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EXAMINING GLOBAL TAKEOFF AND GROWTH OF DIGITAL WIRELESS PHONE TECHNOLOGY

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Abstract

The early phase of IT diffusion plays a critical role. Takeoff involving rapid growth of an IT is an acid test for whether the technology will succeed. We develop a new theory to understand global takeoff for digital wireless phones and technologies with related characteristics. We construct a multi-theoretical model that consists of standards, market competition, technology cost, and technology substitutions to explain takeoff and penetration during the growth phase. We test factors that drive takeoff times and further penetration growth during the growth phase after takeoff. The data are from 41 developed and developing countries. The results suggest that standards drive takeoff and penetration growth. Familiarity with wireless phones and an installed base of analog technology also explain faster takeoff times. Non-price factors are important drivers of penetration growth after takeoff too. Our results have implications on standards and competition policy settings for digital wireless phones.

Keywords: Growth, panel data model, survival analysis, takeoff, technology life cycle, theory-building research, wireless phones

Introduction

Information technology (IT) has to be widely diffused and used to yield social and economic benefits. The early phase of diffusion of a technology plays a critical role in determining its future diffusion. Path-dependent demand is caused by network effects and installed base. The threshold for a technology's diffusion is the *critical mass point*, a penetration threshold when adopters support self-sustaining growth (Rogers 2003). This point of rapid growth is called *takeoff* (Golder and Tellis 1997, 2004), and is a boundary point between the introduction and growth phases.

Though technology takeoff is a basis for successful diffusion, little systematic research has been conducted on the global takeoff of new ITs. Global IT diffusion research in IS can be classified in two streams. One studies current diffusion patterns to get a reading on factors that drive diffusion growth by fitting different diffusion models. These studies have sought to determine if the diffusion process is driven by the influence of current adopters, other external factors, or a mix of both (e.g., Gurbaxani 1990). The second focuses on establishing a set of factors that drive the diffusion process of a technology without reference to any specific diffusion states in innovation diffusion theory or technology life cycle stages (Ford and Ryan 1981). For example, Caselli and Coleman (2001) examined diffusion of computers across more than 80 developed and developing countries using economic variables such as human capital, the extent of trading, and the manufacturing share of the economy. Although these two streams of research have been helpful for understanding the diffusion process, a more refined understanding of the factors that are important at different diffusion states is needed. Since takeoff is a threshold for determining if a technology is going to be widely diffused, research should develop deeper insights into the process dynamics.

We develop a new theory for global takeoff of a new technology. Our takeoff theory is a *middle range theory*: a theory developed for classes of technologies or contexts (Fichman 2000). We examine takeoff of digital wireless phones across developed and developing countries. This new product has different core technology (digital) and provides higher benefits to users than previous products like analog wireless phones. Our theory can be applied to other radical product innovations. Our research questions are: (1) What theoretical basis will aid in understanding global takeoff of wireless phones? (2) In the theoretical framework, what drives global takeoff of digital wireless phones? (3) What are the drivers of penetration growth during the growth phase of the digital wireless phone technology life cycle?

Our theory synthesizes innovation diffusion theory (Rogers 2003) and technology life cycle theory (Klepper 1996). The former provides useful perspectives to understand adoption behaviors. The latter offers an understanding of the dynamics of the industry, supply, and demand necessary for insights on factors associated with takeoff. Then, we develop a theoretical model that consists of standards, market competition, technology cost, and technology substitutes to explain takeoff and penetration growth in the growth phase. We also consider four country contextual variables including wealth, wealth distribution, regions, and education. To empirically evaluate the model, we use proportional hazard regression analysis to test factors that drive takeoff times, and panel data analysis to test factors that drive further penetration growth from the takeoff to the maturity phases. The data are drawn from 41 developed and developing countries. The results suggest that standards are the key driver of takeoff and further penetration growth. Countries that have high analog wireless phone penetration will experience faster takeoff than those with low analog wireless phone penetration. Market competition also explains high penetration growth after takeoff.

Theory

We focus on takeoff, a pivotal precondition for a new technology to be broadly diffused in a country. *Innovation diffusion theory* (Rogers 2003) is a useful starting point to define takeoff and identify its drivers. *Technology life cycle theory* (Klepper 1996) provides an overview of different phases across the life cycle of a technology from introduction to decline, and some underlying interactions of supply and demand, and factors that may explain takeoff.

Innovation Diffusion Theory: Understanding Adoption Behaviors

A diffusion process for most innovations follows an S-curve with three distinct phases (Rogers 2003). The *early diffusion* phase exhibits slow adoption. This is followed by *rapid adoption and growth*. In the last phase, *maturity*, the diffusion rate tails off, as the adopting population becomes saturated with the technology. The *tipping point* that triggers the change from a slower to a faster pace of adoption occurs when a critical mass of users adopts. Defined as the minimum number of adopters to self-sustain the technology's future diffusion, a *critical mass* is relevant to the growth of interactive systems, in which two or more adopters are allowed to communicate, interact, and ex-

change information (Rogers 2003). Markus (1987) applied critical mass theory, originally used in physics and sociology, to explain the diffusion of interactive innovations. She derived a number of propositions related to the extent to which an interactive innovation is adopted by all potential adopters from two key characteristics unique to interactive innovations. First, once an interactive innovation achieves widespread adoption, it becomes a *public good*, allowing everyone (including those who do not to contribute to the successful diffusion) to derive associated benefits. Second, there is an *interdependence of benefits* from the use of an interactive media between early adopters and later adopters. Later, Mahler and Rogers (1999) empirically tested the critical mass theory on the diffusion of twelve new telecommunications services among German banks. A low degree of diffusion was cited as one of the key reasons for non-adoption, suggesting the significance of the critical mass in the early diffusion process.

The increasing benefits as additional users adopt an interactive technology are referred to as *network effects*. For example, Gurbaxani (1990) found that the growth of BITNET increased dramatically once a critical mass of universities adopted the system. Similarly, the growth of computer networks has increased at an exponential rate since around 1990, when the critical mass for the Internet was reached. Since the value of an interactive technology is strongly related to the number of the adopters (e.g., firms), these technologies often experience a later takeoff compared to non-interactive innovations. For example, Lim et al. (2003) compared average time-to-takeoff of fax machines as an interactive technology with 21 non-interactive consumer durable products (e.g., air conditioners, refrigerators, televisions). Their results show U.S. and Korean time-to-takeoff of fax machines at fourteen years, twice as long as consumer durable products, which have exhibited an average time-to-takeoff of about seven years.

