	–0.0322	–0.0543**	−0.00216	−0.0276
	(0.136)	(0.0221)	(0.0300)	(0.0182)
Trade/GDP	−0.0765	0.00943*	0.00718***	0.0450*
	(0.179)	(0.00504)	(0.00212)	(0.0269)
R^2 (within)	0.513	0.127	0.224	0.191
Observations	1,213	2,690	1,723	3,774
Time period	1991–2003	1870–1992	1870–1969	1880–1992
Countries	148	68	64	101

Note: The dependent variable is the annual growth rate in technology uptake. Standard errors in parentheses. Country dummies and year-specific time dummies included but not reported. GDP = gross domestic product.
** Significant at 0.1. ** Significant at 0.05. *** Significant at 0.01.*

Table 4 *Generalized method of moments (GMM) estimation results*

	Internet	Mail	Telegram	Telephones
ln (Internet users per 1,000 people)$_{t-1}$	0.708***			
	(0.0377)			
ln (mail items per capita)$_{t-1}$		0.683***		
		(0.0345)		
ln (telegrams per capita)$_{t-1}$			0.737***	
			(0.0354)	
ln (telephones per capita)$_{t-1}$				0.867***
				(0.0475)
ln GDP per capita	0.427	0.207***	0.162***	0.101**
	(0.441)	(0.0573)	(0.0509)	(0.0488)
Primary enrollment ratio	0.00328			
	(0.00521)			
Primary students per capita		1.660***	1.765***	1.352***
		(0.290)	(0.276)	(0.308)
Institutional quality	−0.143	0.0119	0.0982**	−0.0262
	(0.142)	(0.0288)	(0.0423)	(0.0279)
Trade/GDP	0.301	0.00689***	0.00690***	0.122**
	(0.363)	(0.00237)	(0.00212)	(0.0495)
Test no second-order autocorrelation (*p* value)	−.660	1.127	0.415	1.446
	(0.510)	(0.259)	(0.679)	(0.148)
Observations	1,059	2,759	1,526	3,449
Time period	1991–2003	1870–1992	1870–1969	1881–1992
Countries	148	68	59	101

Note: The dependent variable is the natural log of technology uptake. Absolute z values in parentheses. Year-specific time dummies included but not reported. Trade openness assumed to be endogenous. GDP = gross domestic product.
** Significant at 0.05. ** Significant at 0.01.*

However, our measure of institutional quality appears to have no statistically significant influence on any of the three historic communication technologies, with coefficients for mail, telegrams, and telephones statistically indistinguishable from zero. Although contradicting conventional wisdom about the importance of institutional quality on large infrastructural investments, our results might simply reflect the leading role played by the private sector in financing Internet growth (Warf 2001). Although mail, telegraph, and telephone systems often began their life in the private sector, a large share of investments in expanding these systems was subsequently made by public actors (John 1986; Willmore 2002). Because private actors are likely to be more sensitive to domestic factors influencing investment returns, differences in ownership provide a possible explanation for this anomalous result.

As with Internet users, a country's share of trade in GDP is a statistically significant determinant of growth in mail items, telegrams, and telephones per capita. A possible explanation for this finding is that, by exposing firms to greater competition, domestic imports and exports might stimulate demand for productivity-enhancing communication technologies. Higher levels of trade are also likely to expand demand for communication technologies to the extent that they imply the need for increased long-distance transactions between actors in different countries. As per epidemic models of diffusion, international trade additionally potentially supports cross-country learning, with actors in countries more open to trade more likely to learn about the benefits of new communication technologies.

Note that the reported R^2 values are relatively low. This is because we have chosen to take the growth rate in uptake as the dependent variable. If we had taken the logged uptake level as the dependent variable instead, then the R^2 values would be far higher (above 0.9), and the estimated coefficients and standard errors of all the explanatory variables other than the LDV would be exactly identical. The coefficient of the LDV itself would be that of the growth rate estimation plus one, as pointed out earlier, and the standard error would again be identical. The relatively low reported R^2 values should therefore not be mistaken as evidence of a poor fit of our model: Measures of fit tend to be low when the estimating equation is in growth rates rather than in levels.

