# Examining the Takeoff of Digital Technologies in Developing Countries

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**April 2005**

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## ABSTRACT

In an increasingly global economy, information and communication technologies (ICT) are critical for nations to participate in trade and reap the benefits of access to world markets. Economists call for investments that generate new innovations to spur economic development in the country. In addition to being the source of innovation, economic growth also depends on the ability of nations to absorb and apply new innovations that germinated elsewhere. Despite accumulating evidence that several factors play an important role in the assimilation of new technologies, the drivers of adoption of digital technologies are not well understood and the findings remain inconsistent. Based on theories of economic growth and innovation diffusion theory and using the well known *takeoff* phenomenon as the underpinning, we hypothesize and empirically examine the relationships between human capital (literacy, life expectancy), cost, international trade (foreign direct investment), communications infrastructure (Television and Telephone) and the *takeoff* of digital technologies. Our findings confirm that important differences exist among the high, medium and low income countries with respect to the takeoff times for digital technologies. In addition, our study reveals the differential impact of the covariates on takeoff for the three income groups. In sum, we find partial support for the influence of the covariate factors we modeled. Policy implications include the need for tailoring the adoption programs based on country income group, technology type and adoption stage (before or after takeoff).

## 1. Introduction

In an increasingly global economy, information and communication technologies (ICT) are critical for nations to participate in trade and reap the benefits of access to world markets. The capability of businesses, in both developing and developed nations, to participate in the global supply chain will largely depend on their ability to communicate with their partners distributed worldwide and maintain a competitive edge. In this vein, particularly for developing countries, adoption of digital technologies is critical to increase productivity and growth (Joseph, 2002) to make them competitive in the global market. A recent study by Clarke and Wallsten (2004) found strong evidence that the penetration of the Internet had a significant impact on export performance from low income to high income countries. Kraemer and Dedrick (2001) report on the positive effects of information technology on both productivity and GDP. On the other hand, lagging behind in the assimilation of new technologies will not only put these countries at a disadvantage for global commerce opportunities, but also contribute to widening the *digital divide* (Wallsten, 2004) that potentially could stunt economic growth and isolate the nation from the rest of the world. Recognizing this consequence and the need for encouraging the adoption of new technologies, organizations like the World Bank and United Nations have embarked on several initiatives to accelerate the adoption of ICT in developing and underdeveloped nations around the world (e.g., infodev program).

Theories of economic growth call for investments that generate new innovations to spur economic development in the country (Romer 1990). In addition to being the source of innovation, economic growth also depends on the ability of nations to absorb and apply new innovations that germinated elsewhere (Hall and Jones, 1997). In essence, this requires efforts to facilitate strategic planning, policy and program development to promote the assimilation of innovations (e.g., digital technologies) in countries across the globe. Hence, organizations like the United Nations rely on an understanding of the drivers of diffusion to develop appropriate programs. To this end, prior studies have studied the importance of level of income (Ahn and Lee, 1999), trade and financial indicators, education/human capital (Pohjola 2003, Shih et al., 2002, Lee 2001,), price (Madden et al., 2004, Pohjola, 2003), network effects (Rouvinen, 2004) and infrastructure in the diffusion of digital technologies (Baliamoune-Lutz, 2002, Kshetri and Cheung, 2002). However, despite accumulating evidence that several of these factors play an important role in the assimilation of new technologies, the drivers of digital technologies are not well understood and the findings inconsistent. For example, while some studies report the influence of education on the diffusion of ICTs (Shih et al., 2002[1]), others (e.g., Baliamoune-Lutz, 2002) find little evidence linking adoption to education. Also, interestingly Shih et al., (2002) find the factors of human capital and telecommunication infrastructure only relevant for developing countries and insignificant for developed countries.

In addition to the lack of consistent findings, there are also data related issues with prior studies. A quick look at the adoption of digital technologies like the Internet and mobile phone reveals the right truncated nature of the data i.e., with the introduction of these innovations only recently, they did not have enough longitudinal data to conduct rigorous analysis using panel data. This problem is compounded when applied

[1] The study relied on investments in hardware and systems as a surrogate measure for adoption of information technologies. Although expected to be highly correlated with the measure that other studies use for adoption (e.g., PC users per 1000), this relationship is not known.

to low income countries where the introduction of technologies occurred even much later compared to the med-income countries.

The purpose of this research is to empirically examine the relationships between drivers and the *takeoff* of digital technologies. Diffusion patterns of various technologies typically exhibit the "takeoff" phenomenon, i.e., adoptions are very low for extended period of time during the early stages of a technology introduction. Following this period, successful adoption to a broader user base will result in eventually a sharp increase (e.g., Golder and Tellis 1997; Agarwal and Bayus 2002). In most cases, the takeoff in the technologies can be visually identified (see Figure 1). The takeoff point is conceptually significant as it signals the point at which deep penetration of the technology begins. The idea is also related to the concept of *critical mass*[2] discussed in the innovation diffusion theory. Critical mass is the minimum adoption needed for future diffusion to be self-sustaining (Rogers, 2003). Rogers emphasizes the importance of critical mass for interactive innovations like the fax and Internet. The takeoff point reflects the achievement of critical mass. We aim to build on prior work and use the takeoff framework widely used by marketing researchers (Agarwal and Bayus, 2002) in our study and seek to understand the drivers for the innovation takeoff. By using the takeoff framework, our focus shifts from the overall diffusion to the point of inflexion that signals the beginning of a period of broad assimilation of the innovation.