The critical mass point is synonymous with takeoff. Lim et al. (2003) proposed that *time-to-takeoff* from the introduction to takeoff can be determined when the adoption rate is maximal. This time can be derived by differentiating the adoption function. Diffusion theory further suggests takeoff occurs between 10-20% of penetration (Rogers 2003). The transition between early slow diffusion and rapid growth is takeoff, when a shift in adoption behaviors occurs. The theory classifies five groups of adopters: innovators, early adopters, early majority, late majority, laggards. If takeoff occurs when 10-20% of the population adopt, the innovators, early adopters, and perhaps some in the early majority will adopt. Their decisions are influential to those who adopt after takeoff.

Rogers characterizes innovators as risk-takers who try new technologies, even if some technologies don't succeed. Early adopters are opinion leaders and are among the first to adopt. They also take their roles to evaluate new innovation for others seriously. The early majority are deliberate in their adoption decisions. They often wait until the technology has been evaluated by others before they decide to adopt. Early adopters also are technology enthusiasts who appreciate the benefits of the innovation. In contrast, later mainstream adopters are more risk-averse. They fear being trapped with a technology that is not user-friendly, is poorly supported, or is at risk of losing a standards war. Earlier adopters are more educated and affluent too. So the cost to adopt a technology might not be an important concern for them. In their nationwide survey of household adoption of PCs in the U.S., Brown and Venkatesh (2003) found that early adopters were influenced by social status gains and the pleasure derived from using PCs.

Technology Life Cycle: Explaining the Dynamics of Technology Diffusion

Technology life cycle theory (also known as *product life cycle theory*) offers useful perspectives to understand the characteristics of technology and its market from initiation to obsolescence (Bayus 1998). Research in this area spans a number of disciplines including Economics, IS, Management, and Marketing. It offers implications for strategic decisions related to resource allocation, and forecasts for engineering, marketing and production. Though innovation diffusion theory provides insights on adoption behaviors, technology life cycle theory is a *process theory* that explains activities surrounding each phase in the life cycle through the dynamics of market structure (e.g., firm entry, firm exit, competition) and technological innovation (e.g., product and process improvement). Market competition, quality improvement, and technology cost may help explain the uptake in demand that leads to takeoff.

A technology life cycle is characterized by plotting technology penetration on two axes across four phases: introduction, growth, maturity, decline (Bayus 1998). Introduction has slow sales growth, followed by rapid sales growth in the growth period. Sales level off when the technology reaches maturity and sales drop off in the decline period. The evolution of technology performance follows an S-shaped curve. Technology evolves through an initial period of slow advancement, followed by a period of significant progress and improvements as the technology becomes widely established. Eventually, the rate of improvement declines because the technology reaches some physical limit (i.e., things become either too small or too large) or becomes too complex (i.e., no longer works flawlessly). Generally, the evolution and development of technology in the life cycle are associated with two types of innovation: product and process innovation. *Product innovation* is investment to improve quality and performance of a technol-

ogy. *Process innovation* is investment to bring the production cost of technology down. The literature widely agrees that there is a pattern associated with product and process innovation across industries (Klepper and Graddy 1990).

Early in the life cycle when an industry is new, it attracts a number of firms to enter the market. The market is likely to have many different versions of the product. Product innovation dominates process innovation during this period. Over time, as the market grows, the number of firms sharply decline, and the technology begins to stabilize. To expand their market, firms tend to increase their investment in process innovation while reducing their investment in product innovation. This leads to lower production costs, and falling prices for the technology. When the market reaches maturity, the number of firms stabilizes, and both product and process innovation begins to slow down.

There are different explanations for product innovation. Intense product innovation in the beginning may lead to dominant designs with standardized parts, software, and equipment. Others suggest that the dominant design paradigm does not apply well to some products. Windrum (2005) studied the camera industry between 1955-74, and found that a dominant design did not emerge in an environment of heterogeneous demand. Similarly, Funk (2004) found no evidence of dominant design during 1981 to 1999 for wireless phone handsets. Klepper (1996) offered an alternative explanation, scale economies, for patterns of firm entry, exit, and dynamics of product and process innovation.

Technology life cycle research, however, has focused on the supply explanation (e.g., entry, exit, capabilities) of technology evolution. In a study of 46 new products ranging from tires and computers to windshield wipers and zippers, Klepper and Graddy (1990) saw that technological characteristics and consumer preferences have an effect on the life cycle. They did not provide systematic evidence to support their claim though. Adner and Levinthal (2001) have argued that consumer demand and preferences influence technological progress, but are missing in the literature. They modeled consumer valuation of technology through two components: functionality requirements and willingness-to-pay. *Functionality threshold* refers to the minimum performance that a technology must have to be of value to a consumer. *Net utility threshold* is the highest price that a consumer is willing to pay for a technology that satisfies the functional requirements. They included decreasing marginal utility from technology performance improvements. Differences in consumer demand are consistent with innovation diffusion theory, which explains its influence on adoption decisions. Adner and Levinthal's simulation results suggest a new phase in the technology life cycle that is often observed in digital and information-based industries. This phase shows stable prices and increasing performance, which contrasts with the prediction of the decline in innovations by others (e.g., Klepper, 1996). The main force that leads firms to improve performance without increasing price is competitive pressure.

Evidence of this last phase can be found in the PC industry. Despite a more than quadruple increase in the performance of PCs between 1992 and 1996, the average unit price was stable at around $2,000. In addition to the discovery of the new phase, Adner and Levinthal's analysis offers a fuller explanation of the innovative activities during the early stage of technology life cycle. They argued that the extent of product and process innovation efforts depend on the initial cost and performance of technology. For new tech products (e.g., PCs, PDAs, and VCRs), initial efforts are dominated by innovation to improve performance to meet consumer demand. Process development is the primary focus to drive costs down for previously-introduced technologies in a market with higher quality and enhanced features (e.g., GPS commercialization). Modified products become affordable for potential consumer-adopters.

Technology life cycle theory and the related empirical evidence are appropriate to identify drivers and barriers to technology takeoff at a global level. Takeoff will be influenced by competition, evolution of technology development, and the cost of technology. The timing of a sales takeoff of a technology may also be related to the existence and evolution of market infrastructure (e.g., distribution channels, methods of payment, and complementary products and services). In the case of digital wireless technology, data services on wireless phones such as games, shopping, and TV channels need operating systems, applications, and contents are designed for wireless phones (Maitland et al. 2002).

