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The Dive and Disruption of Successful Current Products: Measures, Global Patterns, and Predictive Model*

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This study examines the diffusion of pairs of substitute products (current versus new) in five categories across 86 countries between 1977 and 2011. The study finds that current products reach a peak at about 56% of market penetration. Subsequently, they suffer a dramatic decrease in penetration of 286%, which we call the dive. A dive occurs in 96% of current products in five categories across 86 countries between 1977 and 2011. On average, the time from takeoff of new product to a peak in penetration of the current product is 6.6 years and to the dive of the current product is 8.4 years. The total time-to-dive includes a hidden discontinuance period (10.4 years), from the introduction of the new product to the peak of the current product, plus an overt time-to-dive (1.8 years), from the peak to the dive of the current product. The hidden discontinuance period and the overt time-to-dive are shorter, and the dive is steeper in emerging markets than in developed ones. A discrete-time hazard model shows that the introduction of the new product, prior penetration of the current product, the population density of the country, and prior dives in other countries predict intercountry the hazard of a peak. Subsequently, takeoff of the new product, relative percentage growth in penetration of the current product prior to a peak, the length of the hidden discontinuance period, and prior dives in other countries predict the hazard of a dive. The models can predict the occurrence of a peak with true positive rate of 62% and a true negative rate of 87%, and a dive with a true positive rate of 82% and a true negative rate of 61%.

Introduction

Sony, BlackBerry, Kodak. These companies (like many others before) stumbled, sold out, or went bankrupt because they failed to adapt in a timely manner to the dive in the market penetration of their current products (Tellis, 2013). Sony's Walkman lost out to MP3 players, BlackBerry lost out to touchscreen smartphones, and Kodak lost out to digital photography. The *dive* is a sudden and substantial decrease in penetration of a successful current product due primarily to consumer adoption of a new substitute product (Figure 1). The current and new substitute products fulfill the same consumer need but are based on substantially different technological platforms (Sood and Tellis, 2005, 2011). Besides the three examples above, other examples of this phenomenon are black-and-white versus color television sets, cassette-radio players versus CD players, videocassette recorders versus DVD players, landline telephones versus mobile phones, and CD players versus audio storage digital devices. In the aeronautical terminology, dive is a steep descending flight path, the opposite of a takeoff (Crane and Crane, 2006).

The current paper proposes a metric and model for the dive in the penetration of a current successful product threatened by a new substitute product. The dive is the opposite of a *takeoff* in penetration, defined as the dramatic increase in adoption of a new product in its early life (Golder and Tellis, 1997). The dive is the key part of the phenomenon of disruption (Christensen, 1997).

This paper defines *time-to-dive* as the period between the introduction of a new product and the dive in penetration of the current product. The time-to-dive is composed of the sum of two periods: the hidden discontinuance period and the overt time-to-dive. The current study defines the *hidden discontinuance period* as the time between the introduction of a new product and a peak in penetration of the current product (Figure 1). The hidden discontinuance period is equivalent to the *hidden time-to-dive*. The *overt time-to-dive* is defined as the period between a peak in penetration and the dive. The discontinuance period will end after the *landing*, when the level of penetration of a product is negligible (Figure 1). Defining, explaining, and predicting the dive are important for the following reasons.

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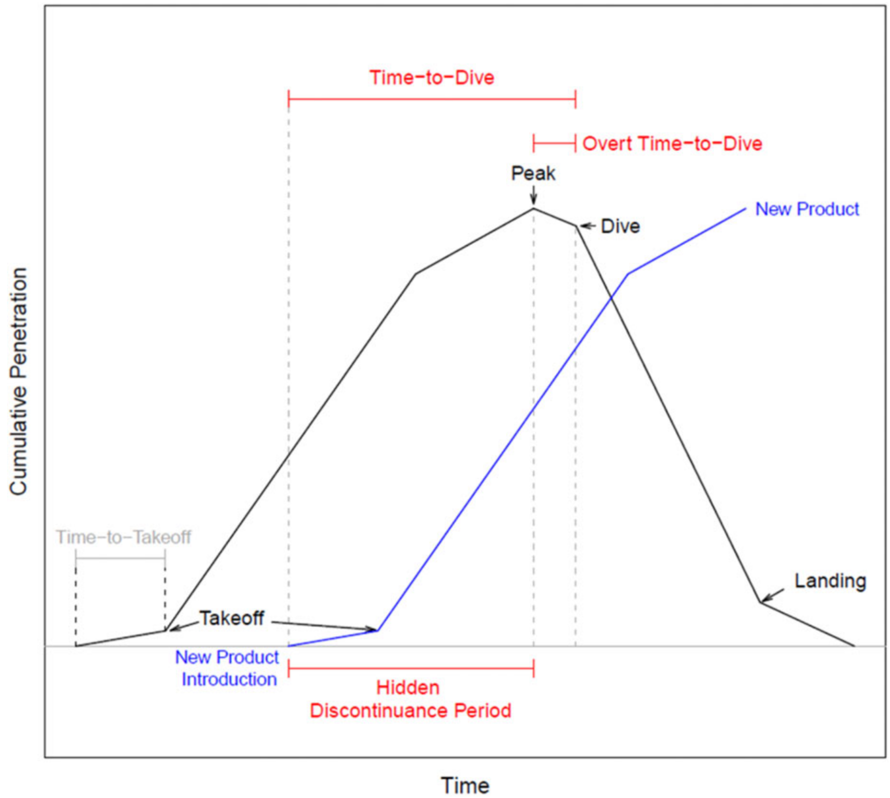