Insert Figure 1 about here

[2] Originally, the notion of critical mass is derived from physics, where it is defined as the quantity of radioactive material necessary to generate a nuclear reaction (Rogers, 2003).

With this backdrop, we specifically seek to answer the following questions: (a) Does country Income influence the takeoff of digital technologies?, (b) Does human capital (education and life expectancy) influence the takeoff of digital technologies?, (c) Does price influence the time to takeoff for digital technologies?, and (d) What are the differences between developed and developing countries with respect to the takeoff of digital technologies?. Using data from the World Bank and International Telecommunication Union we study the spread of four digital innovations – Cable TV, Personal Computers, Internet and Mobile Phone, in both developed and developing countries. Using survival analysis we report on the strength of the factors in influencing the takeoff of digital technologies.

The rest of the paper is organized as follows. We present the theoretical underpinnings and hypothesize relationships in the next section. In § 3, we present the details of data and the methods used for analysis. Results and discussion of our findings are reported in § 4 followed by conclusions.

## 2. Theory & Hypotheses

*Human Capital*

While the quantitative impact of investments in human capital on growth has been not precisely measured, there is a preponderance of empirical support that it does result in higher growth rates for the countries. For example, a recent World Bank study (Chan and Dahlman, 2004) documents a link between investments in education and growth rates for countries. Barro (1991), based on a study in 98 countries found a positive relationship between school enrollment rates and growth (per capita real GDP).

Consistent with this, Cohen and Soto (2001) reported a positive relationship between average years of school and economic growth. A well educated population is critical to the generation of new innovations and should result in increased productivity and hence, economic growth. In the context of innovation diffusion theory, Rogers (2003) describes the early adopters of an innovation to be more literate than non-adopters clearly suggesting that they are best prepared to adopt new technologies. Hence, we posit -

H1: Higher literacy rates will be associated with shorter time to takeoff of digital technology

Economic growth models have long treated life expectancy as an exogenous variable that increases the time horizon over which investments in education can be realized in turn driving investment in human capital and spurring growth[3] (Zhang, et al., 2001, de la Croix and Licandro, 1999, Rosenzweig, 1990, Kalemli-Ozcan et al., 2000, Boucekkine et al., 1999, Kalemli-Ozcan, 2002). With the increase in the time horizon over which the educated can be tapped, the likelihood that the technology will be adopted increases. Hence, we expect -

H2: Higher life expectancy will be associated with shorter time to takeoff of digital technology

[3] But there exists other perspectives that treat life expectancy as an endogenous variable (Cervellati and Sunde, 2002). The issue of whether life expectancy is an exogenous or endogenous with respect to growth is the subject of discussion in several economic articles. But a comprehensive treatment of this subject is outside the scope of this study. Suffice it to say that there is enough empirical evidence supporting the use of it as exogenous and will be used as such in this study.

*Communications Infrastructure*

The ability of a country to create conditions for rapid adoption of digital communication technology requires a sound infrastructure in place. With a more robust infrastructure and higher resources directed toward it, the country will have higher absorptive capacity for new digital technologies. Consistent with this rationale, recent evidence shows that the distribution of the Internet follows that of the existing communications infrastructure (e.g., Oxley and Yeung 2001, Kiiski and Pohjola 2002). Hence, we posit -

H3: Higher levels of communications infrastructure (Televisions and Telephones) will be associated with shorter time to takeoff of technology

*International Trade*

Higher levels of international trade in the form of foreign direct investment (inward) allows host economies access to new innovations and knowledge. Further, global corporations tend to standardize their business processes thereby providing valuable knowledge about the operations to the host country. Multinational companies competing in the global marketplace are most likely to use and advance the use of new technologies for communication to improve productivity. As an indirect benefit of the foreign direct investment, we posit -

H4: Higher levels of FDI will be associated with shorter time to takeoff of digital technology

*Technology Cost*

Supply side economics reasons that increased competition lowers prices resulting in takeoff. This argument has been supported by several prior studies (e.g., Bass 1980, Russell 1980, Metcalfe 1981, Foster 1986, Stoneman and Ireland 1983, Golder and Tellis 1997). Consistent with this argument, innovation diffusion theory recognizes the role of cost of an innovation as influencing the adoption process (Rogers, 2003). In line with this rationale, we posit -

H5: Higher costs of the digital technology will be associated with longer time to takeoff of digital technology

## 3. Data & Method

### 3.1 Data

All data were obtained from the world-bank development indicators (WBI) database 2002. The adoption variables for CATV, Cell Phone, Internet, PC, Telephone, TV were from WBI, but the original source of the data is "International Telecommunication Union, World Telecommunication Development Report and database."

