Factors Influencing Information Technology Adoption: A Cross-sectional Analysis

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The Importance of Information

As Stiglitz expounded years ago, information is pervasive in society. All of the economy's activities are based around the amount of information that is available. The Internet has been an extremely important tool in disseminating information in the United States and beyond. The ease with which it allows information transfer over space has not yet been equaled. Given the relative newness of this technology, the impacts of the information revolution have not reached their full potential in the United States or globally.

Internet History

> "It seems reasonable to envision, for a time ten or fifteen years hence, a 'thinking center' that will incorporate the functions of present-day libraries together with anticipated advances in information storage and retrieval and the symbiotic functions suggested earlier in this paper. The picture readily enlarges itself into a network of such centers, connected to one another by leased-wire services. In such a system, the speed of the computers would be balanced, and the cost of the gigantic memories and the sophisticated programs would be divided by the number of users."

J.C.R. Licklider, a visionary and a leader in the field of interactive computing proposed the first computer network in 1960. This description is remarkably similar to the modern-day networks that form the Internet. Although, at the time, the means of this network was yet to be developed, Licklider believed it was possible.

The precursor to the elaborate web of nodes that constitutes the Internet today was a four-node network called ARPANET (Advanced Research Projects Agency Network). The network, launched in 1969, consisted of three nodes in California and one in Utah. Initially, network access was restricted to university and Department of Defense researchers. In 1973, Xerox's Bob Metcalfe developed Ethernet technology. This technology is probably the dominant network technology in the Internet. The original ARPANET model was designed for a small number of networks and hosts. The development of local area networks (LANS), PCs, and workstations expanded rapidly in the 1980s. To make possible extensive use of the Internet, Transmission Control Protocol (TCP) and Internet Protocol (IP) were developed and implemented in the early 1980s. These protocols allowed previously incompatible networks to interact with one another.

Two developments facilitated the adoption of the Internet beyond university settings. First, in 1989, the development of the World Wide Web provided a user-friendly interface for transmitting and receiving information. Then, in 1995, the National Science Foundation (NSF) backbone was shut down. All NSF subsidies to the Internet were eliminated along with barriers to commercial traffic. Since then, an Internet presence has become nothing less than a survival requirement for many businesses.

The Internet's Potential Contribution to Economic Development

The study of economic development is motivated by the desire to better understand the transition out of poverty. This transition can be aided by appropriate technology (Besley and Case). The Internet provides potential to connect some low-income countries to world markets and information that were previously unavailable. Knowledge gained from access to this information empowers people to make more rational production and marketing decisions. This information can also decrease risk in the decision-making process. The knowledge and information that the Internet can provide are essential if countries ever expect to enter global markets.

While the Internet holds much potential for economies, its adoption has been slower than expected. As the adoption process is better understood, policies may be put in place to encourage use of the Internet thereby speeding its adoption.

Objectives

This research will distinguish between information technology and other technologies. The unique characteristics of information technology will be identified and discussed. The adoption of information technology will also be investigated. Both factors that promote and factors that constrain information technology adoption will be addressed. Benefits and hazards to adoption will also be identified. Finally, a statistical model of Internet adoption will be developed to estimate the impacts of certain variables on the underlying process of information technology adoption.

Relevant Literature

Griliches (1957) estimated the fraction of land planted with hybrid corn using a logistic function. Using the rate of acceptance, the aggregate adoption at the start of the estimation period, and an adjustment for different adoption ceilings, he obtained an s-shaped adoption curve. This curve was symmetric around a point of inflection and asymptotic to zero and one. This article has been the basis for much of the technology adoption literature.

In another basic technology adoption study, Mansfield analyzed the adoption of twelve innovations by firms in their respective industry. From his data, he noted that the diffusion of new technology is a slow process, and that the rate of diffusion varies widely between industries and innovations. The model he estimated brought him to the conclusion that generally, "the growth in the number of users of an innovation can be approximated by a logistic curve." He continued to deduce that innovations that had a higher expected return and required a smaller initial investment were adopted at a higher rate than others.