Figure 1. Turning Points of the Current Product
Note: Landing may also occur at a certain *petrification* level of market penetration, where penetration remains but a lower level.

BIOGRAPHICAL SKETCHES

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First, technological platforms underlying products change frequently (Christensen, 1997; Foster, 1986; Sood and Tellis, 2005). When they do change, a new product based on the new technology (e.g., LCD monitor) has the potential to disrupt and render obsolete the current product based on the current technology (e.g., CRT monitors; Tellis and Sood, 2010). Managers need to know when to abandon the current product and embrace the new one (Bergek, Berggren, Magnusson, and Hobday, 2013; Guiltinan, 2009, 2010; Slater, Mohr, and Sengupta, 2014). Failure to do so in a timely manner can lead to loss of market leadership (Foster, 2012). For example, Sony took too long to switch from CRT to LED TVs and lost leadership in this market to Samsung (Tellis, 2013).

Second, the life cycle of the current and new products has fairly sharp events or turning points (Bayus, Kang, and Agarwal, 2007; Chandrasekaran, Arts, Tellis, and Frambach, 2013; Foster, Golder, and Tellis, 2004; Golder and Tellis, 1997, 2004; Markovitch and Golder, 2008). Examples of these are the introduction and takeoff of the new product and the peak and dive of the current product. Developing clear definitions and models to predict these events is essential to managing globally the timely transition from current to new products in a firm's portfolio (Christensen, 1997; Tellis, 2006, 2013; Tidd, 2010).

Third, the life cycles of new products are getting shorter (i.e., Bayus, 1994; Chandrasekaran and Tellis, 2008; Stremersch, Muller, and Peres, 2010; Van den Bulte and Stremersch, 2004). Thus, these transitions from current to new products are getting more frequent (Danneels, 2004). Failure to predict transition points in a timely manner could lead to a firm losing its current customers, getting obsolete, or dying with its current product (Foster, 2012; Libai, Muller, and Peres, 2009). For example, Nokia failed to see the transition from mobile phones to smartphones; it initially lost leadership to BlackBerry and ultimately sold out to Microsoft. BlackBerry failed to see the transition from smartphone to touchscreen smartphones and lost leadership to Apple. Kodak failed to make the transition from analog to digital photography and went bankrupt (Lucas and Goh, 2009). However, firms that can predict the dive are successful at marketing current and new products at the same time. For example, Philips used audio cassettes as a cash cow to develop CD players.

Fourth, the extant literature has either focused entirely on the takeoff of the new product (e.g., Agarwal and Bayus, 2002; Golder and Tellis, 1997) or has modeled the smooth diffusion of intergenerational products on the same technological platform (Jiang and Jain, 2012; Norton and Bass, 1987, 1992). Only a few studies have focused on the discontinuance of current products (e.g., Palacios Fenech and Longford, 2014). None of these studies modeled the turning points in the disruption of a current product by a new product. For product managers in the today's highly competitive environment, knowledge of clear measures and good models to predict these turning points is essential.

This is the goal of the current study. It focuses on addressing the metrics, patterns, drivers, and predictive models of the dive and disruption of an existing product. In particular, it seeks answers to the following questions:

1. What are good metrics to define and measure a dive?
2. What are the global patterns of a dive?
3. What are the key drivers (market and country level) of a dive?
4. What models can predict the dive and with what level of accuracy?