To create country categories we segmented the data into high, medium and low groups, based on income. GDP was averaged for the period 1992-2002, and the countries were sorted by this average. The lowest 50 were put into group 1, the highest were put into group 3, and the median 51 were put into group 2. For each product within each country, we identified the *takeoff*[4] point by examining a plot of the technology (product) adoption per 1000 people, a plot of the point-percent change for each time, and the residual of a fitted linear regression. We identified the “start point” (introduction) for each product by finding the earliest-use point of data collection across all countries for each product.

### 3.2 Variables

A list of the variables along with a brief description is shown in Table 1. Variables used in the study were drawn from four different categories – Human capital, Communications infrastructure, International trade, and Technology Cost. We include two variables in the human capital category – Literacy level and Life expectancy. In the communications infrastructure category we use the number of telephone lines per 1000. In the international trade category, consistent with (Baliamoune-Lutz, 2002), we use foreign direct investment. The only measure of digital technology cost available to us in the database was the price of accessing the Internet. Hence, we are only able to use the cost variable only for modeling personal computer and Internet takeoff. It may be noted that all the four categories of variables have been extensively used in prior studies (e.g., Baliamoune-Lutz, 2002, Benhabib & Spiegel, 2002, Kraemer and Dedrick, 2001).

[4] As discussed in Agarwal and Bayus (2002), we follow the general procedure outlined in Gort and Klepper (1984) for computing the takeoff point. In a nutshell, this procedure involves a methodical search for the first occurrence of a relatively very large increase in the adopter population after the introduction of a new digital technology.

### 3.3 Method

The dependent measure of interest was takeoff duration of the digital technology under consideration and was defined as the length of time from when the product was first available in the world (start point) until the point of *takeoff*. Those products for which no takeoff was observable or had indeterminate plots were deemed to not have achieved takeoff, and are right-censored. Indeterminate plots had no break point, insufficient number of points, or constant low growth rates (another instance of no break point).

We analyzed the non-takeoff of each of the product-countries, grouped by income, to determine if there were, in fact, differences in takeoff point between them. Based on income (group) differences, also known as strata, we analyzed the impact of covariate variables. We used survival analysis technique[5] to determine the takeoff point for all the countries in our sample. Survival analysis methodology is discussed extensively in Collett (1994), Cox and Oakes, (1984), Kalbfleish and Prentice (1980), Lawless (1982), and Lee (1992). For a comprehensive treatment of the subject, we refer the readers to these texts but we present a brief note on the procedure here. The analysis of survival data involves, first, the estimation of the distribution of the survival times. Survival times are frequently labeled as *failure* times. The survival distribution function (SDF), also known as the survivor function, is used to describe the lifetimes of the population of interest (see Figure 3). In our case, the event of interest is the *takeoff.* Survival, in this, case represents the lack of occurrence of the event at time t. The SDF

[5] LIFETEST function of SAS was used to estimate the hazard function and the LIFEREG procedure provided follow up tests on the covariates.

evaluated at t is the probability that an experimental unit from the population will have a lifetime exceeding t, i.e., $S(t) = Pr(T > t)$, where $S(t)$ denotes the survivor function and T denotes the lifetime of a randomly selected experimental unit. Other functions that are closely related to the SDF are the cumulative distribution function (CDF), the probability density function (PDF), and the hazard function. The CDF, denoted $F(t)$, is defined as $1 - S(t)$ and is the probability that a lifetime does not exceed t. The PDF, denoted $f(t)$, is defined as the derivative of $F(t)$, and the hazard function, denoted $h(t)$, is defined as $f(t)=S(t)$. Frequently, the analysis of survival data involves the comparison of survival curves. Researchers applying this type of analysis are typically interested to determine whether two or more samples have arisen from identical survivor functions. To facilitate such analysis, two rank tests and a likelihood ratio test for testing the homogeneity of survival functions across strata are generally used. The rank tests are censored-data generalizations of the Savage (exponential scores) test and the Wilcoxon test.

Insert Figure 3 about here

## 4. Results & Discussion

### 4.1 Takeoff of Digital Technologies

Figures 2a-2d show the diffusion patterns for the four products – Cable Television, Personal Computer, Internet and Mobile Phone. Each figure shows the adoption pattern for all the three categories of countries – High, Medium and Low Income. A quick look at the figures reveals that the takeoff of all four digital technologies occurs much earlier for High Income countries compared to Medium or Low Income nations. In addition, looking at Table 2 reveals a surprising fact that more number of countries in the medium and low income countries had experienced a takeoff in Personal Computers, the Internet and Mobile Phone than Cable Television (considering the recency of the PC and Internet versus the Cable Television this is revealing). An explanation for the more recent technologies to have taken off in such large numbers even in medium and low income countries is the network effect (Katz and Shapiro,1985,1986,1994). Except for Cable Television which is a one-way medium of communication, all the other technologies under consideration facilitate two-way communication thereby making the benefits a function of the user base; the more number of adopters use the technology, the more benefits everyone in the network derives. In addition to this direct network effect, there is also an indirect network effect for the Internet and PCs. i.e., With increasing number of adopters of the Internet, personal computers were more readily available and lower in prices. In effect, it could be argued that Internet diffusion accelerated the adoption of personal computers and influenced an earlier takeoff.

