Global Digital Divide: A Dynamic Analysis Based on the Bass Model

Chun-Yao Huang and Hua-Ning Chen

Heterogeneity in Internet diffusion across countries is the core issue of the global digital divide—a phenomenon that has attracted wide academic discussions and various international initiatives. However, prior studies on the global digital divide have addressed the issue mainly from a cross-sectional perspective. This article attempts to examine the topic from a longitudinal perspective by using the Bass new product diffusion model, which has been successfully applied in diffusion studies over the past four decades. Summarizing information from an empirical study on 48 countries, the modeling framework finds three types of divide dynamics; assesses the severity of the global digital divide at various Internet diffusion stages; and identifies cultural, economic, and educational factors as the major causes of the global digital divide at different stages. The article concludes with a discussion on marketing and policy-making implications.

Keywords: digital divide, Bass model of diffusion, Internet access, quantitative marketing models, longitudinal study

The "digital divide," which generally refers to the gap between the more privileged who have access and the less privileged who do not have access to information and communication technology (ICT), has been the subject of discussions, analyses, and debates for more than a decade. A keyword search on Google's search engine in June 2009 reported almost four million results for "digital divide." Such attention in the public domain is due mainly to the importance of ICT for productivity gains in the fiercely competitive new economy (Castells 1996; G8 Information Centre 2000; Organisation for Economic Co-operation and Development [OECD] 2003). Because the Internet represents ICT through removal of geographical, temporal, and presentational constraints of information distribution (Cellary 2007), the main focus of the digital divide discussion has been on the "haves" and "have-nots" of Internet access (Sassi 2005; Van Dijk 2006). On the public policy front, a series of reports issued by the U.S. Department of Commerce's National Telecommunications and Information Administration chronicle government endeavors to address digital divide issues (see http://www.ntia.doc.gov/reports.html). Governments around the world also have taken various steps to mitigate the disparity in opportunities to access the Internet (e.g., "e-Japan Priority Policy Program" by Japan's Cabinet, the "i2010" initiative by the European Commission).

On the broader, global stage, the digital divide across countries seems even more obvious. "Issues pertaining to the 'digital divide' will be a key part of the development agenda in the early 21st century, especially as nations compete for success in the global marketplace on the basis of their information technology capacity" (USAID 2001). At the turn of the century, for example, the number of Internet users in Sweden was more than the number of users in all of Africa (Norris 2001, pp. 46–48). Facing such a huge gap, the Global Alliance for Information and Communication Technologies and Development under the United Nation's secretary-general and the United Nations Educational, Scientific and Cultural Organization's Information for All Programme represent attempts of international cooperation by governments to address the global digital divide.

Because the topic has attracted so much attention from the public policy perspective, a large body of academic research has been conducted over a span of ten years, including more than 400 journal articles with the term "digital divide" in their titles that can be extracted from the ISI Web of Knowledge database. Before then, most of the digital divide studies focused on the intracountry divide, though cross-country research on the topic has appeared in recent literature (e.g., Chinn and Fairlie 2006; Martin and Robinson 2007; Ono and Zavodny 2007). However, given the seemingly rich research on both the national and the global digital divide, a methodological problem of related research up to this point is that most studies are "rather static, both in arguments produced and in empirical data used. There is a lack of dynamic approach" (Van Dijk 2006, p. 232). Without a dynamic perspective, insights extracted

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from prevalent static studies that attack digital divide issues are limited in their contribution to public policy making because the latter requires a longitudinal viewpoint.

Considering such a deficiency in the current digital divide literature, it is surprising that marketing scholars are almost absent from the digital divide discussions/debates; none of the aforementioned 400-plus articles were published in a major marketing journal, and few marketing scientists (e.g., Hill and Dhanda 2004; Hoffman, Novak, and Schlosser 2000) have published research addressing the digital divide issue in academic journals outside the ISI Web of Knowledge database. This lack of interest is puzzling because the digital divide pertains to different patterns in ICT product/service diffusions, whereas new product/service diffusion is a popular area of marketing research. Furthermore, marketing scientists are equipped with relatively more sophisticated analytical tools than those typically applied in published digital divide research. The most relevant analytical tool in this respect is the Bass new product diffusion model, which has been widely applied and extended in hundreds of empirical contexts since Bass (1969).

The diffusion of an innovation (like that of the Internet) "over time among the members of the social system" (Rogers 1983, p. 5) has long been of research interest to marketing scholars. The applications of and extensions to the Bass new product diffusion model alone have been numerous among marketing scientists, such that empirical generalizations of diffusions have been available since the 1990s (Mahajan, Muller, and Bass 1995). If it is accepted that "macromarketing" is legitimately within the scope of marketing (Hunt 1976) and if it is agreed that marketing is a form of constructive engagement so that everyone in the world is a stakeholder of the marketing system (Shultz 2007), there is no reason that marketing researchers should stay away from the policy implication–rich digital divide dialogues. This is the motivation of the current study.

In this article, we use the Bass model as the foundation for the analysis of the dynamics of the global digital divide. In what follows, we first sketch a related conceptual background of the digital divide, introduce the Bass model, and outline a set of research questions to be addressed. Then, we report the measurement and data applied in the empirical research, followed by a series of empirical results. Finally, we discuss the limitations and implications and provide issues for further research.

The Digital Divide

The concept of the digital divide has aroused much attention and interest, primarily because information is believed to be an important source of productivity and, consequently, a form of power in the new economy (Castells 1996; Van Dijk 2006). Because the term commonly refers to "the gap between those who do and those who do not have access to new forms of information technology" (Van Dijk 2006, pp. 221–22), the digital divide as a container concept pertains to the inequality in access to information sources, which is generally taken as a segregation or a marginalization process (Sassi 2005). Since the commercialization of the Internet in the mid-1990s, the focus of digital divide discussions has been on unequal access to the Internet across social strata and/or across countries. On the international level, there is a wide gap of Internet diffusion rates between developed and developing countries (Van Dijk 2006). Even within a developed country group, obvious disparities in Internet access also exist (Erumban and De Jong 2006). Given such huge international differences, the global digital divide is widely recognized as a significant challenge to policy makers (Chinn and Fairlie 2006).

Given its universal connectedness, the Internet holds the potential to be a socially leveling technology, which may reduce social inequality. However, the disparities of Internet access diffusions have led many to believe that the Internet, given the gap between those who have access and those who do not have access to it (i.e., digital divide), reinforces and further polarizes inequality (Martin and Robinson 2007; Willis and Tranter 2006). Therefore, the dynamics of Internet diffusion and the future digital divide that such dynamics shape are fundamental in understanding the various roles of the Internet in different countries in the future. As we argue in this study, public policies that attempt to address the disparity should be based on such a consideration so that the resources can be more efficiently allocated.

Temporary or Persistent Divide?

Whether the digital divide is widening or narrowing has been an important public policy question that has attracted much debate. Some studies claim that the gap between the digital haves and have-nots is narrowing (e.g., Camagni and Capello 2005; Martinelli, Serrecchia, and Serrecchia 2006; Shelley et al. 2004), while some comment that the digital divide issue is "on the sidelines" (Strover 2003). However, some research has concluded that the digital divide problem has not been mitigated and, on the contrary, that the existing gap may get wider (e.g., Coco and Short 2004; Demunter 2005; Sassi 2005).

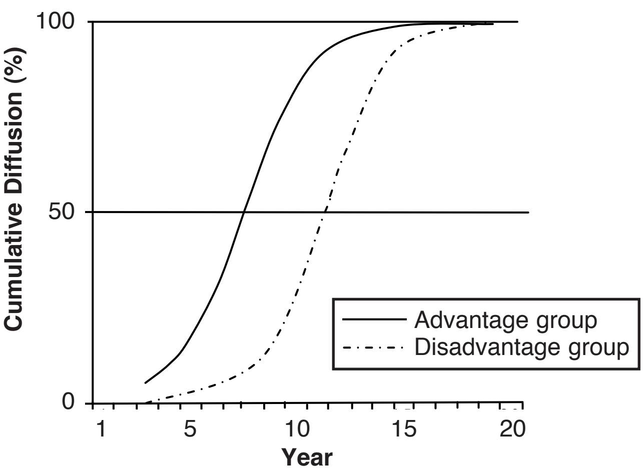
Such controversies can be represented by Norris's (2001) distinction between the "normalization" picture and the "stratification" one. According to Norris, the digital divide in a normalization model is a temporary phenomenon—the advantaged group just leads the diffusion process, while the disadvantaged group ultimately catches up in Internet diffusion. The digital divide in this sense pertains not to the gap between haves and have-nots but rather to that between "have-nows" and "have-laters" (Shelley et al. 2004).

Conversely, the digital divide in a stratification model implies a double jeopardy of the disadvantaged group: People in this group will have access to the Internet later, but fewer people in this group will ultimately gain access to the Internet. The digital divide in this sense is a "trickle-down" process (Willis and Tranter 2006), whereas inequality is persistent rather than temporary. Figure 1 illustrates the two models.