Few studies have examined sales or penetration takeoff from a demand perspective. Golder and Tellis (1997) studied the takeoff of 31 new products (e.g., camcorders, VCRs, and refrigerators) in the U.S. They found that price reduction is associated with takeoff. Their results also suggest that the average time-to-takeoff is six years, with a 1.7% penetration at takeoff time across all products. Agarwal and Bayus (2002) conducted a large-scale study of 30 consumer and industrial innovations (e.g., automobiles, dishwashers, and microcomputers) introduced in the U.S. between 1849 and 1983. Their research challenges the wisdom that sales takeoff is caused by declining prices resulting from increases in capacity from firm entry. They argued that increases in supply and demand lead to market takeoff. Their results suggest that sales takeoff occurs quicker for innovations with a highly competitive market, and that competition on demand through non-price factors (e.g., actual and perceived product improvements) dominates the

influence of price on sales takeoff times. Tellis et al. (2003) examined takeoff for ten consumer durables (e.g., CD players, dishwashers, and refrigerators) in sixteen Western European countries, emphasizing economic, cultural, and product variables. The results suggest that sales of most new products take off after an average of six years. Also, time-to-takeoff varied widely across countries and product categories.

Although these studies offer interesting explanations related to takeoff of new innovations, there are still limitations and gaps. First, there is a lack of empirical research that systematically examines takeoff of new technologies in the IS literature. Understanding of factors (e.g., standards and related technologies) important to IS practitioners, policymakers, and researchers is needed. Second, there is a lack of validated measures to determine when takeoff occurs. Researchers (e.g., Tellis et al. 2003) have developed specific heuristic measures that may not be widely applicable to other contexts (e.g., other products, a larger number of countries particularly developing countries).

Third, though diffusion of many new technologies is global, existing studies in this area have focused primarily on the U.S. (e.g., Agarwal and Bayus 2002) and other developed countries in Western Europe (e.g., Tellis et al. 2003). Because developing countries may have different economic conditions, infrastructure and human capital development, theories developed in the context of developed countries need to be tested in the context of developing countries. In addition, studies seeking to establish generalizability beyond the original setting offer opportunities for important scientific advances in research and to increase usefulness of theory for practice. We address these limitations. First, unlike some studies that used an heuristic approach to identify takeoffs, we use a validated analytical method to identify phases and takeoff times in the digital wireless phone life cycle. Second, we consider variables (e.g., cost, standards) that provide insights for IS managers and policymakers on the dynamics of takeoff. Third, we include developed and developing countries in our sample. This should enhance our understanding of drivers that are important to takeoff in developed and developing countries.

Model and Hypotheses

Theory Development and Theoretical Model

Drawing on the innovation diffusion and technology life cycle theories, we identify *four variables* to explain global takeoff of digital wireless phones: number of standards, market competition, technology cost, and technology substitutes. To be consistent with prior research, we use the dependent variable *time-to-takeoff*: the duration from introduction to takeoff (Golder and Tellis 1997). We also examine another related dependent variable – *the extent of penetration growth during the growth phase* – as a means to provide deeper insights. The theory needs to be refined for the context though. Technology diffusion studies must incorporate variables specific to the technology. In the wireless phone context, the number of standards is important for digital wireless phones, for example, although the two theories that we use do not directly suggest standards as a factor influencing takeoff.

Innovation diffusion theory argues that uncertainty delays adoption. Since a lack of standards creates associated market risks and uncertainty, we include it. According to technology life cycle theory, competition and technology cost are important drivers for takeoff. Firm entry and competition generate market changes, including capacity expansion, product variety, and price declines. These regularities are observed across IT industries, including mainframe computers, PCs, and wireless phone handsets. Thus we expect that competition and prices may explain takeoff of digital wireless phones too. We include technology substitutes as another explanatory variable for takeoff. They are related to *technology clusters*, elements of technology that are perceived as being closely interrelated (Rogers 2003). Rogers has criticized past research, which has tended to investigate each innovation as if it were independent from other innovations. These studies oversimplified reality: several interdependent innovations are diffusing together. So the diffusion patterns of these technologies are interdependent and the direction of influence depends on their complementarities and substitutability. He suggested including technology clusters. We include technology substitutes as an explanatory variable and investigate its influence on takeoff of digital wireless phones. Global diffusion of a new IT is complex though. Many countries go through diffusion with disparate local preconditions (e.g., infrastructure, institutions, culture) that influence the likelihood of adoption. The concern that needs to be addressed is to what extent an integrated global perspective can explain digital wireless phone takeoff and growth across countries. We examine this concern in our theory development, as well as identify appropriate strategies to address the local country conditions from previous international studies in the IS literature.

From a theory development standpoint, generalization about a phenomenon is viewed as the core of a theory (Gregor 2006). *International generalizability* is critical for the global study of IT (Rosenzweig, 1994). Barrett et al.

(2003) emphasizes the importance of local diversity in understanding the global application of ITs. In less developed countries, the environment presents greater obstacles to IT adoption and diffusion. It is less likely that IT is used and value appropriated in the same manner across countries in the world. Country diversity, including economic development, cultural differences, infrastructure elements, and institutional actions, have been examined in previous global IT studies. Table 1 shows how these studies contextualize their theories for cross-country differences. See Leidner and Kayworth (2006) on culture and Walsham and Sahay (2006) on developing countries for IS research.

Table 1. Selected International Studies in IS

FOCUS	STUDY	CONTEXT	COUNTRIES	APPROACHES
Differences	Zhu et al. (2006b)	Firm e-business adoption	10 developed and developing	Sub-sample analysis
Culture	Strite & Karahanna (2006) Jarvenpaa & Leidner (1998) Straub (1994) Walsham (2002)	PDA adoption Info. industry E-mail use Software team	30 countries Mexico Japan and the U.S. India, Jamaica, U.S.	Cultural dimensions Case study Cultural dimensions Case studies
IT infrastructure	Zhu et al. (2006a)	Firm Internet adoption	10 developed and developing	ICT penetration as a control variable
Institutional support	Montealegre (1999) Silva & Figueroa (2002)	Internet adoption IT adoption	Chile, Costa Rica, Ecuador, Peru Chile	Case studies Case study

International IT studies suggest that economic development, infrastructure, education, culture, and institutions are critical to IT diffusion. We include four variables: wealth, its distribution, education, and regions. Diffusion research has suggested that wealth shows adopters' ability to pay, permitting them to evaluate a technology for adoption (Talukdar et al. 2002). Wealthier individuals can afford to take risks adopting a new technology early (Tellis et al. 2003). New technology costs tend to be high when introduced too (A wireless phone in 1983 cost $3,000!) Wealthier people (only) are able to afford the new technology (Rogers 2003). How wealth is distributed in a country has important effects diffusion and takeoff. If wealth is concentrated, many people may be unable to afford to adopt and diffusion will be slow. This will delay takeoff – or it may never occur. Tellis et al. (2003) found support for this too.