Insert Table 2 about here

Insert Figures 2a-2d about here

*Country Income and Takeoff*

Both Log-rank and Wilcoxon tests for equality of strata confirm that the time to takeoff are indeed different for all the three income level country groups for all the four digital technologies (see Tables 3-6). This finding is consistent with several prior studies for a variety of innovations (e.g. Van den Bulte, 2000). It is interesting to note that the variance in the time to takeoff for all the digital technologies for low and medium income countries is relatively small compared to the high income country group. This suggests that the high income group is not as homogeneous a group as the other two.

Another insight in looking at the diffusion patterns is that the point of takeoff for the digital technologies also varies from a user base perspective. For example, for high income countries the takeoff of cable television occurred almost from the point of introduction (practically very few users per 1000) whereas for the Internet it required almost 50 users per 1000 (a 5 % penetration level) to achieve takeoff.

### 4.2 Covariates of Takeoff for Digital Technologies

*Human Capital and Time to Takeoff*

We examined two variables – literacy and life expectancy as covariates to the takeoff of digital technologies. Overall, our findings suggest that the importance of these variables is dependent upon which income group the country group belongs to.

Based on univariate analysis, the literacy variable was a significant covariate with the time to takeoff for only the Cable TV technology (see Table 7). However, based on a forward sequence of chi-squares literacy is no longer significant as a covariate. But an analysis using LIFEREG revealed that the importance of literacy as a covariate is not consistent across all the three country groupings[6]. For example, in the case of Cable TV, literacy emerges as an important covariate for both high and medium income countries but not for low income countries. Similarly, for the takeoff of personal computers, literacy again is an important predictor of takeoff for high and medium income nations but not for low income countries (see Table 8). Low income countries have extremely low rates of literacy and hence, it appears that there is little evidence at this time to show the influence of the variable. However, if the medium and high income

[6] It is important to note that owing to the lack of data for many countries for specific variables, the sample size in each of the country groupings was small (varied between 6 and 14).

countries are an indication, as the literacy rate grows in the low income group it is expected to play a more significant role in the adoption and takeoff of the new technology.

For the takeoff of the Internet, literacy is a significant predictor for high and low income countries but not for medium income countries (see Table 9). This is an interesting finding suggesting that the type of initial users in the medium income countries was drawn from a broader base than either of the other two groups. This also points to the broad nature of use that this technology can support (from knowledge dissemination to recreation). Interestingly, it seems to be the case that the initial adopter population in both high and low income countries was largely drawn from the literate group versus a broader participation in the medium income countries.

For the takeoff of mobile phone technology, literacy is an important covariate for medium income countries but not for high or low income countries (see Table 10). The finding of non-significance in the low income sector is consistent with Cable TV and is possibly for the same reason of low literacy rates in these countries. But it is not clear why literacy appears to be a significant covariate for high income countries for takeoff.

Insert Tables 7-10 about here

Next, we examine the role of life expectancy as a covariate of takeoff of digital technologies. Overall, life expectancy is a significant covariate of takeoff for Cable TV and mobile phone technologies. Once again, we conducted a follow up test for each of the income groups to note the variation in the influence of this variable across income groups. For Cable TV we found that life expectancy is significant for high and medium income countries but not for low income countries. For mobile phone technology, we found that the variable is significant only for high income countries but not for medium or low income countries. Our findings taken in total provide only partial support for support for H1 and H2.

*Communications Infrastructure and Time to Takeoff*

At the univariate level, telephones and televisions emerged as influencing covariates for Cable television takeoff. But when forward sequence for the Wilcoxon test was conducted, there turned out to be not significant implying that some other covariate captured much of the variance they explain in the takeoff timing (in this case it happened to be life expectancy, see Table 7). Interestingly, the factors were not significant for any of the other technologies except for mobile phone. The number of telephone connections emerged as an important covariate of the takeoff of the mobile phone technology. This is quite interesting because the very nature of the mobile phone technology does not require any pre-existing telephone lines. In this case, it is possible that learning effects from the use of the old technology are transferred to the new mobile phone technology. Essentially, our results provide only partial support for H3.

*Foreign Direct Investment and Time to Takeoff*

The most striking finding was the non-impact of FDI on all the four digital technologies' time to takeoff. There are several reasons why this was the case. First, the variable FDI could probably be a variable that doesn't fully capture the transnational corporation presence. Second, it could interact with other variables like literacy that is a better predictor of the time to takeoff. Third, with the developing countries receiving FDI being relatively small in number and size, perhaps there needs to be a threshold that needs to be crossed before its impact can be felt on a broader scale. We find no support for H4.