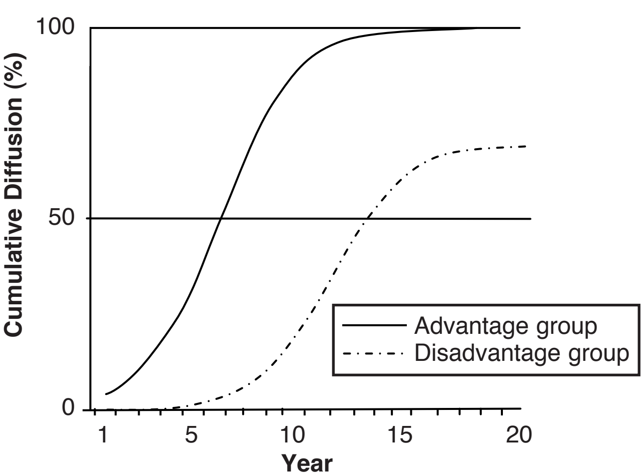
The question regarding which of the two models best represents the dynamics of digital divide, as scholars use cross-sectional data drawn from various times in different studies, is controversial and inconclusive in the related literature. A more comprehensive answer to this question

Figure 1. Norris's (2001) Normalization and Stratification Model of the Digital Divide

A: Normalization



B: Stratification



hinges on a dynamic analytical framework that is missing from the related literature.

Factors Contributing to the Digital Divide

Inequality of access to the Internet is often treated as a function of macrolevel factors (Ono and Zavodny 2007). In this light, the level of income is usually the dominant indicator of the digital divide (e.g., Chinn and Fairlie 2006; OECD 2003; Van Dijk 2006; Vicente and Lopez 2006). Other factors that explain the digital divide include geographical location (Whitacre and Mills 2007), economic equality (OECD 2003), national culture (Erumban and De Jong 2006), English language exposure (OECD 2003), and age (Van Dijk 2006; Vicente and Lopez 2006). However, note that such findings are from cross-sectional studies of the digital divide in which the time of analysis is arbitrarily chosen.

Research Questions

Given the foregoing background discussion and our focus on the global digital divide, this research aims to address a set of questions that are critical to understanding the digital divide on a global scale and are relevant to policy making but have not been addressed in the current literature. The main research questions of interest in this study are as follows:

RQ1. Longitudinally, how can we describe and classify the dynamics of the global digital divide?

RQ2. Without large-scale international coordination and cooperation, what type of prediction can we make about the global digital divide in the future?

RQ3. Which variables explain differences in diffusion of the Internet across countries at various stages of diffusion? Do their roles change over time?

Cross-sectional approaches are not capable of posing these questions, let alone answering them. These important questions are absent from prior global digital divide discussions, at least partly because of the lack of an appropriate analytical tool for a longitudinal analysis of dynamics in global disparities of Internet diffusion. As we propose in the following, such a tool exists and has long been applied to various contexts by marketing researchers analyzing and predicting the diffusion of new products/services—the renowned Bass new product diffusion model (Bass 1969).

The Bass Model

The Bass (1969) model assumes that subjective to both "external" influences (e.g., mass communication and marketing activities) and "internal" influences (e.g., word of mouth) that work through network effects of consumer interdependencies, people in a market system adopt a new product. The underlying assumption of the model is that the hazard function (the probability that a person will adopt the product at time point t, given that he or she has not yet adopted it) is as follows:

$$\frac{f(t)}{1-F(t)} = p + qF(t), \tag{1}$$

whose cumulative density function is

$$F(t) = \frac{1-e^{-(p+q)^t}}{1+\frac{q}{p}e^{-(p+q)^t}} \tag{2}$$

and whose probability density function is

$$f(t) = \frac{\frac{(p+q)^2}{p}e^{-(p+q)^t}}{\left(1+\frac{q}{p}e^{-(p+q)^t}\right)^2}. \tag{3}$$

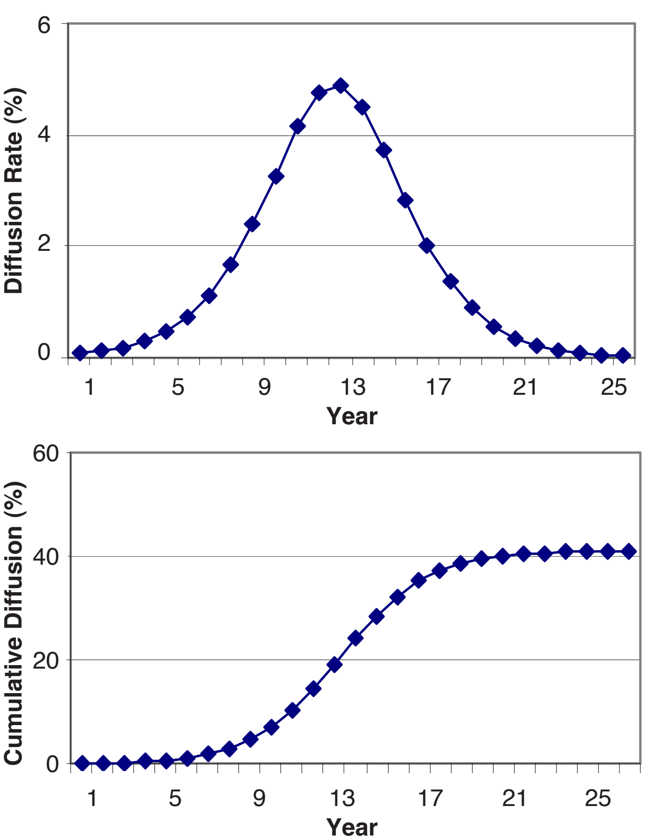
In our context, we have the following:

$$\frac{N(t)}{Y(t)} = \frac{M}{Y(t)}F(t) = mF(t). \tag{4}$$

In these equations, p captures external influences, q captures internal influences, N(t) is the cumulative number of adopters at time point t, Y(t) is the population in the market system of concern at time point t, M is the market's expected number of adopters in the long run, and m is the market's expected ultimate penetration level. In our empirical setting, which we discuss subsequently, we estimate the three parameters p, q, and m of Internet diffusion for each country from the data, and these serve as the foundation for us to address the three research questions. Figure 2 illustrates the S-shaped cumulative diffusion level and the bell-shaped diffusion rate of the Bass model when $q > p$—the case observed in most diffusion contexts.

During the past four decades, the Bass model of diffusion has been widely used (Talukdar, Sudhir, and Ainslie 2002) because it "has great appeal,… is simple, generally fits data well,… [and] performs better than many more complex models" (Hauser, Tellis, and Griffin 2006, p. 690). Furthermore, it "has been the most often used method also in cross-cultural diffusion studies" (Puumalainen and Sundqvist 2005, p. 24). Numerous academic publications report studies that have successfully used the model on hundreds of categories ranging from consumer packaged goods to household durables and from services to industrial products (see Bass's Basement Research Institute 2008). It is one of the few models in marketing science that is robust enough and has accumulated a substantial amount of empirical studies such that an empirical generalization is feasible (Mahajan, Muller, and Bass 1995). Scholars with various backgrounds have used the Bass model for the analysis of multicountry diffusion of technology (for a review, see Chandrasekaran and Tellis 2007), Internet diffusion (e.g., Everdingen, Aghina, and Fok 2005; Fornerino 2003; Puumalainen and Sundqvist 2005), and public policy studies (e.g., Redmond 1996). However, the Bass model has not been applied to the study of the digital divide.

Figure 2. The Bell-Shaped Diffusion Rate and the S-Shaped Cumulative Diffusion Level from the Bass Model



Determinants of the Global Digital Divide

The Bass model, per se, is sufficient to address the first two research questions we posed, given appropriate longitudinal data. The third question (on the determinants of the global digital divide) requires some discussion before we move to the empirical stage of analysis. Referring to both the extant digital divide literature and the innovation diffusion literature, we propose a series of factors that are likely to affect the global digital divide in the long run. In the next section, we empirically validate their hypothetical influences using the Bass model of diffusion.

Income

In the context of international diffusion, it has long been established that wealthier countries adopt earlier (Dekimpe, Parker, and Sarvary 2000; Lee 1990; Mascarenhas 1992). Given the socioeconomic implications of this, a country's general income level should be closely associated with the penetration of Internet access. This also suggests that income is the variable that most directly correlates with economic barriers to Internet use (Martin and Robinson 2007). Prior research has proposed that income affects the speed with which an inhabitant of a specific country adopts a new product (Helsen, Jedidi, and DeSarbo 1993). A well-known study in the diffusion literature also posits that, in general, innovators are wealthier than later adopters (Rogers 1983). Thus, we posit that a wider digital divide occurs between two countries that have a wider gap of income levels.

Education

A general finding in the diffusion research is that educated people tend to adopt new products earlier than noneducated people (Dholakia, Dholakia, and Kshetri 2003; Rogers 1983). Education has been empirically found to make people more receptive to innovations so as to accelerate the diffusion process (Tellis, Stremersch, and Yin 2003). Because Internet usage requires skills that are strongly related to education, a country's general education level is likely to be an important determinant of the speed of Internet diffusion in the country over time (Hargittai 1999). Therefore, we posit that a wider digital divide occurs between two countries that have a wider gap of education levels.