IT innovation research, and product takeoff research in particular, suggest that culture explains differences in IT diffusion and takeoff times across countries (e.g., Straub (1994), who studied e-mail and fax in the U.S. and Japan). Tellis et al. (2003) also found that the probability of takeoff was higher in countries with cultures with lower uncertainty avoidance, and which place higher value on achievement and industriousness. Tellis et al. (2003)'s results use Hofstede's four measures of culture, and are somewhat weak predictors of cross-country differences for new product takeoff. Anecdotal evidence suggests different patterns of usage by region. Japan, Korea, and other Asian countries, for example, enjoy advanced multimedia data applications on wireless phones (Ishii 2004). Due to their economic challenges, users in developing countries in Africa rely on wireless phones for basic economic needs including seeking employment, access to health care needs, and finding markets for small businesses. Previous studies (e.g., Caselli and Coleman 2001; Talukdar et al. 2002) have used regions to study differences in IT diffusion and takeoff across countries. We expect regional differences in takeoff times and growth for digital wireless phones.

Diffusion of innovation theory and related empirical studies identified education, and other demographic characteristics, as influential in IT adoption. Early adopters before the takeoff of a new technology tend to be better educated than later adopters (Rogers 2003). Education also is an important requirement to use advanced ITs like the Internet (Kiiski and Pohjola 2002). Figure 1 shows our model of global digital wireless phone takeoff and growth.

Figure 2 presents the model of the global digital wireless phone takeoff and growth.

Hypotheses

We examine the influence of the number of standards, market competition, technology cost, and technology substitutes on the global takeoff of digital wireless phones and associated penetration growth during the growth phase.

Standards. According to innovation diffusion theory, the influence of network externalities on telecom adoption is related to compatibility standards. Competing standards slow down diffusion and create uncertain outcomes. With two competing standards, there are a few possible outcomes. One standard may take off and gain wide acceptance while the other fails. The worst case is that, due to the uncertainties about one standard over another, neither takes

off, leading to unsuccessful diffusion. A good example is Beta and VHS in the video tape format. The lack of a single standard slowed the rate of adoption of VCRs until the VHS format dominated the market. Funk (2004) analyzed 1G, 2G, and 3G wireless phone technologies and found that the choice of the single analog AMPS standard by the U.S. or the single 2G digital GSM standard by the European Union was important to create a large-scale adoption leading to one global standard. These arguments suggest that a lack of standards or the presence of multiple standards slows down diffusion and delays the takeoff of digital wireless phones. We propose:

- **H1a (Single Standard Hypothesis for Takeoff)**. *Countries with a single standard experience faster takeoff of digital wireless phones.*
- **H1b (Single Standard Hypothesis for Penetration Growth).** *Countries with a single standard experience higher penetration growth of digital wireless phones after takeoff.*

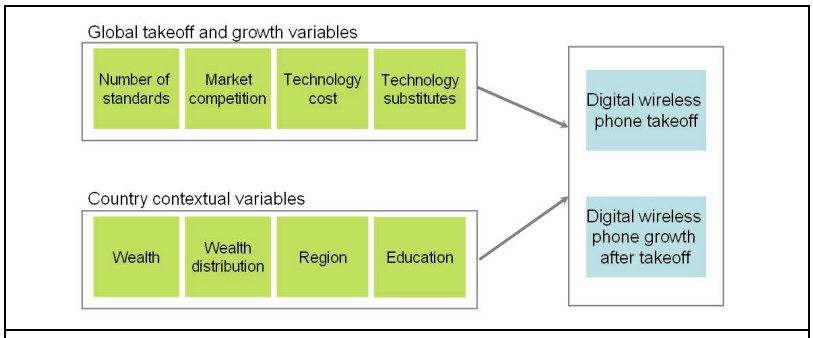

Figure 1. A Model of Digital Wireless Phone Takeoff and Growth

Market Competition. Technology life cycle theory suggests that competition can increase market demand through mechanisms related to prices and products. For products, competition exerts pressure for firms to improve their technology, expand product offerings, and increase product differentiation. Competition also puts pressure on firms to reduce prices, which leads to increases in sales. For some IT products and services (e.g., PCs, O/Ss and application software), the market is not subject to regulation. Thus, market processes, firm capabilities, and anticipated demand are the mechanisms underlying firm entry and competition. However, some network technologies (e.g., the Internet, and fixed and wireless phones) are subject to regulation in a number of countries. To effectively manage the radio frequency spectrum, countries offer a limited number of wireless phone licenses and operators have to compete for a license before they can start providing services to subscribers. Several countries award one available license to the incumbent fixed-phone line operator while the rest go to new market entrants.

The number of operators in digital wireless phone markets tends to be small. In 2004, Australia had four operators, China had two, and Germany had four. Nevertheless, empirical evidence has suggested that competition in wireless phone markets is likely to increase demand and speed up diffusion. As early as 1995, when the digital wireless phone industry was just establishing itself, competition in the wireless phone market created several benefits, including price reductions, increased market growth, and increased applications (OECD, 1995). Also, Agarwal and Bayus (2002) found that higher competition led to faster takeoff of several products, including the analog wireless phone technology in the U.S. Based on this theoretical argument and empirical evidence, we propose:

- **H2a (Telecom Market Competition Hypothesis for Takeoff)**. *Countries with higher telecom market competition experience faster takeoff of digital wireless phones.*
- **H2b (Telecom Market Competition Hypothesis for Penetration Growth)**. *Countries with higher telecomm market competition have higher penetration growth of digital wireless phones after takeoff.*

Technology Cost. Technology cost is considered as one of the barriers to technology adoption. In their large scale survey of household PC adoption in the U.S., Brown and Venkatesh (2003) found that more than 40% of households cited cost as a strong barrier to adoption. Anecdotal evidence from the analog wireless phone market suggests that falling prices of handsets increased market growth in the late 1980s (Funk 2004). Other studies that examine takeoff of new innovations (e.g., Agarwal and Bayus 2002) also found that falling prices can trigger increased demand and subsequently lead to takeoff. This is because prices tend to be very high when an innovation is first introduced. Wireless phones were $2,000 when initially introduced (Golder and Tellis 1997). Over time, prices declined due to competition and investment in process innovations. Takeoff occurs when prices drop so innovations are affordable

to the larger consumer population. Thus, we propose:

- **H3a (Technology Use Cost Hypothesis for Takeoff)**. *Countries with lower cost to use digital wireless phones experience faster takeoff of digital wireless phones.*
- **H3b (Technology Use Cost Hypothesis for Penetration Growth)**. *Countries with lower cost to use digital wireless phones experience higher penetration growth of digital wireless phones after takeoff.*

Technology Substitutes. Economic theory suggests that consumer willingness-to-pay depends on the availability and price of substitute products or services. With rapid advancing technology, technology substitution is observed across a number of different technological products (e.g., generations of PCs, O/Ss and wireless phones). Two products are considered substitutes if a price increase for one leads to an increase in sales of the other. Analog and digital wireless phone technologies are considered substitutes. Although digital technology offers significant improvements over analog technology in a number of ways, including increased voice quality and enhanced security, the introductory handset and service prices of digital technology are considerably higher. Individuals compare technology price and performance when they make adoption decisions.

Digital wireless phone adopters occur into two groups: those who use analog wireless phones and are considering upgrading, and others who never used wireless phones. *Referent point theory* posits that individuals use their most recent purchase as a reference point for future purchases in the same product category. Kim et al. (2002), in their study of PC adoption among small office and home office professionals, found empirical evidence that an owner of an older generation PC was more likely to use that machine to compare performances and prices of newer PCs. Thus, we expect those who use analog wireless phones to use their experience with analog technology as a reference point when evaluating performance and prices of new digital wireless phones. Similarly, those who consider adopting wireless phones for the first time also will use available information to compare prices and performance of analog and digital wireless phones and make informed choices. The takeoff of digital wireless phones may be delayed if many decide to adopt analog technology during the introduction of digital technology. Thus, we propose:

- **H4a (Analog Technology Substitution Effects Hypothesis for Takeoff)**. *Countries with weak substitution effects from analog technology are likely to experience faster takeoff of digital wireless phones.*
- **H4b (Analog Technology Substitution Effects Hypothesis for Penetration Growth)**. *Countries with weak analog substitution effects will have higher diffusion growth of digital wireless phones after takeoff.*

Empirical Models

We examine two dependent variables: *time-to-takeoff* and the *extent of penetration growth during the growth phase*.

Survival Model

Since takeoff can be considered as a time-dependent binary event, survival models are useful to test the influence of related factors on time-to-takeoff. We use the *proportional hazard regression* model to examine the time-to-takeoff. Parametric models are less appropriate because there is no predisposing belief about the form of the underlying distribution of the baseline hazard. Interpreting the results is not constrained or biased by a particular distribution of the baseline hazard. Time-to-takeoff is modeled as a function of a baseline hazard and explanatory variables. The hazard function of country i is $h_i(t) = h_0(t)e^{X\beta}$. $h_0(t)$ is the baseline hazard, X_{it} is a vector of explanatory variables for country i at time t, and β is a vector of parameters. The survival model of takeoff captures the dynamic influence of explanatory variables on the time-to-takeoff.

The proportional hazards model assumes that the hazard ratio is proportional over time. For example, let us assume we know that the hazard or the likelihood of digital wireless phone takeoff of countries that have one standard is twice the rate as that of countries that have more than one standard. The proportional hazards assumption implies that this ratio stays the same across time. If the assumption is violated, alternative models may be more appropriate.

Panel Data Model

We use a panel data model to examine factors that influence penetration growth after takeoff. Previous studies suggest that the growth phase of most products often lasts several years. In their study of thirty products, Golder and Tellis (2004) reported that the average duration of the growth phase is more than eight years. Our panel data consist

of several observations for each country in the sample. We use a random-effects panel data model to test explanatory factors for penetration growth during the takeoff phase of the digital wireless phone life cycle: $y_{it} = \alpha + \beta X_{it} + u_i + \varepsilon_{it}$, where $i = 1, ..., I$ denotes countries and $t = 1, \ldots, T_i$ denotes years. The dependent variable, y, is the annual penetration growth of digital wireless phones, α is an intercept, the vector X contains explanatory variables, and the βs are the estimated coefficients. There are two unobserved components in the model: u_i reflects country heterogeneity, and ε_{it} is an error term that varies across time, and may also vary across groups of countries.

The random effects panel data model treats differences across countries through u_i as normally-distributed random variables. As a result, we can extrapolate from the estimation results to other countries outside those in the sample. The country-specific effects must be uncorrelated with the explanatory variables though. We will test this assumption and report the analysis in the results section. Similar to the survival model of takeoff, the panel data model allows countries to have a different number of data points depending on the time a country is in the growth phase.

Measurements and Data

Definitions and Measures

The first dependent variable is *duration from commercialization to takeoff* in the digital wireless phone life cycle. It tests the model of factors that influence time-to-takeoff. The second is *penetration growth during the growth phase*. We follow Bayus (1998) and Golder and Tellis (2004), who classified the technology life cycle into four phases: introduction, growth, maturity, and decline. To operationalize our dependent variables, we define three events to mark the boundaries of the introduction and growth phases. The first identifies the beginning of the introduction phase. This is *commercialization*, when digital wireless phones are first introduced to users. The second event that identifies the end of the introduction phase and the beginning of the growth phase is *takeoff*, the first dramatic and sustained increase in penetration. The third event that identifies the end of the growth phase and the beginning of the maturity phase is *slowdown*, the beginning of a period when sales growth slows down or levels off.

Our commercialization measure is the first year in which digital wireless phone services are available. Measures of takeoff and slowdown are more difficult, requiring proxy variables. The rapid increase in penetration associated with takeoff and the leveling off of sales associated with slowdown can be problematic to recognize. Different analysts have their own expectations. Three methods are proposed to measure takeoff: *heuristic approach* (Tellis et al. 2003), *diffusion model estimation approach* (Lim et al. 2003), and *discriminant approach* (Agarwal and Bayus 2002).

The heuristic approach relies on visual inspection of penetration growth. The pre-specified takeoff threshold is simple and works across many products and countries, but it lacks theoretical or empirical support. The diffusion estimation model approach makes a strong assumption about patterns of diffusion and bias estimation of takeoff time. We chose the discriminant approach because this method is rigorous and not subject to the assumption that all technologies have four life cycle phases. . It uses a visual analysis to classify time-series that belong to certain phases. We classified the remaining data that can be in either of two adjacent phases as being *in-between phases*. They include the *in-between introduction and growth* phase, the *in-between growth and maturity* phase, and the *in-between maturity and decline* phase.