This paper seeks answers to these questions based on data from 86 countries and five current products that are being or have been disrupted due to the introduction and takeoff of five corresponding new substitute products. The subsequent sections present the theory, hypotheses, data, method, results, and discussion of the study.

Theory Development

This section first presents the theory and then the hypotheses of the study.

Theory

The theory builds on two lines of diffusion research: the rate of adoption and the takeoff of a new product, and the rate of discontinuance of a current successful product. Research on diffusion describes how an innovation is adopted in a social system (Rogers, 2004). For instance, the literature addresses the internal and external influences that affect the life cycle of a given product or service in a social system. However, the dynamics on the early stage of the discontinuance process have not been addressed (Peres, Muller, and Mahajan, 2010; Tellis and Chandrasekaran, 2012). Discontinuance is defined as the consumer's decision to disadopt a product (or an innovation) after having previously adopted it (Rogers, 2004, p. 217). Discontinuance is sometimes referred as disadoption (e.g., Prins, Verhoef, and Frances, 2009) or abandonment (e.g., Berger and Le Mens, 2009). This study uses the term *discontinuance*, from the diffusion literature, to avoid confusion (Rogers, 2004).

Only a few studies have directly examined discontinuance due to pro-innovation bias (Rogers, 2004). Black (1983) examines the relation between the rates of adoption and discontinuance and proposes a conceptual model of the post-adoption process. Redmond (1996) investigates smoking cessation as an adoption/diffusion process. Hogan, Lemon, and Libai (2003) develop a model to determine the effect of discontinuance on the value of a lost customer. Athiyaman (2008) explores the discontinuance of tiger parts consumption in China. Prins et al. (2009) analyzes the effect of adoption timing on discontinuance. And only one study has examined discontinuance in an international context. Palacios Fenech and Longford (2014) analyze the international rate of discontinuance of some products by using a Mansfield model. Common to all these studies is the psychological process by which a consumer makes a break from his or her current use of a product due to the appeal of new one. The process involves important dynamics explained below.

In a stylized form, the phenomenon of discontinuance is similar but opposite to the phenomenon of adoption (Rogers, 2004). In a noncumulative form, period-by-period discontinuance follows an inverted bell shape that can be categorized by five different types of discontinuers[1] (Palacios Fenech and Longford, 2014). Yet the current study argues that stages of the complete diffusion pattern are generally separated by four key turning points: takeoff, peak, dive, and landing (Figure 1). A dive of a current product is usually preceded by a peak in its level of penetration in the market before it declines.

The adoption of two substitute products tends to overlap. In these cases, although the discontinuance of the current product starts when the new product is introduced, the penetration of the current product only starts to decline when the number of adopters of the current product is smaller than the number of its discontinuers. As a result, after the introduction of a new product, the current product may still grow in penetration even though some consumers are already discontinuing it for the new product. This study calls this period the *hidden discontinuance* because the current product is being discontinued even though it is not visible in its aggregate penetration rate. So during the hidden discontinuance, the number of adopters of the current product is greater than the number of its discontinuers (who go on to adopt the new product). Thus, the levels of penetration of both products grow.

When a large number of consumers start adopting the new product, it takes off. Many of these consumers are those who disadopt the current product and switch to the new product. After this point, the penetration of the current product will tend to reach a peak, and eventually start to dive. After the peak, the number of discontinuers is greater than the number of adopters of the current product.

Note that the dive and the hidden discontinuance of the current product are neither passive nor spontaneous. Rather, they are triggered by the introduction of the new substitute product. The introduction of the new product triggers the hidden discontinuance period, and the takeoff of the new product triggers the dive (Peres et al., 2010). Thus, the new product disrupts the current one. Further, the introduction of the new product need not always be by a competitor (e.g., Chandy and Tellis, 1998; Immelt, Govindarajan, and Trimble, 2009). A firm may intentionally cannibalize its own product before a competitor does so (Aboulnasr, Narasimhan, Blair, and Chandy, 2008; Slater et al., 2014). Thus, for a business selling both the new and the current product, the new product sooner or later cannibalizes the current. For example, Gillette has regularly cannibalized its established brand of razors with a new one based on a superior blade technology (e.g., double-edged, triple-edged, five-edged; Tellis, 2013). Apple cannibalized sales of the iPod with the introduction of the iPhone, and cannibalized the sales of its laptop and computers with the introduction of the iPad.