National Culture

Prior research has suggested that a country's culture influences the speed with which its consumers adopt a new product (Dekimpe, Parker, and Sarvary 2000). When considering national culture, the most popular referential system is that which Hofstede (1980, 2001) proposes. According to Hofstede, four dimensions characterize a country's culture in terms of attitude, values, and social norms: power distance, uncertainty avoidance, individualism/collectivism, and masculinity/femininity. Here, power distance pertains to the degree to which the less powerful in a culture accept unequally distributed power; uncertainty avoidance refers to the general degree of anxiety for people in a culture when facing unstructured or unusual situations; the dichotomy of individualism/collectivism represents the extent to which people in a culture are on their own and only loosely coupled (individualism) in the society or are highly, cohesively integrated by a strong social bound (collectivism); and the dichotomy of masculinity/femininity reflects the preference of a society between assertive and competitive values (masculinity) and the contrasting values of modesty and caring (femininity) (Hofstede 2001). Although prior studies have not elaborated on the relationship between the diffusion gap and culture, they have examined the association of culture with diffusion speed. Rogers (1983) proposes that societies low in uncertainty avoidance are more willing to take risks and more readily accept new products. Moreover, societies high in uncertainty avoidance consider novel ideas dangerous and are more intolerant toward change than those low in uncertainty avoidance (Hofstede 2001). Previous research has also found that products take off faster in countries low in uncertainty avoidance than in countries high in uncertainty avoidance (Tellis, Stremersch, and Yin 2003).

Prior studies have not directly elaborated on the relationship between the digital divide and culture, but there is empirical evidence that Hofstede's (2001) cultural dimensions influence (1) new product diffusion in the Bass modeling context (e.g., Talukdar, Sudhir, and Ainslie 2002; Yaveroglu and Donthu 2002), (2) Internet adoption (e.g., Gong, Li, and Stump 2007; Yeniyurt and Townsend 2003), and (3) the takeoff in diffusion (e.g., Chandrasekaran and Tellis 2008). Therefore, we posit that a wider digital divide will occur between two countries that have a wider gap of national culture, as assessed using Hofstede's (2001) measurement system.

Empirical Analysis

Method

Given a set of countries, we calibrate the Bass model on each country's household Internet diffusion data so that the country's Internet diffusion in the past can be captured by the three parameters and its future path can be predicted. Focusing on the digital divide on a global scale and addressing the first two research questions (RQ1 and RQ2), we next compare the diffusion paths derived between any two countries. If there are K countries under study, we make $[K(K-1)]/2$ comparisons to exhaust every possible combination of a pair of countries.

Figure 3 illustrates a real-world case (as one of many pairs of countries that we empirically studied, please see the following for details) of the aforementioned comparison of Internet diffusion that represents the digital divide dynamics between two countries. As the top panel in Figure 3 shows, the Netherlands had a faster rate of Internet diffusion than Bulgaria during the early years. When the diffusion rate slows down in the Netherlands, Internet diffusion still picks up in Bulgaria, and later there is a time when Bulgaria outpaces the Netherlands in the Internet diffusion rate. The cumulative picture of the process, as the middle panel in Figure 3 illustrates, is that the two countries first have an increasingly widening gap of Internet diffusion up to time point t_1. After t_1, however, the gap narrows. In the long run, the gap is smaller than that at time t_1 but will never close. Thus, the bottom panel in Figure 3 presents the gap of Internet diffusion between the two countries over time. This is a typical case of Norris's (2001) stratification scenario, but there are other possible scenarios, as we report subsequently.

From such an illustration, it is clear that the reality of the digital gap is never a static one. Most of the prior cross-sectional studies on the issue have simply examined the gap of Internet diffusion at an arbitrary time point. Coupled with the heterogeneity in data coverage, it is no wonder that research studies render conflicting views as to the trend (e.g., widening or narrowing of the gap) of the digital divide and inconsistent conclusions as to the influences of certain factors on the digital divide.

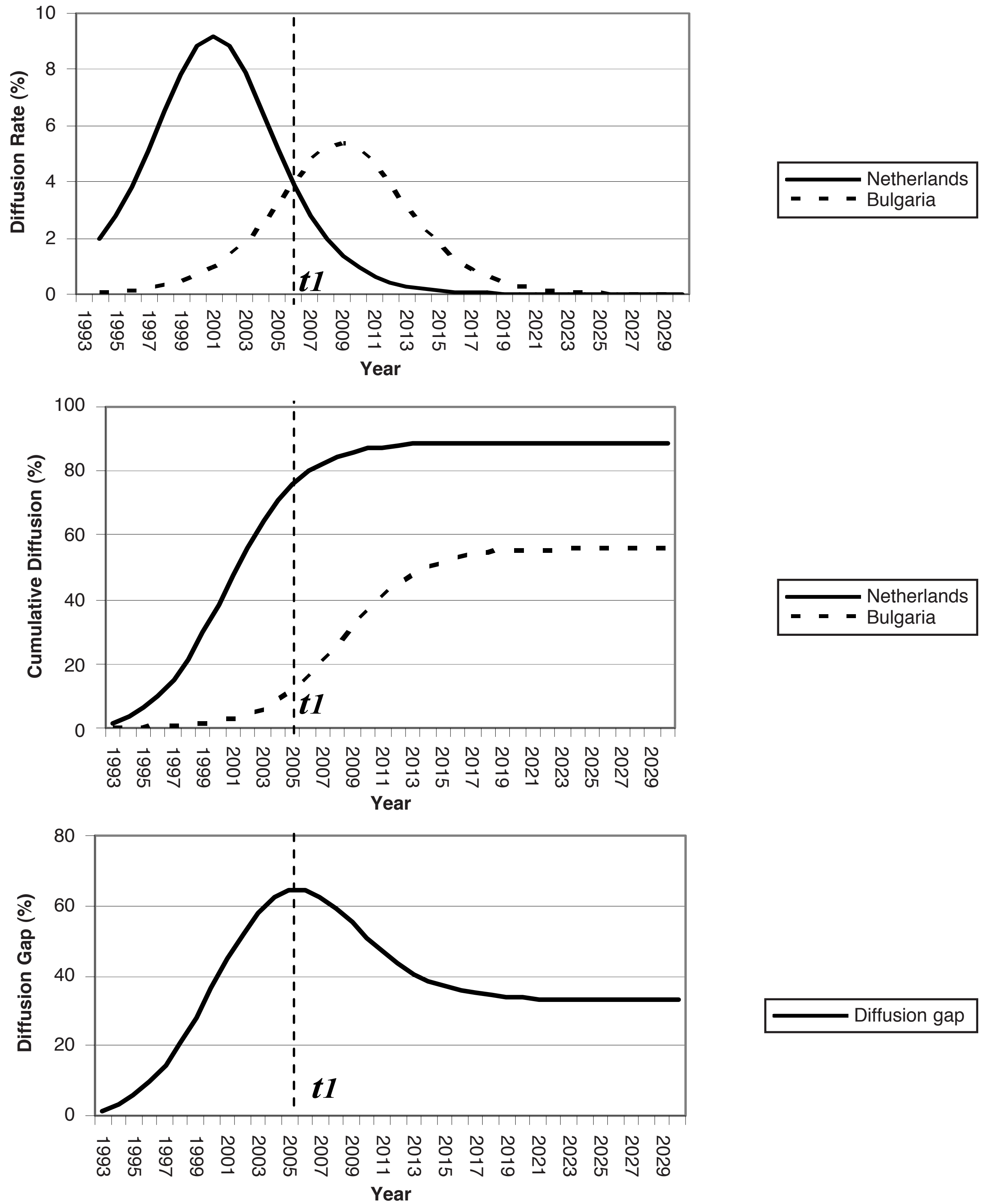
We now report the patterns and extent of the global digital divide in terms of such country-pair comparisons. Because the "divide" is always changing, we especially focus on two crucial points on the timeline. First, we consider the point when two countries under comparison have the maximum gap of Internet diffusion. Here, t_1 in Figure 3 represents such a point. Thus, we are concerned about the explanations of the extent of the maximum diffusion gap (t_1 in Figure 3). Second, we look into the foreseeable future and focus on the gap of "ultimate" (i.e., long-term) diffusions that the Bass model can predict.

To address RQ3, instead of using a single year's data for inference, we calibrate a series of multiple regression models, each for a single year's data (every three years from year 1996 to year 2008; five models), plus one for the predicted ultimate penetration scenario. In each model, a country's level of Internet penetration up to that data year is the dependent variable. The independent variables are the posited determinants of the global digital divide—the income and education variables reflect a country's corresponding levels in the analyzed year, and the cultural variables for a country are assumed to be fixed over the years.

Data

The Global Market Information Database (GMID) published by Euromonitor International provides each country's household-level penetration of Internet-enabled computers—a close proxy of Internet diffusion for each year between 1993 and 2008. The number of data points for each country is the same. Because many research studies during the past decade have considered digital divide issues from the perspective of the gap between households with Internet access and those without (Fisher and Bendas-Jacob 2006), we use household-level data for the calibration of the Bass model and the longitudinal analysis of the digital divide between any pair of countries under study. The GMID records data of 71 countries. Among the 71 countries, 4 cannot converge on model estimation, and another 19 show cultural dimensions that have not been studied by Hofstede

Figure 3. Dynamics of the Digital Divide Between Two Countries



(2009). We drop these 23 countries, leaving data from 48 countries for analysis in the empirical study.