Some authors have modified fundamental adoption theory by means of implementing a dynamic ceiling in diffusion models. Mahajan and Peterson extended classic diffusion models to include a ceiling that was a function of factors that affect the maximum number of potential adopters. The authors employed this model to investigate growth in United Nations membership and growth in sales of washing machines in the United Sates. Results of the dynamic model were improved from those of the static diffusion model.

Both Besley and Case, and Kurtenbach and Thompson state the importance of understanding technology adoption. Besley and Case open with

> "Perhaps one of the main reasons for studying economic development is to understand better how individuals are able to make the transition out of poverty. Technology may be viewed as a means to this end. Yet, while the development of higher-yielding varieties (HYV's) of many crops grown by poor farmers has enhanced this hope, it is essential to understand how new technologies are adopted in practice if their promise is to be fulfilled."

While the Green Revolution fell short of solving the problem of world hunger, it is evidence to the potential of new technology. The information revolution holds the potential to be as important as the Green Revolution. As such, it is important that the characteristics and potential of information technology be investigated.

Characteristics of Information Technology

Several traits of information technology (specifically the Internet) distinguish it from other technologies. First, the value of the Internet increases as more people use it. Metcalfe's law states that the value of a network increases roughly by the square of the number of users. This implies that as an increasing number of people use the Internet, its value will increase exponentially. Standardization of information technology also increases its value. As more people use the same form of a technology, that form becomes more valuable. Another uniqueness is the increasing returns to scale exhibited by information products.

When increasing returns are present in the production of a good, the natural structure of that industry is a monopoly. Along with economies of scale on the supply side, the Internet produces network effects. These constitute economies of scale on the demand side of a technology. As discussed previously, the value of a good increases when more people use it. Therefore, when a technology exhibits both demand and supply side economies of scale, large barriers to entry result. This combination of a natural monopoly structure with barriers to entry elicits two competing schools of thought. At one end of the spectrum, Schumpeter believes in "creative destruction." The process of innovation requires an imperfect market to allow entrepreneurs to gain a return on their investment. Romer, on the other hand, holds that competition is necessary for innovation. The interaction of these ideas leaves the optimal amount of regulation in such an industry yet to be decided.

While the Internet industry itself may be a natural monopoly, the Internet encourages competition within other sectors of the economy. With the advent of the Internet, market entry is promoted because establishing an online business is cheaper and easier than building a brick and mortar operation. The demand side of the economy also moves toward competition since comparing prices can be done with just a few clicks of a mouse. The information available on the Internet has also increased outsourcing opportunities thereby reducing economies of scale. Access to information becomes more scale-neutral as the Internet is more widely adopted.

The Internet's Potential as an Information Source

In relation to the importance of information, Kurtenbach and Thompson maintain,

> "Accurate and complete information is vital to all market sectors and industries including agriculture. Information promotes competition and improves market performance (Thompson and Sonka). At the firm level, information promotes the efficiency and effectiveness of production and customer service. Information may also increase the level of trust consumers have in a product or firm leading to increased demand."

Information technologies have potential to improve the efficiency of agricultural markets as Thompson and Sonka illustrate. Market thinness is decreased with the use of the Internet and various electronic information systems. Futures markets are utilizing information technologies extensively to reduce operating costs. In a perfectly competitive economic model, information is free and universal. The Internet allows markets to move one step closer to the textbook model as it increases both access to the market and the amount of information available to buyers and sellers. By giving consumers greater access to information, the Internet will make it more difficult to sell information about distorted markets. Improving market access will also encourage more market entry and niche market development and thus discourage the trend toward integration. While information technology holds numerous advantages, Thompson and Sonka also warn of what has come to be known as the digital divide. "Until access to and adoption of information technology becomes widespread internationally in rural and urban areas, there will be a disparity between 'haves' and 'have nots'." They go on to suggest that government should support rapid adoption of the technologies in order to improve overall economic performance and to reduce the time period in which early adopters have advantages over late adopters.

Data

In order to determine the impacts of certain variables on Internet adoption, both OLS and logistic models were estimated. The data is a combination of numbers from the World Bank Development Indicators and the Euromonitor database. All of the numbers are from 1999. To obtain the most complete picture possible, a cross section of data was sought. In order to maximize the number of countries available for use, most of the data were measures of basic development. Complete data was gathered for 91 countries.