In Table 3, we trade off efficiency for potential gains in consistency of estimations by estimating a fixed-effects model instead. For the three historical technologies, the results are all in line with the random-effects estimation results, except that per capita income and primary education variables now become statistically significant with the expected positive coefficient sign for mail.[6]

In the case of the Internet, however, there is a dramatic difference between the random- and the country fixed-effects results. All of the other explanatory variables are statistically insignificant. How might we explain this discrepancy? Most likely, the answer lies in the fact that these explanatory variables change relatively little during the short span of Internet diffusion, such that the fixed-effects estimation becomes extremely inefficient. The fixed effects, together with the existing level of uptake, absorb an enormous amount of variation in the data over the thirteen years of data covered in the study. Hence, the fixed-effects estimator most likely fails to identify the effect of the socioeconomic determinants.

In Table 4, we account for the Nickell (1981) bias and the potential endogeneity of trade openness by using the GMM estimator of Arellano and Bond (1991). For this estimator, the dependent variable now has to be the (logged) uptake level. As pointed out earlier, regressing the log-level on the lagged log-level is equivalent to regressing the growth rate on the lagged log-level, the only difference being that the estimated coefficient of the growth rate equation is that of the log-level equation minus one. The GMM estimation results are very similar to the fixed-effects results in terms of sign and statistical significance of the estimated coefficients. In particular, trade openness, the endogenous variable, remains a statistically significant and positive determinant of mail, telegram, and telephone uptake.[7] This suggests that our results are robust to correcting for the Nickell (1981) bias originating from the LDV and accounting for the potential endogeneity of trade openness.

Conclusion

Among the concerns surrounding the Internet is that it will give rise to new socio-spatial inequalities forged around informational divides between the so-called digital haves and have nots. Underlying these fears is the observation that the global Internet network is not available "anywhere and everywhere" (S. Graham 1998, 168) but, rather, its grounding in place crucially depends on geographic factors influencing the demand for the Internet and the ability of actors to supply this demand (Agnew 2001; Sassen 2002; Warf 2007). Our aim in this article has been to place these anxieties within context by examining whether the adoption of previous technologies—namely, mail, telegrams, and telephone—at the national level was shaped by similar socioeconomic attributes identified in recent work as enabling or constraining the domestic uptake of the Internet. That is, we seek to address the question of whether uptake of the Internet is more a product of material geography than previous communication technologies and therefore more prone to reproducing existing geographically inscribed inequalities.

Our statistical results reveal a striking level of continuity in the territorially grounded socioeconomic attributes shaping the uptake of different communication technologies constitutive of public (i.e., mail and telegraph) and personal mobilities (i.e., telephone and Internet) over the past one and a half centuries. We thus find income has not only influenced spatial variations in the growth of the share of the population with Internet access at the country level over time, but the same applies to mail, telegrams, and telephone systems. Historical continuity is also apparent in the case of education and international trade: Levels of primary education emerge as a positive statistical correlate of domestic growth rates for mail, telegrams, telephones, and Internet users. Similarly, we find that trade openness is associated with a faster growth rate of all four communication technologies examined in this study. Transnational networks via export and import linkages would, in other words, appear to act as a catalyst for the domestic expansion of communication services, both old and new. The sole exception is institutional quality. Although identified as a statistically significant correlate of Internet usage, we find that institutional quality had no statistically significant influence on uptake of mail, telegrams, or telephones. It should, however, be noted that our proxy for institutional quality (i.e., Henisz's political constraints metric) is a crude one, and we cannot discount the possibility that the insignificant result could be due to measurement error.

Our findings therefore indicate that Internet usage would, for the most part, appear to be unfolding unevenly across geographic space according to long-standing geographic determinants that similarly influenced cross-national variations in the uptake of previous communication technologies. Although the Internet might be new, in other words, many of the factors governing its uptake are not. To this extent, our results contribute to a growing body of work that has sought to caution against claims about the supposed novelty of the Internet and the suggestion that it is somehow different (S. Graham 1998; Malecki 2002; Zook et al. 2004; "Better Together" 2007).

Turning to debates about the digital divide, our statistical results indicate that the Internet is not uniquely prone to geographically produced inequality. That is, usage of the Internet does not generally appear to be more a product of the attributes of place than the availability or usage of previous communication technologies. We would qualify this statement by noting that the Internet is the only one of the four communication technologies with uptake that has been affected by institutional quality. Further, because of data limitations, we cannot test the influence of telecommunications regulatory policies or user prices, which are known to influence uptake of the Internet. Yet the finding that income, education, and trade have produced inequalities across the three historic communication technologies examined here suggests that the way in which material geographies affect the Internet is not unique.