*Internet Cost and Time to Takeoff*

Supply side economics reasons that increased competition lowers prices resulting in takeoff. So we expect the cost of the Internet to directly impact the takeoff of the technology but also indirectly impact the takeoff of personal computers that individuals use to access the Internet. Our findings partially support this premise. While the overall results support the hypothesis that costs play an important role in predicting the takeoff of Internet technology, it does not appear to have an overall influence in the takeoff of personal computers. We interpret our findings as partial support for H5.

*Implications – Policy and Future Research*

The findings of this research have implications for policy makers in world organizations such as the United Nations and national governments in various countries. First, it is quite clear that the relationship between various factors influencing the takeoff of digital technologies is quite complex. Second, the type of digital technology does influence the nature of explanatory variable being significant. Third, it is important to note the influence of the variables before and after takeoff to seek a better understanding of the drivers of takeoff. With only a few points after takeoff available for the technologies we studied, it was difficult to conduct post-takeoff analysis for most of them. Future studies can design their research to do a comparative analysis using the panel data for additional insights. Based on this, we suggest that programs be designed to promote new technologies with a contingency framework in mind – the income level of the country, the technology type and the stage of adoption (pre-takeoff vs. post-takeoff).

Future research can build upon this study by focusing on micro-level panel data collection in several countries. This type of micro-level data on who the adopters are and how they use the new digital technology and the manner in which they influence others to adopt the innovation can be the key to understanding phenomenon like social learning that the innovation diffusion theory purports will influence the adoption process. For example, anecdotal evidence on the use of digital technologies like mobile phone reveals that the type and intensity of use may be higher in developing countries like India and China than even developed countries.

**Conclusions**

Our study examined various factors influencing the takeoff of digital technologies globally, with a focus on developing countries. Results suggest that the variables used in several prior studies to predict adoption in developing countries have a differential impact when modeled as covariates to the takeoff of digital technology innovations. Importantly, their predictability is found to depend on technology type and income level of the countries. Note that usually all developing countries are bundled as one for analysis purposes and our results suggest that this may lead to misleading conclusions.

With only partial support for all the variables modeled in our analysis future research can further explore these findings with additional data available in the future.

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## Table 1: Variable Description

| Variable | Variable Description |
|---|---|
| CELL | Mobile phones (per 1,000 people) |
| PC | Personal computers (per 1,000 people) |
| INT | Internet users (per 1,000 people) |
| CATV | Cable television subscribers (per 1,000 people) |
| FDI | Foreign direct investment, net inflows (% of GDP) |
| LIT | Literacy rate, adult total (% of people ages 15 and above) |
| TEL | Telephone mainlines (per 1,000 people) |
| TV | Television sets (per 1,000 people) |
| GDP | GDP per capita, PPP (constant 1995 international $) |
| LIFE | Life expectancy at birth, total (years) |
| ICOST | Cost of Internet access |

## Table 2: Takeoff of Digital Technologies

| | | Cable TV | | Personal Computers | | Internet | | Mobile Phone | |
|---|---|---|---|---|---|---|---|---|---|
| | Sample | Number achieving Takeoff | Mean Time to Takeoff (Variance) | Number achieving Takeoff | Mean Time to Takeoff (Variance) | Number achieving Takeoff | Mean Time to Takeoff (Variance) | Number achieving Takeoff | Mean Time to Takeoff (Variance) |
| **Low** | 50 | 17 | 17.76 (5.48) | 50 | 9.1 (1.27) | 40 | 21.41 (3.90) | 45 | 19.48 (1.30) |
| **Medium** | 51 | 30 | 17.13 (5.42) | 51 | 8.78 (1.33) | 45 | 19.30 (5.67) | 50 | 18.58 (2.12) |
| **High** | 50 | 39 | 14.91 (7.56) | 49 | 7.04 (2.37) | 48 | 15.33 (36.28) | 49 | 16.12 (3.52) |

## Table 3: Cable TV Takeoff

| Income Group | Percent Censored | Log-Rank | Wilcoxon |
|---|---|---|---|
| Low GDP (bottom 50) | 76 | -17.102 | -2195 |
| Medium GDP (median 50) | 54.9 | -2.182 | -368 |
| High GDP (top 50) | 28 | 19.284 | 2563 |

| Test of equality over Strata | | | |
|---|---|---|---|
| Test | Chi-Square | DF | Pr > Chi-Square |
| Log-Rank | 34.6381 | 2 | <.0001 |
| Wilcoxon | 40.041 | 2 | <.0001 |
| -2Log(LR) | 23.0731 | 2 | <.0001 |