Data were collected on the number of people within a country who use the Internet, income, foreign aid received, urbanization, infrastructure, education, population, and age. The variables are explained in Table 1.

Table 1 Variable Definitions and Sources

Variable	Definition	Source
GDP	Gross domestic product per capita reported in US dollars	World Bank (WDIs)
AID	Amount of foreign aid received per capita reported in US dollars	WDIs
FDI	Foreign direct investment reported as a percentage of GDP	WDIs
URBAN	Percentage of population living in urban areas	WDIs
LIT	Percentage of population aged 15 and above who can read and write a short statement on their everyday life	WDIs
TEL	Number of telephone mainlines in use per 1000 people	WDIs
TELCOST	Average cost of a three minute local call reported in US dollars	WDIs
AGE	Percentage of population between ages 15 and 29	Euromonitor
TELCOM	Total capital telecommunications investment reported in US dollars per capita	Euromonitor
POP	Population	WDIs
USERS	Number of people who use the Internet	WDIs

The number of Internet users was divided by the country's population in order to allow inter-country comparisions. The independent variable (USERS/POP) had a mean proportion of 0.08, a maximum of 0.54, and a minimum of 0.0003. The standard deviation was 0.119.

In order to determine the expected sign of each variable, a scatter plot of each variable on Internet users per capita was graphed. Most variables seemed to have a positive relationship to the number of Internet users per capita. The exceptions were AID and AGE. AID showed a possible negative relationship, and AGE displayed more obvious negative relationship.

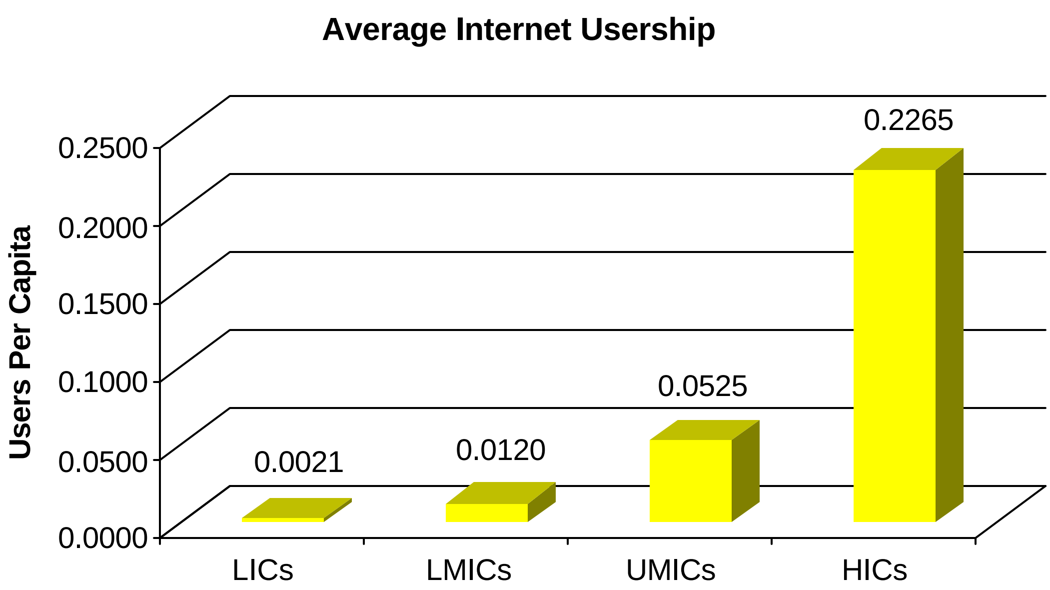
Table 1 Expected Relationship of Variable on Internet Use

Variable	**Expected Sign**
GDP	+
AID	-
FDI	0
URBAN	+
LIT	+
TEL	+
TELCOST	0
AGE	-
TELCOM	+

For comparison purposes, the countries were divided into income categories according to World Bank classifications. The four categories were low-income countries (LICs), lower middle-income countries (LMICs), upper middle-income countries UMICs), and high-income countries (HICs).