To examine RQ3, we collected the gross domestic product (GDP) per capita data from GMID for the measurement of income. We used the literacy rate reported in the GMID as the proxy of the education variable. We adopted the culture dimensions, including power distance, uncertainty avoidance, individualism/collectivism, and masculinity/

femininity, from the work of Hofstede (2001). We standardized the variables before entering them into the regression analysis for RQ3.

Measuring the Gap of Internet Diffusion

As discussed, we use the maximal Internet diffusion gap and ultimate Internet diffusion gap as the two indicators of digital divide between two countries. To begin, we estimate the three parameters p, q, and m of the Bass diffusion model for each country in the data set with nonlinear least squares using the SAS procedure PROC MODEL. However, an empirical limitation of the Bass model is that unless "the data under consideration include the peak of the noncumulative adoption curve" (Putsis and Srinivasan 2000, p. 280), the estimates will be unstable (Putsis and Srinivasan 2000; Van den Bulte and Lilien 1997). Unfortunately, for some countries under study, it is apparent that Internet diffusion has not yet arrived at a "peak," and therefore these countries have, until now, not experience an inflection point in their cumulative adoption of the Internet. To address the problem, use of information derived from other markets or situations to extrapolate model parameters, especially that of m, has been suggested (Elliott, Granger, and Timmermann 2006; Van den Bulte and Lilien 1997). Given that we have similar household-level diffusion data of other digital product categories that have a longer history of diffusion in the GMID, we propose a four-stage estimation that resorts to the extrapolation of model parameter m from these more mature product categories in such countries. We introduce details of the four-stage approach in the Appendix.

Given the parameters, for each country-pair comparison, we are able to identify when the maximal diffusion gap occurs by a numerical search along the diffusion trajectories predicted by the model. We are also able to predict the two countries' ultimate Internet diffusion gap by comparing their m (market potential) parameter. We then calculate a ratio of the higher diffusion level (between the two countries under comparison) to that of another country with a lower diffusion to measure the extent of the maximal gap and, likewise, another ratio to measure the extent of the ultimate gap. For example, if the maximal Internet diffusion gap between countries A and B happens when country A has an Internet diffusion level of .6 and country B has one of .2, the maximal Internet diffusion gap between the two countries is 3 (i.e., measured by the ratio .6/.2). Likewise, if country A's ultimate Internet diffusion level is predicted to be .8 and that of country B's is estimated to be .4, the ultimate diffusion gap between the two countries is 2 (i.e., measured by the ratio .8/.4). Consequently, the ratio has a lower bound at 1 (indicating an identical ultimate level of Internet diffusion between two countries) and no upper bound.

Number of Pairs of Countries

Because we include 48 countries and consider every possible pair among these countries in this empirical study, 1128 (48 × 47 ÷ 2) country pairs (gaps) occur in the study. Following the aforementioned measurement for the variables of concern, we have 1128 data points for the analysis for RQ1 and RQ2. Each data point covers the previously described variables.

Results

Fit and Prediction of the Bass Model

We conduct the empirical research for the purpose of addressing our three research questions. For the analysis to be relevant, however, the necessary condition is that the Bass model for the longitudinal study shows a good fit of the data.

Figure 4 presents the fit of the Bass model on the 1993–2008 yearly data for the 48 countries by R-square—a typical indicator of model fit on applying the Bass model. Judged by the mean of the 48 R-squares at .986 and their range from .944 to .999, it is clear that the Bass model fits the data well. From a one-year-ahead holdout sample forecast using data from year 1993 to year 2007 and predicting the diffusion level of year 2008 across the 48 countries, we achieve a mean absolute percentage error of .0750—a figure close to the lower bound in reported predictions by the Bass model (e.g., Bass, Jain, and Krishnan 2000; Ganesh and Kumar 1996; Michalakelis, Varoutas, and Sphicopoulos 2008). Given the satisfactory fits/predictions, we report results related to the three research questions one-by-one in the following subsections.

Types of Digital Divide

From the 1128 pairwise comparisons, we identify three types of digital divide and label them as Types A, B, and C. For Type A cases (Figure 5, comparing the United Kingdom with Russia as an example), the gap of ultimate (long-term) Internet diffusion between the two countries under comparison is smaller than that of the maximal Internet diffusion. In the figure, the United Kingdom outpaces Russia and reaches the inflection point (point "a" in Figure 5, around year 2001) in the S-shaped cumulative diffusion figure first. After reaching the inflection point, the diffusion rate in the United Kingdom gradually slows down but still outpaces that of Russia until the point at which the two curves of the noncumulative diffusion rate cross (point "b" in Figure 5, around year 2004). Basic calculus shows that this point reflects the maximal diffusion gap. After this

Figure 4. Distribution of R-Square of the Country-Level Internet Diffusion Estimated by the Bass Model Using Data from the 48 Countries

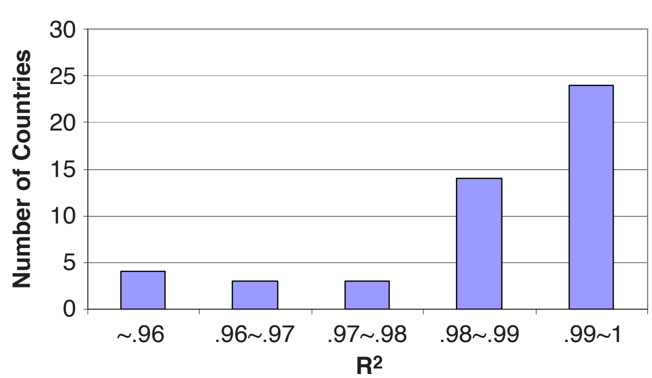
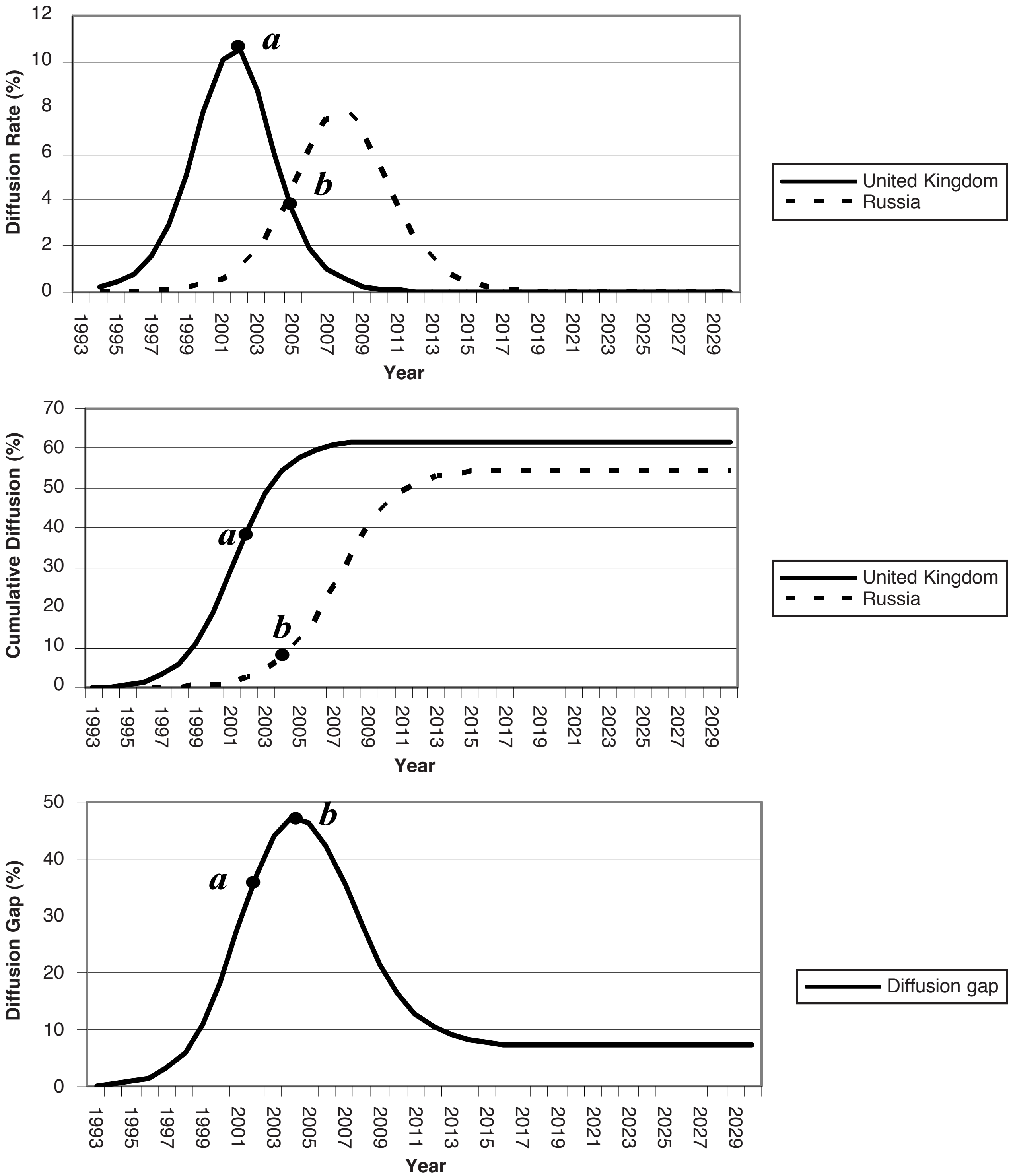


Figure 5. Type A Digital Divide



point, the gap between the two countries gradually narrows and, in the long run, approaches the ultimate diffusion gap.