## Table 5: Internet Takeoff

| Income Group | Percent Censored | Log-Rank | Wilcoxon |
|---|---|---|---|
| Low GDP (bottom 50) | 0 | -15.573 | -2021 |
| Medium GDP (median 50) | 0 | -6.957 | -1183 |
| High GDP (top 50) | 2 | 22.531 | 3204 |

| Test of equality over Strata | | | |
|---|---|---|---|
| Test | Chi-Square | DF | Pr > Chi-Square |
| Log-Rank | 38.4916 | 2 | <.0001 |
| Wilcoxon | 54.321 | 2 | <.0001 |
| -2Log(LR) | 0.8144 | 2 | 0.6655 |

## Table 4: Personal Computers Takeoff

| Income Group | Percent Censored | Log-Rank | Wilcoxon |
|---|---|---|---|
| Low GDP (bottom 50) | 24 | -18.912 | -2118 |
| Medium GDP (median 50) | 13.73 | -4.261 | -765 |
| High GDP (top 50) | 4 | 23.173 | 2883 |

| Test of equality over Strata | | | |
|---|---|---|---|
| Test | Chi-Square | DF | Pr > Chi-Square |
| Log-Rank | 35.1189 | 2 | <.0001 |
| Wilcoxon | 42.3261 | 2 | <.0001 |
| -2Log(LR) | 5.8686 | 2 | 0.0532 |

## Table 6: Mobile Phone Takeoff

| Income Group | Percent Censored | Log-Rank | Wilcoxon |
|---|---|---|---|
| Low GDP (bottom 50) | 10 | -26.517 | -3083 |
| Medium GDP (median 50) | 1.96 | -1.716 | -644 |
| High GDP (top 50) | 2 | 28.233 | -3727 |

| Test of equality over Strata | | | |
|---|---|---|---|
| Test | Chi-Square | DF | Pr > Chi-Square |
| Log-Rank | 67.8429 | 2 | <.0001 |
| Wilcoxon | 81.9178 | 2 | <.0001 |
| -2Log(LR) | 2.278 | 2 | 0.3202 |

## Table 7: Covariates for Cable TV Takeoff

**Univariate Chi-Squares for the Wilcoxon Test**

| Variable | Test Statistic | Standard Deviation | Chi-Square | Pr>Chi-Square |
|---|---|---|---|---|
| FDI | 0.8106 | 5.6464 | 0.0206 | 0.8859 |
| LIT | -58.0019 | 19.7384 | 8.6349 | 0.0033 |
| TEL | -1012.6 | 405.2 | 6.244 | 0.0125 |
| TV | -870.1 | 373.7 | 5.4206 | 0.0199 |
| LIFE | -54.6888 | 16.543 | 10.9287 | 0.0009 |

**Forward Stepwise Sequence of Chi-Squares for the Wilcoxon Test**

| Variable | DF | Chi-Square | Pr> Chi-Square | Chi-Square Increment | Pr > Increment |
|---|---|---|---|---|---|
| LIFE | 1 | 10.9287 | 0.0009 | 10.9287 | 0.0009 |
| TEL | 2 | 12.4722 | 0.002 | 1.5436 | 0.2141 |
| TV | 3 | 12.6845 | 0.0054 | 0.2123 | 0.645 |
| FDI | 4 | 13.0175 | 0.0112 | 0.333 | 0.5639 |
| LIT | 6 | 13.3024 | 0.0385 | 0.2 | 0.6547 |

## Table 8: Covariates for Personal Computer Takeoff

**Univariate Chi-Squares for the Wilcoxon Test**

| Variable | Test Statistic | Standard Deviation | Chi-Square | Pr >Chi-Square |
|---|---|---|---|---|
| FDI | 12.2484 | 12.3398 | 0.9852 | 0.3209 |
| LIT | 9.7377 | 29.0495 | 0.1124 | 0.7375 |
| TEL | -25.3508 | 416 | 0.00371 | 0.9514 |
| TV | -192.0 | 323.9 | 0.3515 | 0.5533 |
| LIFE | -15.3839 | 18.9296 | 0.6605 | 0.4164 |
| ICOST | 12.5016 | 91.7693 | 0.0186 | 0.8916 |

**Forward Stepwise Sequence of Chi-Squares for the Wilcoxon Test**

| Variable | DF | Chi-Square | Pr> Chi-Square | Chi-Square Increment | Pr > Increment |
|---|---|---|---|---|---|
| FDI | 1 | 0.9852 | 0.3209 | 0.9852 | 0.3209 |
| LIFE | 2 | 2.1636 | 0.3390 | 1.1783 | 0.2777 |
| LIT | 3 | 2.4791 | 0.4791 | 0.3155 | 0.5743 |
| TV | 4 | 2.6529 | 0.6175 | 0.1738 | 0.6768 |
| TEL | 5 | 3.6991 | 0.5935 | 1.0462 | 0.3064 |
| ICOST | 6 | 3.7765 | 0.7069 | 0.0774 | 0.7808 |