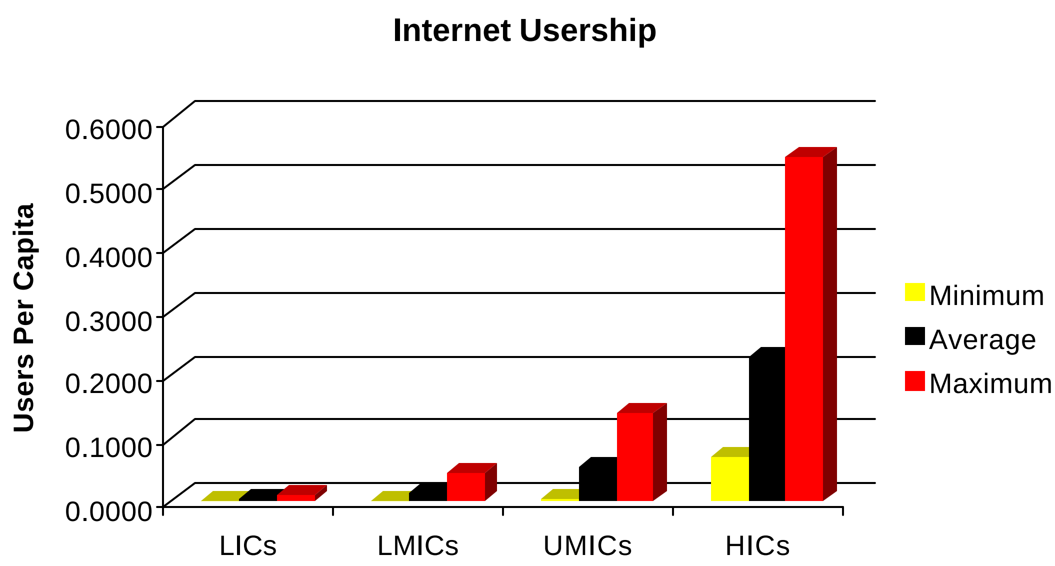
The average usership per capita was compared between country categories (see Figure 1). Low-income countries averaged 0.0021 Internet users per capita. Lower middle-income countries averaged 0.0120 Internet users per capita. The average per capita number of Internet users in upper middle-income countries is 0.0525. In high-income countries, the average number was 0.2265 Internet users per capita.

Figure 1 Average Internet Use Between Income Categories



The minimums and maximums in each category were graphed along with the means (see Figure 2). In LICs the minimum usership was 0.03% and the maximum was 0.79%. LMICs had a minimum of 0.04% and a maximum of 4.32%. The minimum in UMICs was 0.25% and the maximum was 13.87%. Lastly, HICs had a minimum of 7.015% and a maximum of 54.05%. The respective ranges were 0.76%, 4.28%, 13.62%, and 47.05%.

Figure 2 Minimum, Maximum, and Average Internet Use Between Income Categories



Countries in certain percentiles of adoption are listed in Table 2. The largest number of countries (31) have between 0 and 0.5% of people using the Internet. Twenty-eight countries have achieved between 0.51% and 5% Internet adoption. The next range, from 5.1% to 10% adoption, holds eleven countries. In thirteen countries, between 10.1% and 19% people use the Internet. The number of countries in each category continues to decrease as only seven countries have reached between 20% and 29% adoption. The next range (30%-39%) houses only Australia, Canada, and Hong Kong. Likewise, three countries lie within the next range (40%-49%): Sweden, Finland, and Norway. Iceland is alone in the last category (50%-59%) with an adoption of 54%.