There are four main regressors: standards, market competition, technology cost, and technology substitutes. Standards are measured by number of digital wireless phone standards in a country. Market competition measures the number of digital wireless phone operators. Technology cost is measured by purchasing power parity (PPP)-adjusted 60-minute peak-rate local calls. Substitution is measured by analog wireless phone penetration. Country contextual variables are wealth, wealth distribution, regions, and education. Wealth is measured by PPP-adjusted GDP per capita in international dollars, and wealth distribution by the GINI index, ranging from 0 to 100. A greater value of GINI index reflects higher level of wealth inequality. Countries are in four geographical regions: Africa, Asia, Europe, and America. Education is measured by the 2004-2005 World Economic Forum's advanced Human Capital Index which captures secondary and tertiary enrollment, quality of education system, and on-the-job training. See Table 2.

Table 2. Summary Statistics of Key Variables

VARIABLE	MEASURE	MEAN	STD. DEV.
Takeoff	Duration from commercialization to takeoff	2.32 years	0.82 years
Penetration growth	Penetration growth during the growth phase	213%	108%
Standards	Number of digital wireless phone standards	1.17	0.45
Market competition	Number of digital wireless phone operators	2.73	1.45
Technology cost	PPP-adjusted cost of 60-minute peak-rate local calls	25.26	17.84
Technology substitutes	Extent of analog wireless phone penetration	1.66%	3.29%

Data Sources and Collection

We use annual data on 41 countries in Africa, Asia, Europe, Middle East, North America, and Latin America. We have data since the first introduction year of digital wireless phones up to 2003 (except Indonesia and Pakistan to 2002, and New Zealand to 2001). The number of data points is different across countries depending on how early or late they began offering digital wireless phone services. Developed countries were the pioneers. Denmark, Finland, and France introduced services in 1992. Developing countries introduced them up to five years later.

We collected wireless phone subscriber and tariff data from the *Yearbook of Statistics* of the International Telecommunication Union. GDP per capita and the GINI index (inequality in national income distribution), are from World Bank's World Development Indicator Database. Data for standards and market competition are from GSM World, the CDMA Development Group, and *Cellular News*. Data for education is from the 2004-2005 Global Competitiveness Report by the World Economic Forum.

Results

We next present two sets of results based on proportion hazard regression and panel data analysis.

Proportional Hazard Regression Results of Factors Influencing Time-to-Takeoff

Table 3 presents the estimated results of factors that influence the time-to-takeoff of digital wireless phones.

Table 3. Results of Proportional Hazard Regression for Factors Influencing Time-to-Takeoff

VARIABLES	COEFF.	STD. ERR.	Z (SIGNIF.)	HAZARD RATIO
STD	-1.44	0.14	-2.36***	0.24
COMP	0.03	0.15	0.23	1.03
COST	0.007	0.007	1.01	1.01
ANALOG	0.001	0.00003	3.43***	1.00
GINI	0.05	0.03	1.59	1.05
EDU	0.53	0.38	1.39	1.69
Africa	1.71	1.16	1.48	5.53
Asia	3.07	1.22	2.53***	21.61
Europe	4.66	1.49	3.12***	105.42

Notes: 96 obs., 41 countries. Likelihood ratio, model significance = 29.93***. *Z* tests the hypothesis that a coefficient = 0. Signif.: * = $p <$. 10, ** = $p < .05$, and *** = $p < .01$.

Model Diagnostics. We tested the influence of standards (*STD*), market competition (*COMP*), technology cost (*COST*), and technology substitutes (*ANALOG*) on the time-to-takeoff of digital wireless phones. The contextual variables are wealth (*GDP*), wealth distribution (*GINI*), regions (*Africa, Asia, Europe*), and education. All of the variables have correlation coefficients less than 0.7, except *ANALOG* and *GDP* at 0.71. So we dropped *GDP* from our model to avoid unstable coefficient estimates. All the variance inflation factor values are less than 10 (from 1.05 for *COST* to 2.86 for *ANALOG*), indicating that multicollinearity is not an issue. Dropping GDP may lead to loss of

explanatory power for wealthy and less wealthy countries. We compensated by performing sub-sample analysis for systematic differences between developed and developing countries.

Estimated Parameters. The model is significant (*LL* =29.93; $p < .01$). The number of standards (*STD*) also is significant ($p < .01$) with a coefficient of -1.44 and a hazard ratio of 0.24: so an additional standard in a country decreased the hazard rate to reach takeoff by 76%. Thus, the Single Standard Hypothesis for Takeoff (H1a) is supported. Technology substitution reflected in the extent of analog wireless phone penetration (*ANALOG*) also is significant ($p < .01$) but with a near-zero coefficient and a hazard ratio near to 1. Thus, analog wireless phone penetration had little impact on the hazard rate to reach takeoff. Thus, the Analog Technology Substitution Effects Hypothesis for Takeoff (H4a) is not supported. Market competition and technology cost are not significant too. As a result, the Telecom Market Competition Hypothesis for Takeoff (H2a) and the Technology Use Cost Hypothesis for Takeoff (H3a) are not supported. The *Asia* and *Europe* dummies are significant, indicating earlier takeoff in those regions.

Proportional Hazard and Model Fit. We checked the proportional hazard assumption by testing the null hypothesis that the slope of a generalized linear regression of the scaled Schoenfeld residuals is zero. Rejecting the null hypothesis indicates that the proportional hazard assumption is violated. The test results of all explanatory variables are insignificant, indicating the proportional hazard assumption is met, and the model is appropriate. See Table 4.

We plotted the deviance residuals to evaluate model fit. Deviance residuals, a rescaling of the martingale residuals, are symmetric around zero. Similar to residual plots in regression models, the deviance residual plots against the linear predictor of explanatory variables should resemble white noise if the fit is adequate – which is what we found. Table 5 presents the results of the sub-sample analysis for the developed and developing countries.