All of this does not mean that public policymakers should not worry about the digital divide. Approximately four fifths of the world's population remains "offline," indicating that, despite ongoing catch-up in the number of users in developing countries, a significant global divide persists (Dutta and Mia 2008). Indeed, if historic communication technologies are anything to go by, geographic disparities are likely to continue to narrow in the twenty-first century but not disappear. Another reason to warn against complacency is that statistics indicating a growing number of users in developing countries, and a narrowing gap with developed economies, might hide as much as they reveal. For a start, aggregate country-level figures for Internet access, infrastructure, or usage conceal some of the multiple domestic divides of the Internet, manifest in variations between different geographical areas or social groups (Norris 2001; Warf 2001). Moreover, as pointed out by M. Graham (2008), the relationship between Internet access or availability and development is far more complex than binary accounts of usage–nonusage suggest. For example, the ability of domestic actors to exploit the commercial opportunities provided by the Internet (e.g., by penetrating foreign markets) will be mediated by a complex of additional place-based, extraterritorial, and international factors. Indeed, there is a danger of focusing solely on Internet access and of overemphasizing Internet-based development approaches to the exclusion of other crucial development interventions (Chin 2005; Oyelaran-Oyeyinka and Lal 2005). Still, to the extent that inequalities in Internet access and availability might affect human development, tackling the divide remains a matter of public concern. Our finding that the factors producing the divide are not altogether new suggests that policymakers might draw useful lessons from the past in seeking to advance uptake of the Internet. ■

Notes

[1] Our dependent variable for the Internet is the number of users per 1,000 people. Yet, for all intents and purposes, this measures the same ratio as Internet users per capita.

[2] Because we are only interested in the determinants of uptake growth, we restrict our analysis to the period before 1970, during which time the number of sent telegrams is expanding in the vast majority of countries. After this date, telegraph usage begins to decline, sometimes quite dramatically.

[3] For prior discussion of random- and fixed-effects estimators in geographical research, see, for example, Jones (1991) and Eriksson, Lindgren, and Malmberg (2008). A more detailed introduction to these estimators can be in found in Wooldridge (2009).

[4] We say "slight" bias because the Nickell (1981) bias diminishes as T, the time period covered by the estimations, increases and (with the exception of our

Internet estimations) T is large. See Wooldridge (2002) for an excellent discussion of this estimator.

[5] The coefficient sizes should not be compared with each other across the technologies. The samples are too different, particularly with respect to time, for such a comparison to be useful.

[6] We have no explanation for why the political constraints variable becomes significantly negative in the case of mail. Yet institutional quality is a variable that changes very little over time. For such variables, it is not uncommon for the estimated coefficient sign to switch in moving from random- to fixed-effects estimations.

[7] Note that the number of observations is slightly smaller in the GMM estimation compared to the random- and fixed-effects estimations due to the need for instrumenting the lagged dependent and endogenous variable with further lags. The GMM estimation results have to be regarded with some caution as the estimator is more suitable for samples with smaller T. Also, the estimator depends on the assumption that there is no second-order autocorrelation. Fortunately, test results reported in Table 4 suggest that this hypothesis cannot be rejected.

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Appendix *Country and time coverage of samples*

	Internet		Mail		Telegram		Telephone	
Country	**Start**	**End**	**Start**	**End**	**Start**	**End**	**Start**	**End**
Afghanistan	1996	2003					1959	1980
Albania	1996	2003						
Algeria	1995	2002	1964	1992	1964	1969	1962	1992
Angola	1997	1999					1980	1991
Argentina	1993	2002	1931	1991	1933	1969	1928	1991
Armenia	2000	2003						
Australia	1991	2003	1966	1976	1968	1969	1966	1984
Austria	1991	2003	1923	1992	1924	1969	1923	1992
Azerbaijan	1995	2002						
Bahrain	1996	2003						
Bangladesh	1998	2003					1975	1992
Belarus	1995	2003						
Belgium	1991	2003	1872	1991	1872	1969	1897	1991
Benin	1997	2003					1961	1992
Bolivia	1996	2002					1948	1990
Botswana	1993	2002						
Brazil	1992	2002			1873	1969	1928	1992

(Continued on next page)