Table 2 Countries in Certain Ranges of Internet Adoption

0-0.5%	0.51-5%	5.1-10%	10.1-19%	20-29%	30-39%	40-49%	50-59%
Uzbekistan	Guatemala	Kuwait	Slovak Republic	Switzerland	Australia	Sweden	Iceland
Tajikistan	El Salvador	Poland	Cyprus	United Kingdom	Canada	Finland	
Bangladesh	Philippines	Hungary	Spain	Japan	Hong Kong	Norway	
Lao PDR	China	Czech Republic	Italy	Austria			
Turkmenistan	Armenia	Portugal	Slovenia	Singapore			
Papua New Guinea	Fiji	Greece	Belgium	United States			
Pakistan	Bolivia	Brunei	Estonia	Denmark			
Algeria	Maldives	Malta	United Arab Emirates				
Albania	Thailand	France	Luxembourg				
Azerbaijan	Saudi Arabia	Macao, China	Germany				
Vietnam	Peru	Uruguay	Ireland				
Nepal	Colombia		New Zealand				
Iran	Panama		Netherlands				
Morocco	Russian Federation						
Kyrgyz Republic	Mexico						
Argentina	Brazil						
Mongolia	Venezuela						
India	Macedonia						
Ecuador	Turkey						
Cuba	Jordan						
Honduras	Romania						
Tunisia	Lithuania						
Egypt	Bulgaria						
Sri Lanka	Costa Rica						
Paraguay	Latvia						
Ukraine	South Africa						
Nicaragua	Croatia						
Indonesia	Chile						
Solomon Islands							
Kazakhstan							
Belarus							

Model and Results

To begin the analysis, an ordinary least squares (OLS) model was estimated along with a logit model. The theoretical model is given by:

$$USERS = f\left(GDP, AID, FDI, URBAN, LIT, TEL, TELCOST, AGE, TELCOM\right) \quad (1)$$

Several procedures were implemented in a least squares framework to obtain a predictive model. First, a complete model was run. These results are given in Table 3.

Table 3 OLS Model of Percentage of Internet Adoption

Variable	**Estimate**	**t-stat**	**Pr>|t|**
Intercept	-0.05960	-0.57	0.5691
GDP	0.00000259	2.05	0.0441
AID	-0.00003641	-0.77	0.4462
FDI	0.00083038	0.53	0.5995
URBAN	0.00021539	0.48	0.6351
LIT	-0.00048695	-0.92	0.3599
TEL	0.00036489	4.06	0.0001
TELCOST	-0.09985	-0.69	0.4924
AGE	0.22763	0.73	0.4667
TELCOM	-0.00000716	-1.08	0.2834
F-value	25.62	Prob>F	<0.0001
R-squared	0.74	Adj. R-squared	0.71

Two parameter estimates in the OLS model are significant both having the expected signs. These are the estimate for GDP (0.00000259) with a t-statistic of 2.05 and the estimate for TEL (0.00036489) with a t-statistic of 4.06.

The estimate for GDP given by the model implies that as a country's gross domestic product increases by $100 per capita, the proportion of people using the Internet will increase by 0.000259. An example that will be used throughout the analysis to help explain the effects of the numbers is a country with a population of 50 million, 25% of whom use the Internet. In this particular country if average income increases by $100, 12,950 more people would begin to use the Internet. Likewise, if the country invests in one more telephone line per 1,000 people, the proportion of people using the Internet will increase by 0.00036489. In other words, 18,245 more Internet users will result from an investment in 50,000 more telephone lines.

The complete OLS model is highly significant with an F value of 25.62. The fit is also surprisingly good as shown by an adjusted R-square of 0.71. However, only two of the nine variables are significant at a 5% level. Because of the high model significance and few significant variables, a collinearity test was run. As expected, the results showed a high likelihood of collinearity. Belsey, Kuh, and Welsch report that an index number of 10 shows weak dependencies that may affect parameter estimates. When the index is larger than 100, "the estimates may have a fair amount of numerical error." The highest index value in this particular test was 48.

In hopes of eliminating some of the collinearity, the stepwise procedure in SAS was implemented. After the stepwise routine, the reduced model included only GDP and TEL.

Table 4 Reduced OLS Model of Percentage of Internet Adoption

Variable	Estimate	t-stat	Pr>|t|
Intercept	-0.02607	-2.32	0.0225
GDP	0.00000281	2.50	0.0142
TEL	0.00030866	4.77	<0.0001
F value	114.58	Prob>F	<0.0001
R-squared	0.7225	Adj R-squared	0.7162

In this reduced model, both the parameter estimates have the expected signs and are significant at the 5% level. Based on this model, in the example country, if average income increased by $100, the number of Internet users would increase by 40,500 (0.08%

of the population). Similarly, if 50,000 more telephone lines are added to the country, 15,433 more people would use the Internet.