Table 4. Test of Proportional Hazard Assumption

VARIABLE	ρ	χ^2	*P*-VALUE
STD	0.08	0.23	0.63
COMP	0.12	0.44	0.51
COST	0.01	0.01	0.94
ANALOG	-0.09	0.34	0.56

Table 5. Sub-Sample Analysis for the Proportional Hazard Regression of Takeoff

	DEVELOPED COUNTRIES				DEVELOPING COUNTRIES			
VAR.	COEF.	SE	Z	HAZ. RATIO	COEF.	SE	Z	HAZ. RATIO
STD	-0.90	0.93	-0.96	0.31	-1.06	0.51	-2.08**	0.35
COMP	-0.13	0.29	-0.45	0.72	0.09	0.13	0.65	1.09
COST	0.05	0.04	1.28	1.07	0.006	0.007	0.91	1.006
ANALOG	0.03	0.01	2.55***	1.03	0.35	0.23	1.54	1.41
GINI	0.03	0.05	0.55	1.02	-0.01	0.03	-0.54	0.99
EDU	0.82	1.65	0.49	2.51	1.43	0.68	2.12**	4.19

Notes. *Developed countries:* 40 obs., 20 countries. Likelihood, model signif. = 16.58***. *Developing countries*: 56 obs., 21 countries. Likelihood, model signif. = 23.29***. *Z* tests whether a coefficient = 0. Signif.: * = $p <$ .10, ** = $p < .05$, *** = $p < .01$.

The sub-sample analysis reflects a few differences between developed and developing countries. In the case of developed countries, *ANALOG* is the only significant variable ($p < .01$) with a coefficient of 0.03 and hazard ratio of 1.03. For developing countries, two significant drivers of takeoff are the number of standards (*STD*) and education (*EDU*). The number of standards is negative with a coefficient of -1.06 and hazard ratio of 0.35 ($p < .05$). Education is positive with a coefficient of 1.43 and hazard ratio of 4.19 ($p < .05$).

Panel Data Model Results of Factors Influencing Penetration Growth during the Growth Phase

We evaluated multicollinearity, heteroskedasticity, and endogeneity, which might bias the modeling estimates. Multicollinearity increases parameter variance, so the estimates are less precise. We diagnosed multicollinearity by checking pair-wise correlations between the explanatory variables. All of our explanatory variables have correlation coefficients less than 0.7. All VIF values are less than 10 (ranging from 1.02 for *ANALOG* to 1.5 for *STD*), indicat-

ing that multicollinearity is not an issue either for the panel data. We used White's test, which uses a Lagrange multiplier that has χ^2 distribution under the null hypothesis of homoskedasticity. The test result (χ^2 = 62.82, d.f.=36, p<0.004) suggests that heteroskedasticity might be an issue. We used robust standard errors to correct for it. Finally, we evaluated whether endogeneity is an issue. The problem arises when explanatory variables and a dependent variable are simultaneously determined by some unobservable variables. In our model, technology cost or price might be determined by subsidies, discounts, quality of services, and network coverage. These variables may influence subscriber adoption decisions too. We used a Lagrange multiplier test that checks whether the unobserved error term has a large value, which might hint at the presence of endogeneity problems. We found that endogeneity is not an issue (χ^2 = 1.57, d.f.=1, p=0.21). Table 6 presents the results of random-effects panel data analysis.

Estimated Parameters. The coefficient of *STD* is negative and significant (β_{STD} = -4.39, p < .05). Thus, the Single Standard Hypothesis for Penetration Growth (H1b) is supported. An additional standard decreases penetration growth by as much as 439%. *COMP* is positive and significant (β_{COMP} = 0.08, p < .01), which supports the Telecomm Market Competition for Penetration Growth Hypothesis (H2b). An additional digital wireless phone operator increases penetration growth by 8%. *COST* and *ANALOG* are not significant. So the Technology Use Cost (H3b) and Analog Technology Substitution Effects (H4b) Hypotheses for Penetration Growth are not supported. Two contextual variables, *GDP* and *EDU*, are significant. *GDP* is positive but has little influence (β_{GDP} = 0.0003, p < .05). So a 100 international dollar increase in GDP per capita increases growth by 0.03%. EDU is also positive (β_{EDU} = 2.86, p < .05).

Table 6. Results of Panel Data Model for Penetration Growth in the Growth Phase

VARIABLE	COEF.	ROBUST STD. ERR.	*t*-VALUE
STD	-4.39	2.27	-1.94**
COMP	0.08	0.02	3.52***
COST	-0.0004	0.0005	-0.85
ANALOG	10.12	9.66	1.05
GDP	0.0003	0.0001	2.55**
GINI	0.15	0.10	1.55
EDU	2.86	1.32	2.17**
Africa	-6.52	4.51	-1.44
Asia	-3.19	3.70	-0.86
Europe	-2.17	3.21	-0.68

Notes: 313 observations for 41 countries. Dependent variable: penetration growth during growth phase of digital wireless phone life cycle. R^2 = 0.27. Hausman test (χ^2 = 3.42, p < 0.49) showed no correlation of country-specific effects with explanatory variables. Random-effects is appropriate. Signif.: * = p <.10, ** = p <.05, and *** = p < .01.

Table 7. Sub-sample Analysis of Panel Data Model for Penetration Growth in the Growth Phase

	DEVELOPED COUNTRIES			DEVELOPING COUNTRIES		
VARIABLE	COEF.	ROBUST SE	*t*-VALUE	COEF.	ROBUST SE	*t*-VALUE
STD	-1.60	0.72	-2.24**	-2.00	1.061	1.90*
COMP	0.08	0.03	2.86***	0.08	0.02	3.24***
COST	0.03	0.02	1.45	-0.07	0.06	-1.21
ANALOG	16.26	9.64	1.69*	3.92	4.31	0.91
GDP	- 0.0002	0.0001	-2.31**	-0.0005	0.0005	-1.07
GINI	0.05	0.07	0.78	0.15	0.10	1.42
EDU	0.40	1.05	0.39	0.87	0.84	1.04

Notes. *Developed countries*: 162 obs., 20 countries. R^2 = 0.36. *Developing countries*: 151 obs., 21 countries. R^2 = 0.30. Signif.: * = p <.10, ** = p <.05, and *** = p < .01.

Sub-sample analysis identifies influential variables on penetration growth. For developed countries, four variables are significant. *STD* is negative and significant (β_{STD} = -1.60, p < .05). COMP is positive and significant (β_{COMP} = 0.08, p < .05). Analog penetration (*ANALOG*) is positive and weakly significant (β_{ANALOG} = 16.26, p < .10). GDP is negative and significant (β_{GDP}= -0.0002, p < .05). For developing countries, two variables are significant. *STD* is

negative, significant (β_{STD} = -2.00, $p < .10$), and COMP is positive, significant (β_{COMP} = 0.08, $p < .01$).