Appendix *Country and time coverage of samples (Continued)*

	Internet		Mail		Telegram		Telephone	
Country	**Start**	**End**	**Start**	**End**	**Start**	**End**	**Start**	**End**
Bulgaria	1994	2003					1910	1992
Burkina Faso	1997	2003					1960	1992
Burundi	1997	2003					1964	1992
Cambodia	1998	2003						
Cameroon	1998	2002	1968	1970	1965	1965	1961	1992
Canada	1991	2002						
Central African Republic	1997	2002					1962	1990
Chad	1998	2001					1961	1992
Bangladesh	1998	2003					1975	1992
Belarus	1995	2003						
Belgium	1991	2003	1872	1991	1872	1969	1897	1991
Benin	1997	2003					1961	1992
Bolivia	1996	2002					1948	1990
Botswana	1993	2002						
Brazil	1992	2002			1873	1969	1928	1992
Bulgaria	1994	2003					1910	1992
Burkina Faso	1997	2003					1960	1992
Burundi	1997	2003					1964	1992
Cambodia	1998	2003						
Cameroon	1998	2002	1968	1970	1965	1965	1961	1992
Canada	1991	2002						
Central African Republic	1997	2002					1962	1990
Chad	1998	2001					1961	1992
Bangladesh	1998	2003					1975	1992
Belarus	1995	2003						
Belgium	1991	2003	1872	1991	1872	1969	1897	1991
Benin	1997	2003					11961	1992
Bolivia	1996	2002					1948	1990
Botswana	1993	2002						
Brazil	1992	2002			1873	1969	1928	1992
Bulgaria	1994	2003					1910	1992
Burkina Faso	1997	2003					1960	1992
Burundi	1997	2003					1964	1992
Cambodia	1998	2003						
Cameroon	1998	2002	1968	1970	1965	1965	1961	1992
Canada	1991	2002						
Central African Republic	1997	2002					1962	1990
Chad	1998	2001					1961	1992
Chile	1993	2003	1924	1992	1924	1967	1924	1992
China	1994	2003	1950	1992	1950	1969	1950	1992
Colombia	1995	2003	1912	1981	1924	1969	1924	1992
Comoros	2000	2003						
Congo, Democratic Republic of the	1997	2000	1974	1974	1967	1969	1961	1992
Congo, Republic of the	2002	2003					1963	1992
Costa Rica	1993	2002					1952	1992
Cote d'Ivoire	1996	2003	1965	1978	1960	1969	1960	1992
Croatia	1994	2003						
Cuba							1945	1974
Cyprus	1993	1999						
Czech Republic	1994	2003	1921	1992	1921	1969	1948	1990
Denmark	1991	2002	1893	1992	1893	1969	1902	1992
Djibouti	1996	2003						
Dominican Republic	1996	2003					1950	1981
Ecuador	1993	2003					1960	1992
Egypt	1994	2003	1951	1985	1951	1953	1951	1992
El Salvador	1997	2003			1941	1969	1941	1992
Equatorial Guinea	1998	1998						
Eritrea	1998	2003						
Estonia	1993	2003						
Ethiopia	1996	2003					1952	1992
Fiji	1994	2001						
Finland	1991	2003	1919	1992	1919	1969	1928	1990

(Continued on next page)