## Table 9: Covariates for Internet Takeoff

**Univariate Chi-Squares for the Wilcoxon Test**

| Variable | Test Statistic | Standard Deviation | Chi-Square | Pr>Chi-Square |
|---|---|---|---|---|
| FDI | 10.778 | 8.0791 | 1.7797 | 0.1822 |
| LIT | 7.0041 | 33.6548 | 0.0433 | 0.8351 |
| TEL | -635.6 | 393.3 | 2.6112 | 0.1061 |
| TV | -474 | 312.8 | 2.2958 | 0.1297 |
| LIFE | -7.4748 | 9.9619 | 0.563 | 0.453 |
| ICOST | -165.6 | 95.0292 | 3.0352 | 0.0815 |

**Forward Stepwise Sequence of Chi-Squares for the Wilcoxon Test**

| Variable | DF | Chi-Square | Pr> Chi-Square | Chi-Square Increment | Pr > Increment |
|---|---|---|---|---|---|
| ICOST | 1 | 3.0352 | 0.0815 | 3.0352 | 0.0815 |
| TV | 2 | 6.231 | 0.0444 | 3.1957 | 0.0738 |
| LIT | 3 | 7.8795 | 0.0486 | 1.6485 | 0.1992 |
| LIFE | 4 | 8.1379 | 0.0867 | 0.2584 | 0.6112 |
| FDI | 5 | 8.2642 | 0.1423 | 0.1262 | 0.7224 |
| TEL | 6 | 8.3736 | 0.2120 | 0.1094 | 0.7408 |

## Table 10: Covariates for Mobile Phone Take off

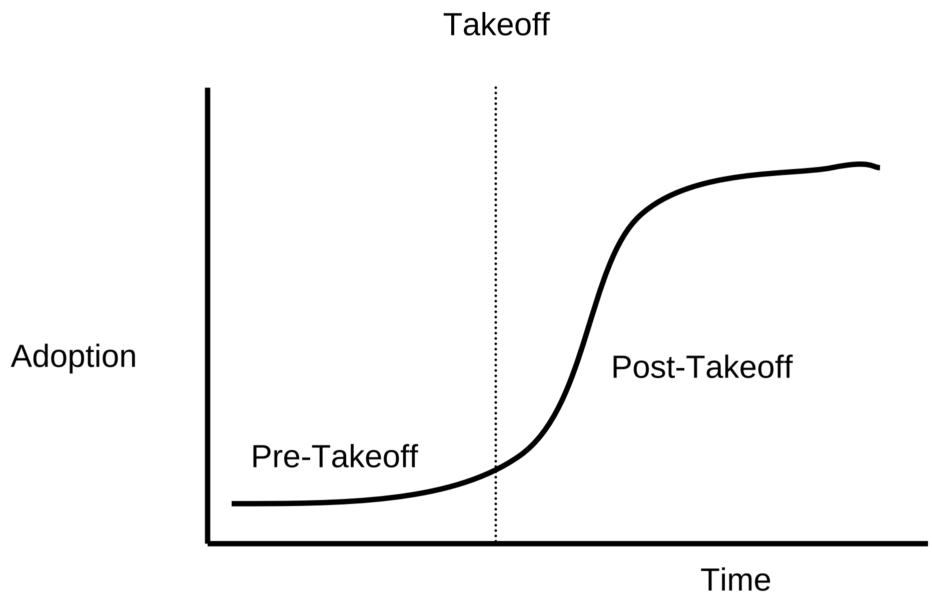
**Univariate Chi-Squares for the Wilcoxon Test**

| Variable | Test Statistic | Standard Deviation | Chi-Square | Pr>Chi-Square |
|---|---|---|---|---|
| FDI | -7.3602 | 21.9295 | 0.1126 | 0.7372 |
| LIT | 15.9064 | 42.765 | 0.1383 | 0.7099 |
| TEL | -720.6 | 356.8 | 4.0786 | 0.0434 |
| TV | -432.9 | 300.3 | 2.0781 | 0.1494 |
| LIFE | -23.6984 | 20.7164 | 1.3086 | 0.2526 |

**Forward Stepwise Sequence of Chi-Squares for the Wilcoxon Test**

| Variable | DF | Chi-Square | Pr> Chi-Square | Chi-Square Increment | Pr > Increment |
|---|---|---|---|---|---|
| TEL | 1 | 4.0786 | 0.0434 | 4.0786 | 0.0434 |
| LIT | 2 | 5.7862 | 0.0554 | 1.7077 | 0.1913 |
| LIFE | 3 | 8.522 | 0.0364 | 2.7358 | 0.0981 |
| TV | 4 | 8.618 | 0.0714 | 0.096 | 0.7567 |
| FDI | 5 | 8.669 | 0.123 | 0.0509 | 0.8215 |

