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Examining the growth of digital wireless phone technology: A take-off theory analysis

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ABSTRACT

The early phase of diffusion plays a critical role in determining information technology (IT) success in a market. *Takeoff*, the transition point from the introduction to the growth phase in the IT life cycle, is viewed as an acid test for whether a technology will succeed. We develop a theory to understand global takeoff for digital wireless phones that can be extended to other technologies with related characteristics. Drawing on technology dominance and product life cycle theories, we build a model that consists of standards, market competition, technology costs, and technology substitution to explain takeoff and subsequent market penetration growth. The data are from 41 developed and developing countries. The results suggest that the presence and effects of standards play an important role in driving takeoff and penetration growth. Familiarity with wireless phones and an installed base of analog phone technologies also explain faster takeoff times. Non-price factors are important drivers of penetration growth after takeoff as well. Our results have managerial and policy implications on innovative strategies, standards and competition policy settings for digital wireless phones.

> A slight incline, a relatively sharp rise, and then a fresh modification of the slope until the plateau is reached. This is also, in abridgment, the profile of every hill, its characteristic curve. This is the law which, if taken as a guide by the statistician and, in general, by the sociologist, would save them from many illusions.
> Gabriel Tarde, in *The Laws of Imitation*, Henry Holt, New York, 1903

1. Introduction

Information technology (IT) has to be widely diffused and used to yield social and economic benefits. The early diffusion phase of a technology plays an important role in determining its subsequent diffusion trajectory and eventual outcome in a market. For example, the fast growth of the VHS standard led it to defeat the Betamax standard and captured the market. The point of rapid growth is referred to as *takeoff* [21], the boundary between the introduction and growth phases of a technology.

Despite the successful global diffusion of various ITs (personal computers, wireless communication technologies, and the Internet), little systematic research has taken a careful look at the global takeoff of new ITs. The global IT diffusion literature in IS is broadly classified into two streams. The first stream studies diffusion patterns to get a reading on a range of factors that drive diffusion growth by fitting different diffusion models. These studies have assessed whether the influence of current adopters, other external factors, or a mix of both drives diffusion [39]. The second stream focuses on establishing a set of factors that drive the overall diffusion process of a technology without reference to any specific diffusion phase [8]. A fuller understanding of the factors that are important in different diffusion periods is still needed. Since successful takeoff determines whether a technology will widely diffuse, deeper theoretical insights into the process are appropriate for this also.

Drawing on technology dominance and product life cycle theories, we develop a new theory for the global takeoff of a new technology. Some researchers use the labels *technology dominance theory* and *product life cycle theory* interchangeably to refer to the evolution of industry dynamics of firm entry, firm exit, and market competition [34,35]. In the past several years, a complementary literature [2,9,47,50] has used the label *product life cycle theory* to develop a related body of knowledge on product life cycles from a user demand and adoption perspective. It identifies four critical phases in a product life cycle: *introduction*, *growth*, *maturity*, and *decline*. The product life cycle literature, in addition to inclusion of the effects of industry dynamics or supply-side factors, examines institutional and contextual factor influences on product adoption during different life cycle stages. We use technology dominance theory for an explanation of the evolution of technological change from an industry perspective, and product life cycle theory to refer to the theory and related studies that offer a complementary explanation to understand technological change through user adoption.

Our aim is to develop a theory to explain takeoff and growth of network-based innovations in general and digital wireless phones in particular. We chose digital wireless phones for two reasons. First,

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wireless phones are widely regarded in the international community as a promising platform to increase economic growth and shape social progress, particularly for developing countries. Second, from the industry and innovation perspectives, wireless phone value networks have become increasingly complex with intense competition, requiring firms to develop effective strategies to grow their revenues.

We emphasize the extension of the *theoretical logic*, *explanatory accuracy* and *generalizability* as key qualities for strong explanatory theory development [25]. We combine a supply explanation from technology dominance theory and a demand explanation from product life cycle theory to offer a more accurate theoretical logic for takeoff and growth of IT innovations. To further enhance our explanation of the logic of successful innovation and diffusion for a complex technological system, we view an industry as "consisting not only of the set of firms producing similar or substitute products … but also many other public and private sector actors who perform critical roles in developing and commercializing a new technology" [52, pp. 367–368]. In the wireless phone industry, institutions shape industry dynamics through standards and competition policies. We aimed to generalize our theory by including both developed and developing countries in our sample.