[1] Rogers (2004) classifies consumers of a country using five adopter-and-discontinuer groups based on their degree of innovativeness and discontinuousness. The five adopter categories are innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%). The five discontinuer categories are triers (2.5%), early discontinuers (13.4%), early majority (34%), late majority (34%), and romantics (16%), followed by collectors (Palacios Fenech and Longford, 2014).

Previous theory and findings on new product diffusion and takeoff provide a useful framework for studying time-to-dive among countries. Economic measures, such as lifestyle, health status, or urbanization, have been found to affect the adoption stages of the diffusion pattern (i.e., Chandrasekaran and Tellis, 2008; Dekimpe, Parker, and Sarvary, 2000a; Kauffman and Techatassanasoontorn, 2005). Two main economic factors affect the rate of adoption. The economic wealth of countries is usually measured by gross domestic product (GDP) per capita, and income inequality is usually measured with the Gini index. The effect of cultural factors on the adoption of innovations also has support in the literature (Krishnan and Thomas, 2009). In addition, time and product categories also affect turning points in the product life cycle (Stremersch and Tellis, 2004).

This study uses a discrete-time hazard model that includes penetration levels of the new and the current product, percentage change in penetration during the late maturity phase of the current product, the length of the hidden discontinuance period, and the takeoff of the new product, controlling for demographic, economic, and cultural factors to predict the hazard of a dive. Our hypotheses deal with the expected effects of substitution on the hazard of dive.

Hypotheses

This paper develops three hypotheses dealing with the role of (1) takeoff of the new product, (2) intercountry contagion, and (3) year of introduction of the new product.

Takeoff of New Product

A successful new product generally shows a sharp takeoff in sales rather than even growth (Golder and Tellis, 1997). Typically, there is tremendous hype surrounding the new product that attracts innovators (early adopters) willing to pay a price premium. Typically, it is the early adopters of the current product that switch to and become early adopters of the new product.

However, expectations of changes in price and the pace and significance of changes in the quality of the new product create uncertainties for consumers about when to discontinue the current product and adopt the new one (Guiltinan, 2010; John, Weiss, and Dutta, 1999; Kleinknecht and van der Panne, 2012). Therefore, the mass of consumers do not switch to the new product. In fact, the level of adopters of the current product may continue to increase after the introduction of the new product. This increase will last as long as the adoptions of the current product are higher than its discontinuers (Boone, 2012). However, with improvements in the new product, uncertainties tend to vanish. Less people adopt the current product and more people switch from the current product to the new, so that the penetration of the current product eventually reaches a peak.

If most uncertainties about the new product are resolved, consumers realize that it clearly performs better than the current one. As such, a large number of consumers are willing to discontinue the current product to adopt the new product. At this point, the new product takes off. After the takeoff of the new product, an increasing number of people adopt the new product in each period and an exponential growth in penetration occurs. This growth in penetration of the new product triggers the rapid discontinuance of the current product by early adopters of the new product resulting in its dive. This line of reasoning suggests that:

H1: The takeoff of a new product increases the hazard of a dive of the current product.

Intercountry Contagion

Lead and lagging countries are defined by their timing of adoption of a new product. Lead countries are those that adopt a new product before other (lagging) countries. The effect of dives in lead countries on the dive in lag countries is caused by contagion. The literature suggests rival hypotheses about intercountry contagion in dives.

On the one hand, researchers have found a positive contagion (or learning) effect among countries regarding the time-to-takeoff of products (Chandrasekaran and Tellis, 2008; Dekimpe et al., 2000a; Dekimpe, Parker, and Sarvary, 2000b; Van Everdingen, Fok, and Stremersch, 2009). Van Everdingen et al. (2009) find that takeoffs but not introductions in lead countries accelerate time-to-takeoff in lagging countries. A takeoff of a product in a country may increase company efforts to enter new markets. Because of contagion, a takeoff is more likely when prior takeoffs occur in lead countries. This pattern may be caused by media reports about takeoff in the leading countries, travelers from the leading countries to lagging countries, or marketers of the new product adopting a waterfall strategy and moving from leading to lagging countries. The positive contagion that occurs for takeoff could also result in a positive contagion effect for dives in the intercountry diffusion of products. This process may occur because more people who adopt the new product discontinue the current one.

This line of reasoning suggests the following hypothesis of positive contagion in dives:

H2a: The greater the number of dives in leading countries, the higher the hazard of a dive in a target country.