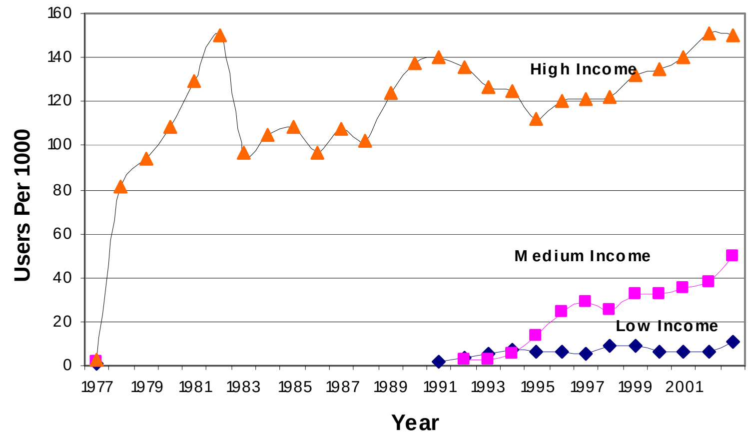
**Figure 1: Typical diffusion curve showing the pre and post takeoff periods**



## Diffusion Patterns for Digital Technologies*

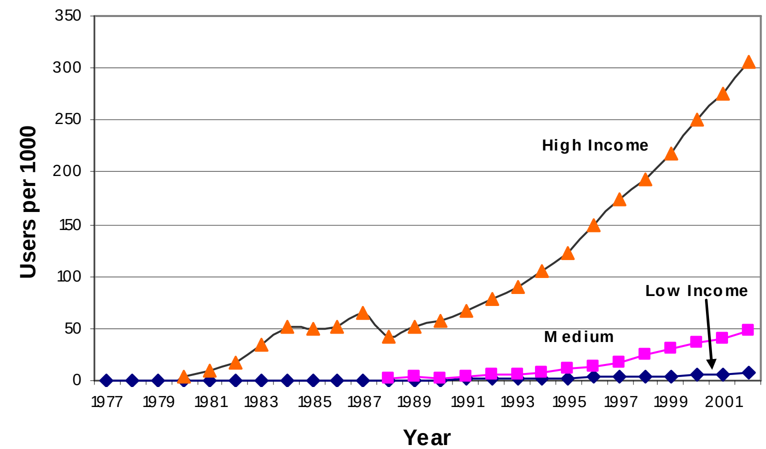
### Figure 2a

Diffusion Pattern for Cable TV



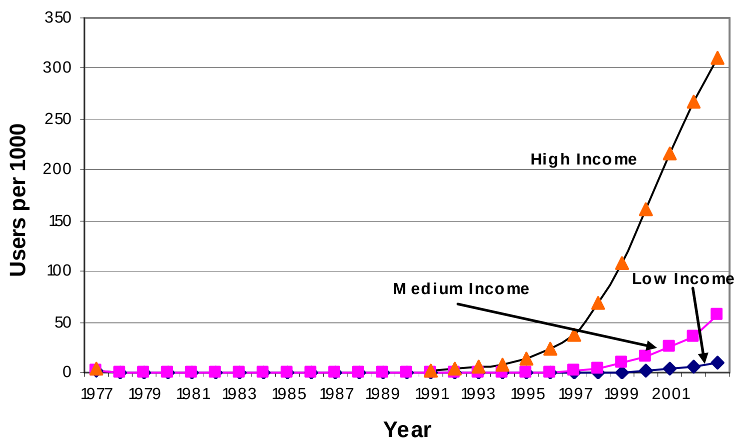

### Figure 2b

Diffusion Pattern for Personal Computers



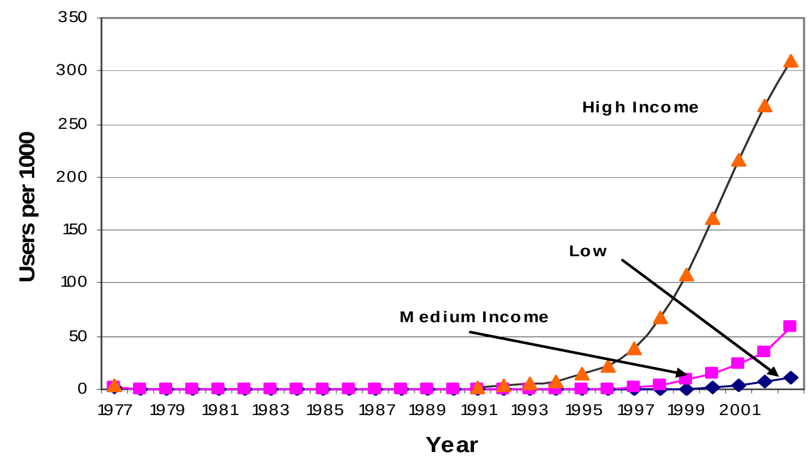

### Figure 2c

Diffusion Pattern for Mobile Phone




### Figure 2d

Diffusion pattern for Internet Use




* Note that these patterns represent the mean for each group of countries. While it gives us an idea of the mean takeoff point for all the three income groups of countries, it is important to emphasize that none of them actually represent adoption pattern in a country and hence are not useful for computing country takeoff points.

**Figure 3: Survival distribution function for Cable TV**