For the Type B cases, as Figure 6 (comparing France with Portugal as an example) illustrates, Portugal never catches up to France's diffusion of the Internet before the corresponding diffusion momentums of both countries gradually vanish. Here, the gap of diffusion gradually widens over time and never becomes narrower. Therefore, the maximal diffusion gap is exactly the ultimate (long-term) diffusion gap.

Type C cases are those in which the leading/lagging status between two countries reverses at some point on the dif-

Figure 6. Type B Digital Divide

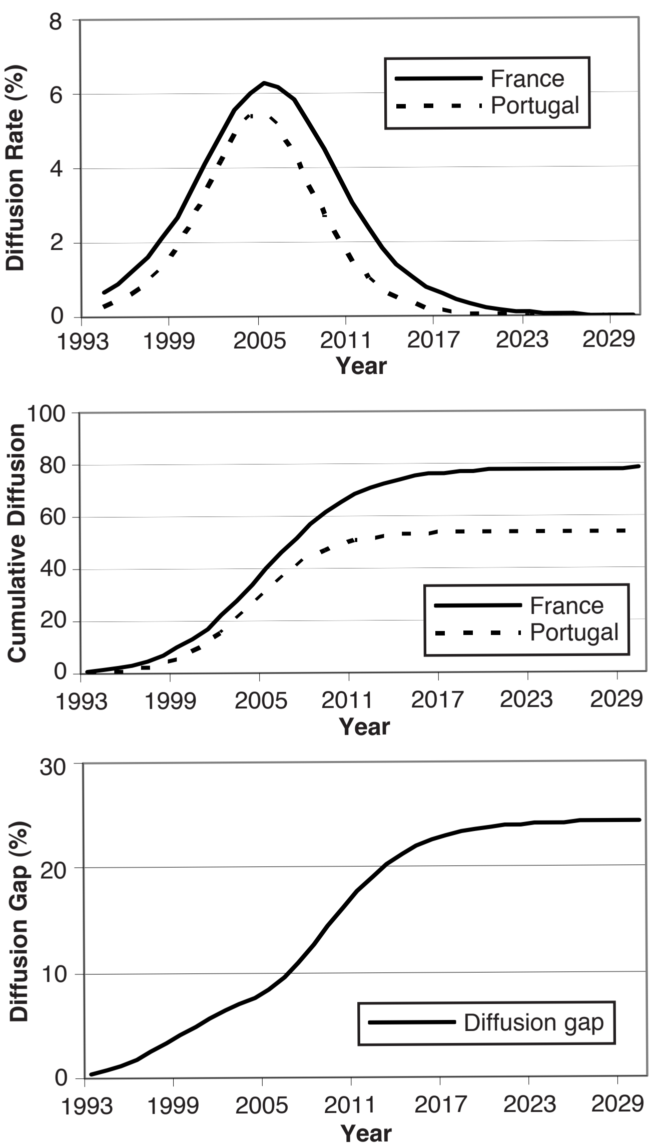
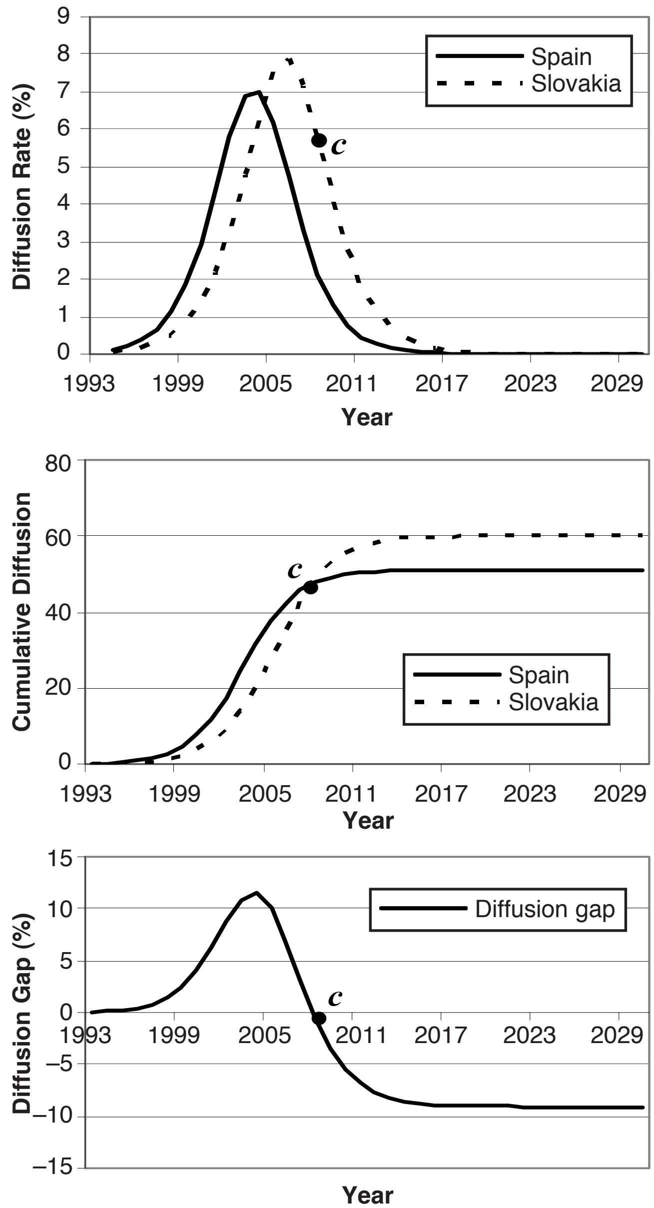


Figure 7. Type C Digital Divide



fusion trajectories of the two countries. As Figure 7 (comparing Spain with Slovakia as an example) illustrates, at point "c" (around year 2008), the former leading country, Spain, becomes the lagging one, and vice versa.

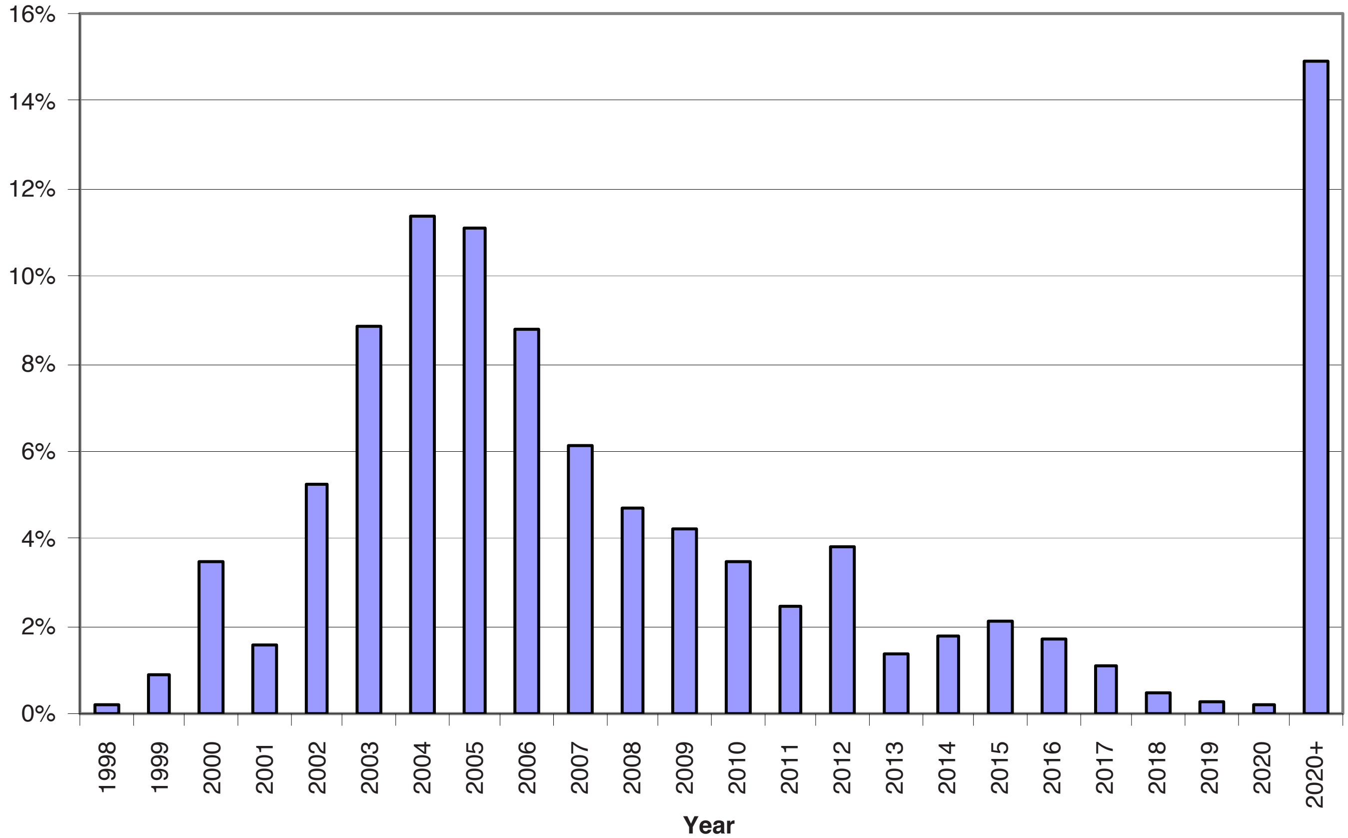
Of the 1128 pairwise comparisons, 63.8% belong to the Type A pattern of digital divide, and 16.1% belong to Type B. The remaining 20.1% show the diffusion gap pattern of Type C.