However, the rival hypothesis can also be proposed, called a negative contagion hypothesis, due to the developmental status of leading dive and lagging dive countries. A dive may be less likely in a lagging dive country when prior dives have occurred in leading dive countries, due to the following reason.

When a new product appears in the market, firms tend to keep improving current products to avoid their replacement and disruption by the new product. This is known as the sailing-ship effect (De Liso and Filatrella, 2008, 2011; Gilfillian, 1935; Mendoça, 2013; Tsoutsos and Stamboulis, 2005). When a new product based on a new technological platform appears, firms producing current products may attempt to keep innovating and generating new strategies to protect and keep increasing their market share (Fouquet, 2010; Schiavone, 2014). Furthermore, new products may generate new notoriety for current products. In lagging dive countries, some firms may learn from the sailing-ship effect that occurred in leading countries to prevent the declining market for the current product and extends its life cycle. For example, companies may learn how to extend the life of the current product by creating new target markets for the current product. In addition, some firms may offer consumers in lagging dive countries technology disadopted in leading dive countries at discounted prices. By applying this marketing strategy, these firms extend the life of the current product and delay its disruption in lagging dive countries. Then, customers learn that they can buy the current product at reduced prices and new methods to extend their durable life. This behavior reduces the hazard of a dive in a lagging dive country as the number of prior dives increases.

This line of reasoning suggests the following rival hypothesis:

H2b: The greater the number of prior dives in other countries, the lower the hazard of a dive in a target country.

Year of Introduction of New Product

Recent research suggests that technological evolution is occurring at a faster rate in recent times than in earlier time periods (e.g., Sood and Tellis, 2005). In particular, the primary driver for this phenomenon is that a technological breakthrough in one market enables progress in this market on the same technology, but also stimulates progress in other related technologies and in other related markets. Other drivers for faster technological evolution could be the entry of new competitors from emerging markets, increasing global competition among firms involved in technological innovation, and increasing global expenditures in research and development (R&D). This state of affairs results in more rapid introduction of new products and shorter life cycles of current products. For example, several studies suggest that new products replace current products at a faster pace (e.g., Kohli, Lehmann, and Pae, 1999, Stremersch et al., 2010, Van den Bulte and Stremersch, 2004). Similarly, research suggests that the time-to-takeoff is shorter for products that are introduced to the market more recently than for products that are introduced earlier (Chandrasekaran and Tellis, 2008).

Shorter life cycles, faster technological evolution, and earlier takeoffs will all cause the dive of a current product to occur faster in more recent times than in earlier times. This effect of time can be measured by the calendar year of the introduction of a new product. The decline of the current product can be measured by the hazard of its dive. The above line of reasoning suggests that:

H3: The calendar year of introduction of the new product will be positively related to the hazard of a dive of the current product.

Method

This section covers data, measurement of dive, and model.

Data

This study creates a data set from three sources: sales from Euromonitor, country characteristics from United Nations, and Hofstede's culture metrics (Hofstede, 2001). The data from Euromonitor contain the annual levels of penetration of five current products—black-and-white television sets, cassette-radio players, videocassette recorders, landline telephones, and CD players—being substituted by corresponding new products (color television sets, CD players, DVDs, mobile telephones, and Internet personal computers, used as a proxy of audio storage digital devices [i.e., MP3]). The time period spans the years 1977–2011. The Euromonitor data set is based on survey matched with market data. The country variables include socioeconomic and cultural characteristics of each country: population density, GDP per capita at purchasing power parity (PPP), Gini index, uncertainty avoidance, power distance, masculinity, and individualism.

To analyze the time-to-dive, from a sample of 86 countries, for each of the five current products, we select countries only if their penetration levels reach a peak between 1977 and 2011, because overt time-to-dive can only be calculated after penetration starts to decline. For black-and-white television, we select 52 countries. For cassette-radio players, we select 62 countries. For videocassette recorders, we select 66 countries. For landline telephone we select 53 countries, and for CD players we select 62 countries (see Appendix S1 for the full list of countries–product combinations).

For substituting new products, color television sets were introduced on average in 1982[2] and used as a substitute of black-and-white television sets; CD players were introduced on average in 1985 and used as a substitute of cassette-radio players. Internet personal computers were introduced on average in the market in 1995 and are used as a proxy for MP3, downloads and audio storage devices, and as substitute of CD players. Mobile telephones were introduced on average in 1991 and substituted landline telephones. DVD players were introduced in the market on average in 1997 and are used as a substitute of videocassette recorders.