Understanding the success of global network-based innovations (e.g., cloud computing, social media, video games, wireless phones) is at the nexus of IS and operations management research. The value networks for these innovations involve a large number of firms with a set of complex relationships. Their innovation and production activities span national and firm boundaries too. For example, key players in a wireless phone value network include operators, phone manufacturers, content and technology providers, component suppliers, infrastructure suppliers, and handset manufacturers, among others. There were tens of thousands of firms in the Japanese wireless phone industry alone [17]. For instance, the Motorola V3 RAZR phone has 640 parts from various companies in multiple Asian countries and the U.S. [10]. Establishing an understanding of global takeoff and further growth of these innovations is important for firms in a value network to develop short and long-term capacity planning, partnerships, and global coordination of supply chain to appropriate value from their innovations.

Our research questions are: (1) Can theory aid in understanding global takeoff of digital wireless phones? (2) What factors appear to be salient in driving global takeoff? (3) What are the drivers of penetration growth during the growth phase of the digital wireless phone technology life cycle?

Our theory development begins with orienting explanations from *technology dominance theory* [3] and *product life cycle theory* [21] for the takeoff and subsequent growth of a technology. The former offers an understanding of the industry and supply-side factors brought about by technological change and how they explain takeoff and growth. The latter highlights user adoption behavior and its antecedents in different product life cycle stages. Then, we develop a theoretical model that consists of salient factors for wireless phone diffusion to explain takeoff and penetration growth in the growth phase. They include standards, market competition, technology cost, and technology substitutes. We also consider the role of country-specific effects that influence technology adoption [4]. The four country contextual variables are wealth, wealth distribution, region, and education. (See Fig. 1 for illustrative examples of slow and fast takeoff of digital wireless phones in selected developed and developing countries.)

To empirically evaluate the model, we use proportional hazard regression analysis to test the factors that drive takeoff times.[2] We conducted 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 penetration. Market competition also explains high penetration growth after takeoff.

2. Theory

To understand takeoff and diffusion growth in a network-based industry, we focus on standards and innovation. Technology dominance and product life cycle theories suggest the role of dominant designs or standards, network effects, firm strategic actions and industry structure in the growth of the IT industry.

2.1. Technology dominance theory

Technology dominance theory examines the interaction between the characteristics of technology and industry dynamics, and the implications for technology adoption from initiation to obsolescence [5]. Research in this area offers implications for strategic decisions related to resource allocation, and forecasts for technology design, production, and marketing. It is a *process theory* that explains activities surrounding technological change via market structure, including firm entry, firm exit and competition, and technological innovation through product and process improvement. Market competition, quality improvement, and technology cost also may explain the uptick in demand that leads to takeoff.

The theory argues that technological changes shape the trajectories of industry attractiveness, structures, and its level of competition.[3] Technological change is an evolutionary process though. Firms invest in product and process innovations to survive and maintain competitiveness. *Product innovation* is investment to improve quality and performance of a technology (cheaper processors, better voice recognition or faster data speeds). *Process innovation* is investment to bring the production cost of technology down (using robots to increase order fulfillment speed, Dell's made-to-order computers, or improved process technology to manufacture semiconductors). The evolutionary process fits the innovation cycles in wireless communications; they are built around generations of dominant designs of wireless standards.

Technological discontinuities trigger introduction of variants of a new technology and intense competition for dominance. Product innovation dominates process innovation during this period. Before the emergence of a dominant design, the rivalry between alternative technological standards creates uncertainty. However, the realization of a dominant design tends to create stronger entry barriers that slow down firm entry and increase exit by firms that lack knowledge, economies of scale in production, or strong inter-firm relationships to compete. Building a dominant design also leads to higher investment in process innovations and incremental technological progress through smaller investments in product innovations. To expand their market, firms increase investment in process innovation while reducing product innovation. This leads to lower production costs and falling technology prices. When the market matures, the number of firms stabilizes, and product and process innovation begins to slow down.

The dominant design explanation and the product and process innovation view do not apply very well to some products, including IT innovations. In the camera industry between 1955 and 1974, a dominant design did not emerge in an environment of heterogeneous

[2] Previous IS studies used variants of event history methods to study IT outsourcing vendor–client firm relationships [23], album popularity on the Internet [6], user search engine visits [49], vertical integration on IT adoption in firms [14], adoption of electronic banking networks [31], and Internet firm failures [30]. A fuller review of event history methods and other relevant methods and literature for IS and e-commerce research is available for the interested reader [32].

[3] The management literature uses the term *dominant designs* to explain technological change and competition. By contrast, economics focuses on the importance of *technology dominance* by referring to *standards* in network industry competition.