Severity of the Digital Divide

Unlike prior cross-sectional analyses, our analytical framework helps facilitate a longitudinal picture regarding the change of severity of the digital divide across countries. In this sense, perhaps the most critical question is whether the gap of Internet diffusion is widening or narrowing. Figure 8 presents our answer and summarizes the year the maximal gap of Internet diffusion occurs between any two countries of the 48 under study. Among all the 1128 possible combinations, we observe that approximately two-thirds of the maximal gaps occurred before or during 2008, while approximately one-third of such gaps are expected to occur only after that year. This finding indicates that any claim that the global digital divide is becoming more severe or that it is gradually disappearing is an oversimplified statement—the gap is narrowing in certain parts of the world, but it is widening in other parts of the world.

Figure 9 further illustrates our prediction of the ultimate global digital divide. The figure presents the histogram of the 1128 country pairs' long-term ultimate gaps. Although for most pairs of countries the digital divide between them is expected to be narrowed over the long run, the figure shows that some ultimate gaps will still be large.

Figure 8. The Maximal Diffusion Gap: 1128 Pairs of Comparison



Factors Associated with the Global Digital Divide

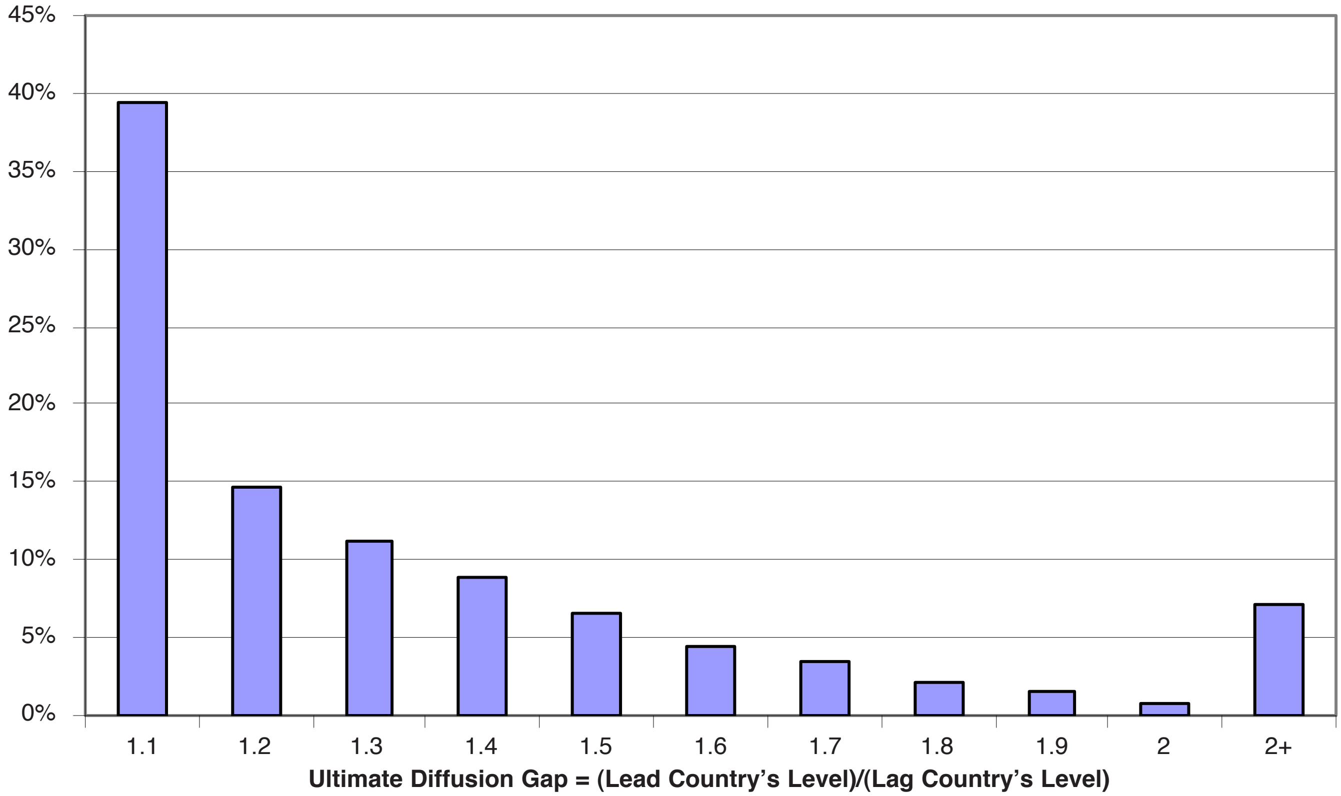
To address RQ3, pertaining to factors that are associated with the global digital divide over time, Table 1 reports the least squares estimation results from six cross-sectional regression models on the 48 countries. The table shows that factors associated with the global digital divide change over time. At the .05 level, in the early days of Internet diffusion, income and uncertainty avoidance explain Internet diffusion (1996, 1999, and 2002), while the degree of individualism is also associated with Internet diffusion in 1999. After 2002, however, individualism and uncertainty avoidance are no longer important. In both 2005 and 2008, income is the only factor significantly associated with the heterogeneity of the Internet diffusion.

The last column in Table 1 shows the predicted ultimate Internet diffusion level as the independent variable; the GDP and literacy variables adopt the latest (at the time of this research) available 2008 data. Together with the cultural variables in the analysis, we observe that only the literacy rate significantly explains the predicted ultimate Internet diffusion level across countries.

Discussion

We can summarize the empirical results in three main points, each of which addresses one of our research questions. First. the Norris (2001) dichotomy of the digital divide is insufficient for the analysis of corresponding issues. From a longitudinal perspective, we identify three types of digital divide across countries. Although many studies quote Norris's dichotomy classification of normalization/stratification to describe digital divide patterns, from the 1128 pairwise comparisons, we find that Norris's system is not adequate because it neither exhausts all possible divide patterns nor distinguishes between certain important differences in the so-called stratification cases. Norris's system ignores the possibility that the lead/lag status of the digital divide between two countries can be reversed, as the Type C cases of the longitudinal diffusion gap suggest. In the stratification model, in which the gap of Internet diffusion between two countries is never close, Norris does not distinguish maximal gap > ultimate gap cases from maximal gap = ultimate gap cases. On the basis of our empirical results, we argue that such a distinction is important in recognizing two main types (Type A and Type B, as we discussed previously) of the digital divide. Furthermore, we find that the normalization model in which two countries have the same level of ultimate Internet diffusion (as Norris proposes) applies to only a few cases. Of the 1128 combinations of country-pair comparison, only 33 pairs (i.e., 2.93%) present ultimate Internet diffusion differences within 1%. Thus, the normalization model that Norris suggests seems to offer rare cases rather than the norm in the context of the global digital divide. In summary, from the large-scale, longitudinal study, we conclude that instead of

Figure 9. The Distributions of Ultimate Diffusion Gaps: 1128 Pairs



Norris's dichotomy of the digital divide, a more realistic classification system to analyze the global digital divide is the three-type system that we arrived at from the empirical setting.

Second, the global digital divide is severe. Certain gaps across countries will slightly narrow, though we predict that the global digital divide will still be deep and wide in the long run. Figure 8 and Figure 9 show a rather disturbing picture, the implications of which have never been fully revealed in the former global digital divide literature. Figure 8 shows that for quite a few country pairs, the worst scenario of the digital divide—when two countries experience the widest gap of Internet access diffusion—is yet to come. Even in the long run, when the lagging countries slightly catch up, Figure 9 shows that in almost half the cases, the leading country will have an Internet diffusion rate several times higher.

Scholars who argue that the global digital divide is an issue of less and less public policy relevance as the gap of concern is narrowing (e.g., Camagni and Capello 2005; Kvasny and Keil 2006; Martinelli, Serrecchia, and Serrecchia 2006; Shelley et al. 2004; Strover 2003) are overoptimistic at best. As long as ICT adoption is considered to have broad implications in people's social and economic lives as well as countries' productivity, the wide and persistent gaps of Internet diffusion among countries should be taken seriously now and in the future by policy makers on the global stage.

Third, the global digital divide is a function of economic, educational, and cultural factors in the long run. The roles of these factors evolve over time. From the empirical study in the form of six separate cross-sectional regressions, we establish that variables reflecting economic, educational, and cultural factors all contribute to the explanation of the digital divide, but at different times. The finding that historical Internet penetration can be explained by income between 1996 and 2008 is not surprising, because affordability matters in Internet adoption. Historically, therefore, the global digital divide has been strongly associated with the income divide among countries.

