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Balaji Rajagopalan
Oakland University

Derek Hillison
Michigan State University

Roger Calantone
Michigan State University

V. Sambamurthy
Michigan State University

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Examining the Takeoff of Digital and Communicative Technologies in Developing Countries

Balaji Rajagopalan

Oakland University
rajagopa@oakland.edu

Roger Calantone

Michigan State University
rogercal@msu.edu

Derek Hillison (coresponding)

Michigan State University
hillison@msu.edu

Vallabh Sambamurthy

Michigan State University
smurthy@msu.edu

ABSTRACT

Information and communication technologies (ICT) are critical for nations to participate in trade and reap the benefits of access to world markets. Despite 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 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 the physical quality of life (literacy, life expectancy), and macroeconomic indicators of overall development (foreign direct investment, communications infrastructure) and the takeoff of digital technologies. Our findings confirm that important differences exist with respect to takeoff in high, medium and low income countries. Our study also reveals the differential impact of the covariates on takeoff for the three income groups.

Keywords

Economic Development, Technology Adoption, Information and Communicative Technologies, Survival Analysis

EXAMINING THE TAKEOFF OF DIGITAL AND COMMUNICATIVE TECHNOLOGIES IN DEVELOPING COUNTRIES

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. For developing countries, adoption of digital technologies is critical to increase productivity and growth (Joseph, 2002). 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). 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).

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,), network effects (Rouvinen, 2004) and infrastructure in the diffusion of digital technologies (Bali moune-Lutz, 2002, Kshetri and Cheung, 2002). One reviewer pointed out that it these are obvious conclusions, but our empiric investigation indicates more complexity than might be expected.

Despite accumulating evidence that several of these factors play an important role in the assimilation of new technologies, the drivers of digital and communicative 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., 2002¹), others (e.g., Bali moune-Lutz, 2002) find little evidence linking adoption to education. Also, Shih et al., (2002) find the factors of human capital and telecommunication infrastructure only relevant for developing countries and insignificant for developed countries.

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.

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.

The takeoff point is conceptually significant as it signals the point at which deep penetration of the technology begins. 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.

With this backdrop, we are specifically interested in two different views of the developing world and their impact on the diffusion of information and communication technologies. Physical quality of life, defined by the UN as literacy, mortality and gross domestic product, appears as a necessary condition to consumer technology diffusion. Conversely, a macroeconomic view looks at income, investment and infrastructure as necessary conditions to the development and expansion of a market for adoption of these technologies. These perspectives were developed from completely different literatures, and are divergent in their assumptions and focus on the importance of different types of development.

Our research questions are (a) Does physical quality of life (income, education and life expectancy) influence the takeoff of digital technologies? (c) Do macroeconomic measures of investment and infrastructure influence 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 test the strength of factors that influence the takeoff of digital technologies.

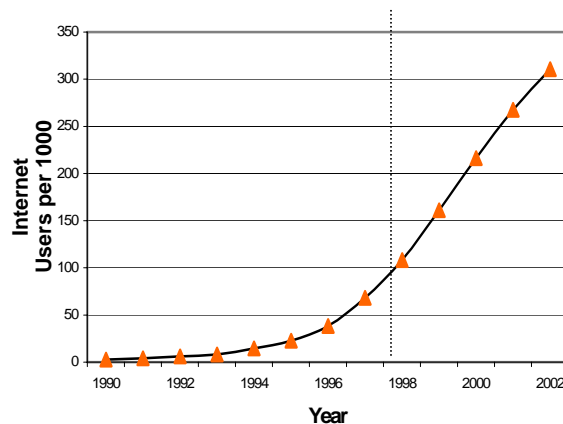


Figure 1--Takeoff

HYPOTHESES

Physical Quality Of Life

Physical quality of life is a way to measure how ‘well-off’ various peoples of the world are, from the basic perspectives of life expectancy, relative production, and literacy. If a country is below a minimum level of these components, the population may not be as able to adopt digital communicative technologies, and may be more interested in basic survival needs. Without basic literacy, a population may not be able to use the more text-oriented technologies such as personal computers and the internet. Gross domestic production serves as a ‘thermometer’ of a given economy, serving as a relative

measure of overall economic productivity of a given country. Higher GDP (PPP) is expected to be associated with shorter time to takeoff of digital technology (H1) Higher literacy rates will be associated with shorter time to takeoff of digital technology. (H2) Higher life expectancies will be associated with shorter time to takeoff of digital technology (H3)

Macroeconomic Development And Infrastructure

Production income (GDP) is also a general measure of macroeconomic development, aside from its use in the PQL index. Many economic models of development view income in this way as a direct driver of wealth and consumer behavior in a particular country. Both balanced and unbalanced growth theories perceive the development of many industries in concert, as they symbiotically grow and form markets for each other as one way that economy grows over time. From this perspective, higher GDP (PPP) is expected to be associated with shorter time to takeoff of digital technology (H1)