The model also shows a high joint significance with an F statistic of 114.58. Little explanatory power was lost as the reduced model has an R-square of .72 and an adjusted R-square of .71. The stepwise procedure allowed the elimination of seven variables from the model. The second model also showed a much lower degree of collinearity.

A logit model was employed in this study to predict the placement of countries on the Internet's adoption curve based on basic development indicators. The likelihood function used to estimate a logit model is

$$l(b) = \sum_{i=1}^{T} \left[F(x_i' b) \right]^{y_i} \left[1 - F(x_i' b) \right]^{1-y_i} \qquad (2)$$

F(.) is the cumulative distribution function for a logit model.

$$P_i = F(x_i' b) = \frac{1}{1 + e^{-x_i' b}} \qquad (3)$$

In this model, the x_i*'s* are GDP, AID, FDI, URBAN, LIT, TEL, TELCOST, AGE, and TELCOM respectively. P_i is USERS/POP. Specifically, the following logit model was estimated.

$$\ln(\text{USERS/POP}) = \beta_0 + \beta_1\text{GDP} + \beta_2\text{AID} + \beta_3\text{FDI} + \beta_4\text{URBAN} + \beta_5\text{LIT} + \beta_6\text{TEL} + \beta_7\text{TELCOST} + \beta_8\text{AGE} + \beta_9\text{TELCOM} + e \qquad (4)$$

The results of the logit model are reported in Table 5.

Table 5 Logit Model of Percentage of Internet Adoption

Variable	Estimate	Marginal Effect	Chi-square	Pr>ChiSq
Intercept	-8.6054		17245493.7	<.0001
GDP	6.092E-6	7.609E-8	241023.255	<.0001
AID	0.000138	1.723E-6	724.8708	<.0001
FDI	0.0126	1.573E-4	290022.087	<.0001
URBAN	0.0119	1.486E-4	2239901.39	<.0001
LIT	0.0177	2.211E-4	1687760.80	<.0001
TEL	0.00575	7.245E-5	25173475.6	<.0001
TELCOST	0.5678	7.093E-3	150801.405	<.0001
AGE	4.6372	5.793E-2	699698.461	<.0001
TELCOM	-0.00006	-7.495E-7	88457.4879	<.0001
Percent Concordant	86.8	Likelihood Ratio	543468991	

The parameter estimates in the logit model have large Chi-square statistics thus making all of the estimates highly significant. To adjust for the differences in population between countries, the model was weighted by population. This produced an extremely large number of observations for each country with no variability in the independent variables. The result of this are unreasonably low standard errors and therefore, highly significant estimates. The model was estimated in three statistical programs (SAS, STATA, and LIMDEP), and all three used the same technique to weight the data.

All of the coefficients were positive except the one for telecommunications investment. A positive sign on GDP implies that the Internet is a normal good. As incomes increase, so will use of the Internet. AID's positive sign was opposite of what was expected. High-income countries receive less foreign aid than do low-income countries. Also, it was expected that a larger percentage of the population would use the Internet in high-income countries than in low-income countries. Therefore, it follows logically that as foreign aid decreases, the proportion of Internet users will increase and AID will have a negative sign. If the amount of aid received is in fact positive as the model suggests, then the relationship being picked up could be one of well-targeted foreign aid programs. FDI exhibited yet another positive sign implying that as the business environment in the country becomes more attractive, Internet use increases. From these results, it is unclear whether or not the increase in Internet use is due to use by employees of the investing company or if when companies invest in a country, more of the population use the Internet. The parameter estimate for URBAN was also positive. This is not surprising given the nature of the technology. The infrastructure that is required for Internet use is much more abundant in urban areas than is it in rural areas. From the results, Internet use increases as literacy rate increases. Again, an intuitive conclusion based on the fact that being able to read is a prerequisite to Internet use. As the number of telephone lines increase, Internet use will also increase based on the findings of the model. This result is somewhat like the previous one in that (in most cases) a telephone line is required for Internet use. The estimate for cost of a telephone call was also positive. One possible explanation is that the data for telephone call cost was sporadic. The parameter estimate for AGE was expected to be negative, but it was not. This could be because people between 15 and 29 are more accepting of new technologies than those who are older. A negative sign on telecommunications investment was unexpected. However, as with most of these results, several relationships could have been picked up. A high-income country will likely invest less in telecommunications because the infrastructure has already been established. In other words, the telecommunication investment occurred sometime in the past making it unnecessary to invest now.