Various cultural factors explain the levels of Internet penetration across countries at different times. In the early days of Internet diffusion, countries that were more socially cohesive and integrative (i.e., lower level of individualism) and were more culturally comfortable at unstructured situations (i.e., lower level of uncertainty avoidance) were more likely to have higher levels of Internet penetration. However, the influences of individualism and uncertainty avoidance disappeared subsequently. Such a finding implies that the soft, latent, cultural factors in a marketing system, beyond the more concrete income level, were important as either facilitators or inhibitors in the early days of Internet diffusion. As more households in different countries gained access to the Internet, the association between cultural factors and Internet penetration was no longer significant.

What is even more intriguing is the role of education. According to our analysis and accounting for the economic

Table 1. Determinants of the Digital Divide: Results from the Multiple Regression Analyses

	1996	1999	2002	2005	2008	Predicted Ultimate Level
Constant	.115	–.021	–.002	–.014	–.030	–.020
	(.713)	(–.226)	(–.031)	(–.194)	(–.473)	(–.166)
GDP per capita	.797*	.795*	.799*	.707*	.688*	.300
	(4.137)	(5.421)	(6.630)	(5.862)	(6.853)	(1.566)
Literacy rate	.066	.038	.078	.129	.163	.422*
	(.432)	(.332)	(.799)	(1.289)	(1.912)	(2.586)
Power distance	–.239	–.152	–.125	–.220	–.190	.024
	(–1.181)	(–1.021)	(–1.073)	(–1.882)	(–1.897)	(.125)
Individualism/collectivism	–.354	–.334*	–.167	–.132	–.027	.003
	(–1.869)	(–2.457)	(–1.519)	(–1.200)	(–.286)	(.019)
Masculinity/femininity	–.085	–.214	–.111	–.109	–.127	–.115
	(–.414)	(–1.857)	(–1.341)	(–1.304)	(–1.775)	(–.839)
Uncertainty avoidance	–.281*	–.262*	–.170*	–.086	–.0003	.080
	(–2.060)	(–2.823)	(–2.106)	(–1.041)	(–.005)	(.595)
R^2	.569	.749	.787	.787	.844	.423
Adjusted R^2	.462	.703	.755	.754	.820	.334

*$p < .05$.
Notes: t-values are in parentheses.

and cultural factors, the importance in the literacy rate—the proxy of education in this research—has been insignificant during the course of past Internet diffusion. However, when we consider the predicted ultimate levels of Internet diffusion across countries, heterogeneity in literacy rates is the sole statistically significant explanation (among a wide array of currently available variables).

If we piece the chunks of cross-sectional analysis together, the longitudinal picture reveals that at different stages, there are different sets of factors that are strongly associated with the global digital divide. Historically, while income has been a persistent factor in explaining the global digital divide, cultural factors were only significantly associated with the global digital divide during the early days. However, the future divide can be best explained by the rate of literacy. Any single cross-sectional attempt for the analysis of digital divide's determinants is, at best. partial and potentially misleading.

Conclusion

The G8's Okinawa Charter on Global Information Society (G8 Information Centre 2000) states that "everyone should be able to enjoy access to information and communications networks." This is an important issue because such networks represent a "revolutionary impact [that] affects the way people live, learn and work and the way government interacts with civil society." The charter, as well as voices heard around the globe, highlights the need for international cooperation to confront the challenge of the global digital divide. This article is an attempt to transform our understanding of the global digital divide by examining the corresponding issues from a new, dynamic, and longitudinal perspective. Relying on the Bass model, which marketing researchers have widely embraced, this article categorizes the longitudinal patterns in the gap of Internet diffusion among any two countries, assesses the worst scenarios of the digital divide, predicts the long-term picture, and analyzes factors associated with the global digital divide.

Limitations and Further Research

There are limitations in the reported research that require further research. First, this article defines the digital divide as the difference of Internet diffusion within two mutually exclusive marketing systems (i.e., countries). There are voices in the literature arguing that such a definition is oversimplified. The digital divide as a container term to some scholars covers dimensions and/or levels of ICT behavioral disparity beyond access (e.g., DiMaggio and Hargittai 2001; Warschauer 2002). Although it is necessary to confine the discussion to the dimension/level of Internet access for us to introduce and use the proposed analytical framework, we recognize that there are multifarious issues surrounding the digital divide that are beyond the scope of our analysis.

Second, the Bass model is not foolproof. Technically, the parameters could be biased in certain situations. This study proposes a four-stage estimation procedure to address the likely bias caused by nonpeak diffusion data and demonstrates its performance. However, parameters estimated from the proposed "predict-by-analogy" method may be subject to change when different sets of analogical product categories are used for inference. Thus, determining what the criteria are for the optimal category inclusion is an important issue for future studies. Furthermore, no matter how good the model performs in fit and one-year-ahead predictions, there is no guarantee that the predictions made for future diffusion will be accurate; our prediction for the future (especially the ultimate diffusion of the Internet in various countries), as with any prediction, is a projection from historical data and does not account for unforeseeable new developments in the future that may change the diffusion of the Internet. For the analysis and prediction of the issues of concern here, however, we cannot find a more robust or more widely tested model that appropriately fits the need of a longitudinal study of Internet diffusion.

Third, we include variables that may explain the global digital divide in this study, but we cannot claim that the list of variables represents all possible factors that affect the global digital divide. Other variables may help explain the gap of Internet diffusion, and these should be addressed in further research.

Fourth, constrained by data availability, we are only able to analyze a set (though we believe it to be a representative set) of countries. Additional research should further generalize these findings.

Implications

Marketing is a societal phenomenon (Zinkhan and Williams 2007) and a societal process (Lusch 2007), and multiple perspectives in its aggregate system are well recognized (Gundlach 2007). Consequently, marketing researchers have long made various efforts to analyze, predict, and compare the diffusion of technology at the macro level. Although studies in the literature have analyzed diffusions across marketing systems (i.e., countries), and some have even focused on the Internet and used the Bass model for analysis (e.g., Puumalainen and Sundqvist 2005), none of them provide a dynamic picture as to the gaps of diffusion, the types of such gaps over time, or the explanations of such gaps at different stages—issues with deep marketing and/or public policy implications.

We focus on different rates of Internet diffusion among countries—a longitudinal perspective of the digital divide whose dynamics are understudied—and use the Bass model as our analytical framework. The research contributes to the marketing literature on several fronts. First, by highlighting the maximal and ultimate diffusion gaps, this study introduces a new perspective for the analysis of the lead/lag diffusion patterns across marketing systems or marketing segments of interest to marketing researchers (e.g., Ganesh and Kumar 1996; Putsis et al. 1997). Second, the typology of digital divide dynamics we present in this research enriches our understanding of heterogeneous diffusion paths among marketing systems/segments. Outside the Internet context, the three types of digital divide we identify here can be directly applied to the analysis of other scenarios of technology diffusion of marketing interests. Third, the analytical framework we use helps us explain the Internet diffusion gap at various stages. The longitudinal picture that we arrive at by having a series of cross-sectional analyses gives us a much more comprehensive grasp of the different roles of economic, cultural, and educational factors in the evolution of global digital divide—an example set for other studies the might consider longitudinal explanations of diffusions of other categories. Fourth, we propose an easy-to-follow, four-stage estimation procedure to address situations in which the data do not include the peak of diffusion—it has long been recognized that the Bass model would have a problem in such situations, but an easy-to-follow solution has yet to be demonstrated in the literature. Empirically, we show that our approach to addressing the issue is satisfactory.

For market practitioners, the research's implications include the following: To marketers at e-commerce Web sites, search engines, or online content providers, the maximal and ultimate diffusion gaps, the three types of diffusion gaps over time, and the empirical findings of diffusion gaps' determinants we introduce here all provide new insights into the assessment of the global market, the plan of market entry, and the strategic allocation of resources to different markets over time. Outside the Internet-related market, our analytical framework and its focuses also offer firms a new perspective for comparing different markets when planning international expansion.

This study also provides a set of takeaways for public policy makers. First, the current static view of the digital divide from cross-sectional analyses provides only a limited picture of the problem. We strongly urge relevant parties that have resources and that intend to address the digital divide to examine the issues from a longitudinal angle because such an angle provides a more comprehensive picture of the dynamics of challenges. Furthermore, by taking a longitudinal view on the global digital divide, the conclusion we draw is that there is no universal trend—the severity of the divide decreases in some cases, but it increases in others. We suggest concentrating resources on the latter cases. If there is no substantial socioeconomic change and/or large-scale international cooperation, we predict that the global digital divide will still be deep and wide in the long run. As long as access to information has broad implications for people's lives, it is inappropriate to argue that the digital divide is no longer a pressing problem and can be erased from public policy agendas.

We conclude that the disparate trajectory of Internet diffusion between any two countries can be largely explained by economic, educational, and/or cultural factors at different stages. Recognizing the historical roles of income and culture in the global digital divide, our analysis further indicates that disparity in literacy rates across countries will have a sole and strong impact on the global digital divide in the future. This finding is encouraging for policy makers because the structural factors that are unchangeable (i.e., the cultural factors) or very complicated to address (i.e., income) will become less important in the long-term Internet diffusion in the future. It also implies that though providing multifarious access points for disadvantaged people and the likes of the One Laptop Per Child initiative may indeed help narrow the global digital divide in the short run, the fundamental remedy lies in long-term investment in education. In hindsight, this is not surprising. Only after a child in a less developed country can read and write is the Internet then meaningful to him or her. Thus, we suggest that long-term investment in education should be consistently emphasized in a wide range of international cooperation agendas initiated by government and nongovernment agents.