Discussion

Our results suggest two drivers of takeoff: standards, and analog wireless phone penetration. Countries that have one wireless phone standard tend to reach takeoff faster than those with multiple standards. Similarly, countries that have many analog wireless phone subscribers reach takeoff faster. This goes against the technology life cycle theory: analog technology should be a substitute for digital technology. We have two explanations. First, the substitution effect may work in the opposite direction. We expected that some early adopters would choose analog technology because of the uncertainty of the potential benefits of digital wireless phones at introduction. Surprisingly, digital wireless phones cannibalized analog wireless growth. Second, analog penetration reflects learning that a society as a whole has with wireless phones. Potential adopters of digital technology adopted soonafter it became available. Early adopters of an innovation like digital technology are likely to have high experience in similar product categories.

The extent of competition and technology cost are not important to takeoff time. This finding is in contrast to the prediction from technology life cycle theory. Others reported similar results. Agarwal and Bayus (2002) examined takeoffs of a number of products, including analog wireless phones in the U.S., and found that prices or costs to users are not important in explaining takeoff times. Innovation diffusion theory also supports the lack of influence of competition and technology costs to takeoff. Early adopters prior to takeoff are risk takers, wealthy, and try new and different technology as soon as it is available. As a result, this group will adopt a new technology regardless of the extent of competition in the market and high introductory prices of the technology.

Finally, digital wireless phone takeoff has been faster in Asia and Europe. The European Union has agreed to use one standard, GSM. Countries that have one standard get to takeoff faster than those with multiple standards. The European countries were more likely to have faster digital wireless phone takeoff. A large increase in growth of wireless phone subscribers in Asia seems to have come from rolling out prepaid services. Asian users embraced wireless phones and operators rushed to offer a variety of services. As a result, fast growth led to takeoff in several countries. For example, users in Japan were among the first to play music, movies, and send pictures and video clips by phone. Users in the Philippines enjoy many innovative services, including wireless-enabled clubs for women, banking money transfers to use for purchases on wireless phones, and domestic transfers and remittances to wireless subscribers.

Interestingly, the influential factors for takeoff appear to be different between developed and developing countries. A large pool of analog subscribers in developed countries plays an important role in the takeoff of digital wireless phones. Multiple standards and the lack of highly educated populations and quality education slow down the takeoff in developing countries. This is not surprising because most users in developing countries are first time phone users and early adopters tend to be those with higher education and understand the different standards and their implications on wireless phone use. For example, a recent survey in Egypt and Tanzania found that almost 60% of wireless phone owners have high school or higher education.

The presence of standards continues to be an important factor to explain high growth during the growth phase after takeoff. We also find that high market competition explains penetration growth. Since price was not significant in our results, we interpret this as supporting the idea that non-price factors, such as actual and perceived technological improvements, product differentiation, and innovative services, are the key drivers of penetration growth. In addition, the installed base of analog subscribers also increases penetration growth after takeoff for developed countries. Since developed countries introduced analog wireless phones early, the phase out of analog technology is likely to happen earlier in these countries.

Although our data does not reveal the usage patterns of digital wireless phones across countries, anecdotal evidence offers additional insights on the issue. In emerging economies like China and India, most new users prefer lower-end services and are price-sensitive (Euromonitor International, 2004a). Phone companies with vested interests in a potentially large market in these countries came up with innovative products that cater to the local demand. Nokia, for example, introduced Nokia 1100 low-priced handsets that have flashlights, an alarm clock, a radio, and an anti-slip grip in India. In another group of countries like Japan, and South Korea, their users enjoy advanced data services and high-end handsets that come with many advanced features. In addition, these users are willing to replace their handsets as soon as new models appear in the market. It was reported that, in South Korea, ten million handsets were

replaced in 2003 (Euromonitor International, 2004b). Yet, in the least developed countries like those countries in Africa, evidence suggests that African people use wireless phones differently (Vodafone, 2005). Wireless phones handsets are often shared between family members or community members in a telecenter. Empirical evidence also suggests that price elasticity is quite high, suggesting that high call charges could inhibit wireless phone usage in these countries.

It is important to point out the notion of technology clusters and its role in the development in the wireless phone industry (Porter 1998). According to Durlacher (2001), the wireless phone industry consists of at least three areas: technology area, service area, and application area. The technology area includes handset, network equipment and other enabling technology companies. The service area includes wireless phone operators, virtual operators, and portal providers. Finally, the application area includes application developers, application providers, and content providers. Although it might be easier for developing countries to lure foreign direct investment to operate wireless phone services (e.g., Vodafone has presence in many developing countries worldwide). However, developing contents that are tailored to local needs require skilled human capital that might become the challenge in the development of these innovative wireless phone services. Therefore, the lack of complementary factors (e.g., skilled human capital, the maturity of content industry) might delay the takeoff and further growth in developing countries.

Conclusion

Drawing on innovation diffusion and technology life cycle theories, this research develops and empirically tests a theoretical model with standards, market competition, technology cost, and technology substitutes to understand takeoff and penetration growth during the growth phase of digital wireless phone life cycle. The combined results of drivers of takeoff and penetration growth during the growth phase suggest insights into the underlying mechanisms of the digital wireless phone life cycle. Standards appear to be important across the introduction and growth phases. Familiarity with wireless phone technology and a large installed base of analog technology also explain faster takeoff times. Non-price factors are important drivers of penetration growth during the growth phase. The results are useful for regulators in countries not yet offering 3G licenses. For operators, we see that non-price factors are more important than price factors to explain high penetration growth. Thus, operators should focus effort on creating innovative services with new technological features (e.g., SMS, location-based services, and contactless smart cards). Policy makers in developing countries also want to invest in programs to educate their populations of the benefits of digital wireless phones to their family lives and work.

Our takeoff theory builds on the theory of critical mass proposed by Markus (1987) and later in an empirical study by Maher and Rogers (1999) that critical mass is the precondition for a new IT to reach its takeoff. Our middle range theory can explain the takeoff of a new IT and further penetration growth. It can be applied to understand takeoff of other ITs in the same class as wireless phones. Some that come to mind are wireless connection technology, HDTV, and WiMAX. The theoretical model is valid for studying technology takeoff in different settings – including within a country too. Similar to other international studies, we face the problem of some missing data. We have done all we can to backfill those missing values from reliable sources. The lack of wireless phone subscriber data from countries in Latin America prevents us from having more of these countries in our sample. Another limitation is that although costs to use digital wireless phones involve handset cost, one-time connection charges, and monthly subscription fees, and usage fees, our cost variable only captures variable usage cost. Our cost variable is conservative for countries where operators do not subsidize handsets or have high connection fees. Finally, careful consideration must be made when one wants to generalize the theory and findings beyond those 41 developed and developing countries that we include in this study. Lee and Baskerville (2003) refers to this type of generalization as "Generalizing from Theory to Description".

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