Appendix *Country and time coverage of samples (Continued)*

	Internet		Mail		Telegram		Telephone	
Country	**Start**	**End**	**Start**	**End**	**Start**	**End**	**Start**	**End**
France	1991	2003	1875	1992	1875	1969	1890	1985
Gabon	1998	2003					1961	1991
Gambia, The	1996	2000						
Georgia	1996	2003						
Germany	1991	2003	1900	1992	1900	1969	1900	1992
Ghana	1996	2002	1957	1975	1957	1968	1957	1992
Greece	1992	2003	1926	1985	1926	1969	1936	1985
Guatemala	1996	2002					1955	1992
Guinea	1995	2003					1959	1992
Guinea-Bissau	1998	2001						
Guyana	1997	2002						
Haiti							1950	1968
Honduras	1996	2002					1936	1991
Hungary	1992	2003	1966	1992	1924	1969	1924	1992
Iceland	1992	2003						
India	1993	2003	1960	1990	1960	1969	1960	1992
Indonesia	1995	2003	1949	1992	1949	1969	1949	1992
Iran	1995	2003	1954	1991			1952	1992
Iraq			1950	1969	1950	1969	1950	1992
Ireland	1992	2003	1926	1992	1926	1969	1926	1992
Israel	1991	2002	1950	1992	1950	1969	1951	1992
Italy	1991	2003	1895	1992	1895	1969	1895	1990
Jamaica	1995	2002	1962	1991	1964	1969	1962	1991
Japan	1991	2003	1876	1992	1873	1969	1952	1985
Jordan	1996	2003						
Kazakhstan	1995	2002						
Kenya	1996	2002	1964	1992			1964	1992
Korea, Republic of	1991	2003	1952	1992			1953	1992
Kuwait	1994	2003						
Kyrgyz Republic	1999	2003						
Lao People's Democratic Republic	1999	2000						
Latvia	1997	2003						
Lebanon	1997	2002	1950	1972	1950	1969	1960	1991
Lesotho	1997	2002						
Libya	2000	2002	1959	1974				
Lithuania	1997	2003						
Luxembourg	1993	2003						
Macedonia	1996	2000						
Madagascar	1997	2003	1962	1984	1962	1969	1962	1992
Malawi	1998	2003	1965	1986	1965	1969	1965	1992
Malaysia	1993	2003	1960	1992	1961	1969	1960	1992
Maldives	2000	2001						
Mali	1997	2002					1966	1992
Mauritania	1998	2003						
Mauritius	1997	2003					1968	1992
Mexico	1992	2003	1907	1992	1907	1969	1945	1992
Moldova	1995	2003						
Mongolia	1996	2003						
Morocco	1996	2003	1962	1978	1957	1969	1957	1992
Mozambique	1997	2002	1976	1977			1976	1992
Myanmar			1960	1975	1954	1967	1954	1992
Namibia	1996	2003						
Nepal	1996	2002						
Netherlands, The	1991	2003	1871	1989	1870	1964	1901	1990
New Zealand	1993	2003	1920	1992	1930	1969	1920	1992
Nicaragua	1995	2002					1938	1992
Niger	1997	2002					1961	1992
Nigeria	1997	2003	1960	1982	1960	1965	1960	1992
Norway	1991	2003	1905	1992	1905	1969	1905	1990
Oman	1998	2002						
Pakistan	1999	2002	1958	1992	1958	1969	1958	1992
Panama	1995	2003					1955	1992

(Continued on next page)

Appendix *Country and time coverage of samples (Continued)*

	Internet		Mail		Telegram		Telephone	
Country	**Start**	**End**	**Start**	**End**	**Start**	**End**	**Start**	**End**
Papua New Guinea	1997	2002						
Paraguay	1997	2003						
Peru	1995	2003	1919	1959	1919	1959	1938	1992
Philippines	1995	2002	1963	1992	1954	1969	1954	1992
Poland	1992	2003						
Portugal	1992	2002	1929	1991	1933	1969	1926	1987
Romania	1994	2003	1926	1985	1926	1969	1926	1975
Russian Federation	1993	2000						
Rwanda	1997	2002					1965	1991
Saudi Arabia	1996	2003					1955	1992
Senegal	1996	2003					1960	1992
Sierra Leone	1997	2002					1964	1991
Singapore			1965	1991	1965	1969	1965	1988
Slovak Republic	1998	2003						
Slovenia	1994	2002						
Solomon Islands	2000	2001						
South Africa	1992	2002						
Spain	1991	2003	1908	1990	1885	1969	1908	1992
Sri Lanka	1995	2003	1980	1992			1980	1987
Sudan	1998	2003			1959	1969	1971	1991
Swaziland	1996	2003						
Sweden	1991	2002	1890	1992	1890	1969	1916	1992
Switzerland	1991	2002	1881	1961	1884	1961	1901	1961
Syrian Arab Republic	1998	2000	1950	1988	1950	1969	1951	1988
Tajikistan	2000	2003						
Tanzania	1997	2003	1966	1992	1969	1969	1963	1992
Thailand	1993	2003	1913	1992	1913	1969	1952	1992
Togo	1997	2003			1961	1966	1961	1991
Trinidad and Tobago	1996	2002	1967	1992			1967	1992
Tunisia	1995	2003	1959	1983	1959	1969	1959	1992
Turkey	1994	2003	1950	1992	1950	1969	1950	1992
Uganda	1996	2003	1962	1977	1969	1969	1962	1991
Ukraine	1994	2002						
United Arab Emirates	1996	2003						
United Kingdom	1991	2002	1870	1992	1871	1969	1895	1983
United States	1991	2002	1890	1992	1871	1968	1880	1982
Uruguay	1995	2001	1883	1947	1928	1968	1890	1992
Uzbekistan	1996	2003						
Venezuela	1993	2003	1931	1976	1926	1969	1926	1992
Vietnam	1997	2003	1963	1973	1963	1969	1963	1990
Yemen, Republic of	1997	2000						
Yugoslavia	1999	2001						
Zambia	1995	2003	1965	1981	1969	1969	1964	1990
Zimbabwe	1995	2002	1979	1986			1980	1992