Although we apply our analytical framework across countries, it can also be easily applied to study heterogeneous diffusion of the Internet or any other technology across segments of a population within a country. For a policy maker focusing on the domestic social welfare implications of such diffusion, the analytical framework renders a comprehensive, longitudinal picture such that the dynamics of inequality of diffusion across segments (e.g., demographic, geographic, or societal ones) can be better predicted and assessed and resources can be better allocated, rather than assessment and resource allocation being made merely on the basis of history.

Appendix

In the GMID data set, in addition to Internet-enabled computers, the household-level diffusion of five other digital product categories (i.e., video camera, video game console, videotape recorder, telephone, and color television set) is recorded for the countries under study. Each share a part of the Internet's functions, such as entertainment, recording, self-expression, and communication, but began their respective diffusions earlier. Therefore, the four-stage estimation is based on the assumption that the diffusion paths of these categories in a specific marketing system (i.e., a specific country) carry information about the tendency of and speed with which members in the system adopt new technology, so that a prediction of the diffusion path of the Internet can be sensibly made by drawing an analogy to the diffusion history of these product categories.

In Step 1, we estimate the Bass model parameters for each country's six categories (Internet and the other five categories). For country i's category j, we have the estimated p_{ij}, q_{ij}, and m_{ij}.

Given the parameters, Step 2 follows by estimating a multiple regression with a series of dummies as the independent variables and then estimating m_{ij} as the dependent variable:

$$\text{(A1)} \qquad m_{ij} = \alpha + \sum_{i = \text{countries}} \beta_i I_i + \sum_{i = \text{countries}} \beta_j I_j + \varepsilon_{ij},$$

where $I_i = 1$ if country i and 0 if otherwise and $I_j = 1$ if category j and 0 if otherwise. Furthermore, when j = Internet, I_j is intentionally set as missing if the latest available penetration level of the j country is below .5 (which indicates that Internet diffusion may have not peaked and a reestimated m is desirable; 18 of 48 countries in the data meet this condition). An estimation of the model is accomplished through ordinary least squares.

After we obtain the country-specific coefficient β_i and category-specific coefficient β_j, Step 3 derives the reestimate of m_{ij} for the reestimated countries by assembling the following:

$$\text{(A2)} \qquad \hat{m}_{(i,j = \text{Internet})} = \hat{\alpha} + \hat{\beta}_i + \hat{\beta}_{\text{Internet}}.$$

In Step 4, with the m parameter fixed at $\hat{m}_{(i,j=\text{Internet})}$, each of the reestimated country's data of Internet diffusion is estimated with the Bass model again to obtain the reestimated p and q.

For the 18 reestimated countries, the mean absolute percentage error of the one-year-ahead forecast based on the 1993–2007 data by the original model parameters is .1487 and that by the reestimated parameters following the four-stage procedure is .0719. It is apparent that the reestimation renders more accurate short-term predictions.

The need for the reestimation is intuitively clear if we further examine country-specific long-term diffusion projections. Taking Mexico for example, Figure A1 presents

Figure A1. Comparing the Two Sets of Estimates: The Case of Mexico

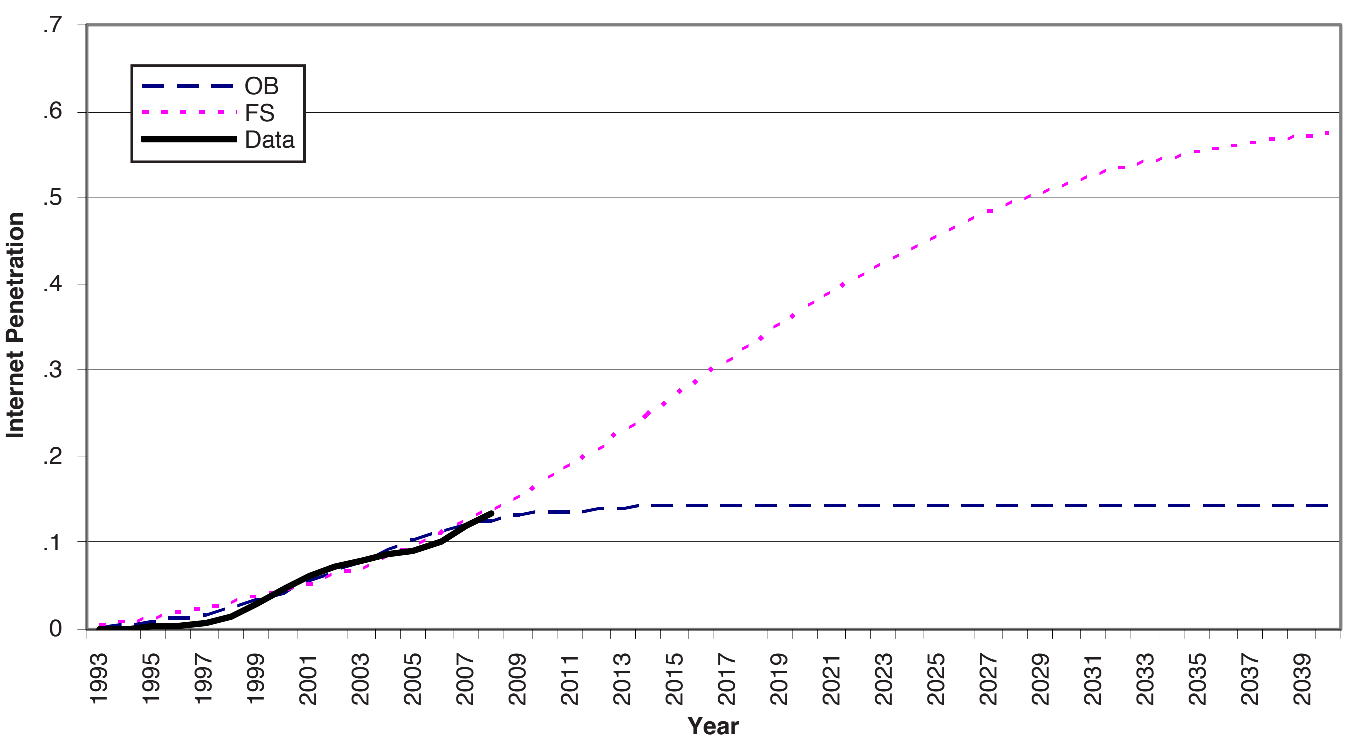


Table A1. Country-Specific Parameters

Country	p	q	m	Country	p	q	m
Argentina*	.0079	.1615	.5719	Malaysia	.0041	.1652	.8714
Australia	.0073	.5711	.6608	Mexico*	.0054	.1277	.5962
Austria	.0118	.2611	.8440	Netherlands	.0127	.3895	.8890
Belgium†	.0014	.6754	.5940	New Zealand	.0051	.5341	.6798
Brazil*	.0086	.1618	.4717	Norway	.0116	.5074	.7411
Bulgaria*	.0007	.3847	.5595	Philippines*	.0003	.3648	.4563
Canada	.0185	.4019	.7283	Poland	.0014	.3308	.9374
Chile*	.0073	.2519	.5355	Portugal	.0029	.4027	.5376
China*	.0017	.3264	.5148	Romania	.0001	.4806	.9748
Colombia*	.0021	.2873	.4691	Russia*	.0001	.5807	.5474
Czech Republic	.0013	.3533	.7855	Singapore	.0081	.6278	.7112
Denmark	.0075	.5464	.7994	Slovakia*,†	.0005	.5275	.5997
Estonia	.0009	.5030	.6913	South Africa*	.0001	.4236	.5119
Finland	.0145	.3102	.7907	South Korea	.0123	.4325	.9953
France	.0055	.3106	.7811	Spain	.0011	.5582	.5091
Germany	.0018	.6364	.6628	Sweden	.0187	.4328	.8120
Greece*	.0052	.2283	.6563	Switzerland	.0036	.5139	.7876
Hungary	.0004	.4673	.7611	Taiwan	.0180	.3656	.7716
India*	.0003	.3515	.2195	Thailand	.0038	.1514	.5454
Indonesia*	.0003	.2447	.3457	Turkey*	.0004	.3929	.6150
Ireland	.0073	.3815	.6559	United Kingdom	.0012	.6941	.6185
Israel	.0056	.3330	.8316	United States	.0114	.5635	.6294
Italy*	.0132	.2221	.7096	Venezuela*	.0021	.2595	.5976
Japan	.0032	.6560	.6181	Vietnam*	.0001	.3907	.3574

*Reestimated m parameters by the four-stage estimation.
†The p estimate is not significant at the .05 level.

the projected Internet diffusion curves from both the original Bass estimates (the "OB" curve in the figure) and the four-stage estimates (the "FS" curve in the figure). Given that the end point of the data in 2008 has a .135 level of Internet diffusion for Mexico, if we stick to the original Bass estimates, the m estimate—the "ceiling" of the predicted long-term diffusion—would be .1425, and a downward bias is apparent, which is strongly influenced by the end point of the data. Conversely, the four-stage estimation renders an m at .5962, and the peak of diffusion is around 2015—a more realistic prediction if we consider the diffusion history for other product categories in this specific marketing system. Table A1 summarizes the country-specific parameters we used to address our three research questions.

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