The ability of a country to create conditions for rapid adoption of digital communication technology requires a sound infrastructure. A robust, well resourced, infrastructure increases absorptive capacity for new digital technologies within a country. 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, higher levels of communications infrastructure (Telephones and Televisions) is associated with shorter time to takeoff of technology (H4 & H5)

Higher levels of international trade in the form of foreign direct investment (inward) allows host economies to access new innovations and knowledge. Further, global corporations tend to standardize their business processes thereby providing valuable knowledge 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, thus higher levels of FDI are associated with shorter time to takeoff of digital technology (H6)

DATA & METHOD

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 are 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 takeoff² 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.

Variables

Variables used in the study were drawn from two main categories – physical quality of life (PQL) and macroeconomic development. We include variables in the PQL – gross domestic product (purchasing parity power), Literacy level and Life expectancy. For macroeconomic development, we include GDP (PPP), communications infrastructure measures such as the number of telephone lines per 1000 and, consistent with (Baliamoune-Lutz, 2002), we use foreign direct investment.

Type	Variable	Description
PQL		
	GDP (ppp)	GDP per capita, PPP (constant 1995 international \$)
	Literacy	Literacy rate, adult total (% of people ages 15 and above)

² 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.

	Life Expectancy	Life expectancy at birth, total (years)
Economic Development		
	GDP (ppp)	GDP per capita, PPP (constant 1995 international \$)
	Telephone	Telephone mainlines (per 1,000 people)
	TV	Television sets (per 1,000 people)
	FDI	Foreign direct investment, net inflows (% of GDP)
Products		
	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)

Table 1: Variable Descriptions

Method

The dependent measure of interest is 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 (insufficient number of points, lack of discernable break-point) are deemed to not have achieved takeoff.

We grouped countries by income, to determine if there were differences in takeoff point between them. Based on income (group) differences, also known as strata, we then analyzed the impact of covariate variables, allowing the investigation of the remaining hypotheses. Survival analysis methodology was used to model differences in functions that drive takeoff for these countries, starting with general classification of income, and moving to a more in-depth analysis of covariates.

The analysis of survival data involves 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. In our case, the event of interest is the takeoff. For a more comprehensive treatment of survival analysis methodologies, we refer the reader to Collett (1994), Cox and Oakes, (1984), Kalbfleish and Prentice (1980), Lawless (1982), and Lee (1992).

Survival, in this, case represents the lack of occurrence of the event (takeoff) at time t . The SDF 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, and were used to evaluate H_1 . The remaining hypotheses (H_2 - H_6) were evaluated by running both a univariate chi-square Wilcoxon test and a forward stepwise sequence chi-square Wilcoxon test on the income-stratified data.

RESULTS & DISCUSSION

Income and Its Effect On Takeoff Of Digital Technologies (H1)

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, indicating support for H_1 . 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.

		Cell Phone	Internet	PC	Cable TV
PQL					
H1	GDP (ppp)	Supported	Supported	Supported	Supported
H2	Literacy				
H3	Life Expectancy				Supported
Economic Development					
H1	GDP (ppp)	Supported	Supported	Supported	Supported
H4	Telephone	Supported			
H5	TV		Supported		
H6	FDI				

Table 2: Summary of Hypotheses and Support

Covariates of Takeoff for Digital Technologies

Physical Quality of Life and Time to Takeoff (H2, H3)

Based on univariate analysis, literacy and life expectancy were a significant covariates with the time to takeoff for only the Cable TV technology. However, once the effect of life expectancy is partialled out, literacy is no longer significant as a covariate for this product. Further analysis, not reported here, indicates that there are differences between income groups that determine the relative prediction power of literacy on takeoff for all products investigated.

Overall, life expectancy is a significant covariate of takeoff for Cable TV. 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. There are differences between income groups as to the significance of life-expectancy. Our findings taken in total provide only partial support for support for H2 and H3.

Communications Infrastructure And Time To Takeoff (H4,H5, H6)

At the univariate level, telephones and televisions emerged as influencing covariates for Cable television takeoff. But the forward sequence for the Wilcoxon test indicated these were not significant after implying that some other covariate (life expectancy) captured much of the variance that explains takeoff timing.

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, but may indicate network effects from the installed base or may be related to learning effects from the use of wired phones. Essentially, our results provide only partial support for H4 and H5.

The most surprising 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 H6.

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. Despite the intuitive and theoretically obvious preconditions of quality of life and macroeconomic development, the empiric evidence presented here points to a much more complex relationship than previously thought. 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, and examine the income-level dependent functions of PQL and macroeconomic development.

References available from author upon request.

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