While many of the signs on the logit model parameter estimates were expected, it is necessary to note that various rationale could exist for these results. The multicollinearity that was present in the OLS model continues to be a concern in the logit. If the variables in a model are interrelated, the relationships implied by the results may not hold in reality.

Given the results of the reduced OLS model, a logit model was estimated with only GDP and TEL as independent variables. The results of this reduced model are given in Table 6.

Table 6 Reduced Logit Model of Percentage of Internet Adoption

Variable	Estimate	Marginal Effect	Chi-square	Pr>ChiSq
Intercept	-5.3157		740446698	<.0001
GDP	4.052E-6	5.943E-8	119077	<.0001
TEL	0.00651	9.548E-5	79673194	<.0001
Percent Concordant	86.7			

Marginal Effects

The marginal effect of a variable quantifies the change in the dependent variable given a one-unit change in the explanatory variable. Equation 5 gives the marginal effects for a logit model.

$$\frac{\partial Y_i}{\partial X_i} = \frac{e^{bX} b_i}{\left(1 + e^{bX}\right)^2} \qquad (5)$$

Where X is the mean of the respective variable.

As can be seen from Table 7, the marginal effects are very small. For example, if average income in a country increased by $100 per person, the percentage of people using the Internet would increase by 7.6E-6. In other words, if the country had 50 million people, 25% of whom use the Internet, as average income increases by $100 (holding all else constant), approximately 380 more people would use the Internet.

Table 7 Increase in Number of Internet Users in Example Country

Variable	Marginal Effect	Increase in Variable	Increase in Internet Users	% of Population
GDP	7.61E-08	100	380.49	0.00076
AID	1.72E-06	2	172.38	0.00034
FDI	1.57E-04	1	7869.60	0.01574
URBAN	1.49E-04	5	37161.98	0.07432
LIT	2.21E-04	2	22109.82	0.04422
TEL	7.25E-05	1	3622.51	0.00725
TELCOST	7.09E-03	0.02	7092.63	0.01419
AGE	5.79E-02	0.02	57925.23	0.11585
TELCOM	-7.49E-07	5	-187.37	-0.00037
Population	50,000,000		% Internet Users	25

Conclusions

The Internet's impact on markets, communications, technology, history, and daily life is yet to be realized. Its adoption holds much promise for low-income countries in catching up with others.

While the Internet is undeniably unique, the question remains as to if its adoption is beneficial or hazardous. This paper contends that it can be both depending on the adopter. Information technologies have potential to improve the efficiency of agricultural markets by decreasing market thinness and reducing futures markets' operating costs. Despite the advantages of Internet adoption, the digital divide remains a concern.

Using proxies for basic development indicators, both ordinary least squares and logit models for Internet adoption were estimated. A reduced OLS model seemed to estimate well with a lower degree of multicollinearity than was present in the complete model. All of the parameters in the logit model were significant, and most of the signs on the parameter estimates were expected. The weighting procedure used in the logit model caused unreasonably small standard errors and, therefore, highly significant estimates. The multicollinearity that was present in the OLS model continues to be a concern in the logit model. The logit model seemed to fit the data well, but the marginal effects of the parameters on Internet adoption were very small.

The information provided by the Internet holds great promise for those who have never had access to such information before. Markets work more efficiently in the presence of more abundant information. The knowledge to be gained from the Internet makes a different set of skills more valuable in the market. As the unique characteristics of the Internet are better understood, a more accurate picture of how to best use the technology can be gathered, as can the most productive ways to encourage its adoption.

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