Measurement of Peak and Dive

The peak is identified as the year in which the level of penetration of the current product reaches a maximum. If the maximum level of penetration is reached for more than one year, the last year in which the level of

[2] The early stage of the diffusion pattern for color television sets is available only for four countries: India, Nigeria, Cameroon, and Kenya. The reason is that color television sets in other countries were introduced before 1977, which is the start of our sampling period, and therefore time-to-takeoff cannot be estimated for all product–country combinations.

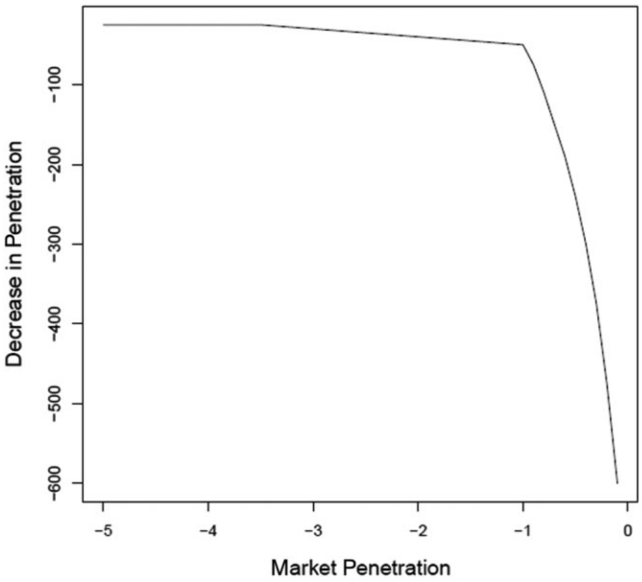

Figure 2. Threshold for Dive

penetration of the old product reaches a maximum is the peak. This year is used to calculate overt time-to-dive.

We measure dive using a threshold rule as specified for the measurement of takeoff (Tellis, Stremersch, and Yin, 2003). The logic for the threshold for takeoff is that it adjusts for the growth rate of sales as penetration increases: when the base level of sales is low, a large increase in sales is required to signal takeoff and vice versa. The threshold for takeoff was inferred so as to give the best prediction of takeoff based on visual identification (Golder and Tellis, 1997; Tellis et al., 2003). The reason for a threshold is to provide an object heuristic that can identify takeoff as it occurs rather than in retrospect (Golder and Tellis, 1997; Tellis et al., 2003; Van Everdingen et al., 2009) (Figure S1 in Appendix S2).

Likewise, we define the threshold for dive as a standard plot of a required decrease in penetration for various levels of market penetration. The *dive* is defined as the first year a product's decline in penetration falls below this threshold. Figure 2 shows the threshold for dive. In this analysis, the threshold of market penetration is raised to 5% because in many cases a dive may happen above the original threshold bound of 3.5%. These modifications are not problematic and solve the limitation of the original threshold rule, which is bounded by a maximum increase/decrease of penetration of 3.5%. These modifications are presented in Appendix S3.

Mann–Whitney Test

A Mann–Whitney test (Hollander and Wolfe, 1999) is used to compare overt time-to-dive, time-to-takeoff, and the hidden discontinuance period between inter-generational product categories and between developed and emerging markets. The Mann–Whitney is more robust to the presence of outliers and to distributions far from normal than the *t*-test. Although both tests tend to provide similar results, we display the Mann–Whitney test for reasons of robustness and efficiency in our data (Conover and Iman, 1981). A note attached to the table of reported results explains rare cases in which results could differ.

Model

The current paper models the dive with a hazard model following the tradition for modeling takeoff (e.g., Dekimpe et al., 2000b; Tellis et al., 2003). A Cox (1972) discrete-time hazard model (via logistic regression) captures the hazard of a dive associated with time-varying covariates (Cox, 1972). This formulation reduces to considering whether or not a dive occurs in each year as a function of time and the various independent variables. To apply the model, we pool the five product pairs together. The model is specified as:

$$\text{logit}\,\lambda_0\left(X_i|t_j\right)=\alpha_j+\gamma Time+\varphi Time^2+\beta X_{ij}+\delta Y_i+\varepsilon,$$

where X_1, X_2,. . . represent the covariates included in the model, β captures the effect associated with each time-dependent covariate and δ captures the effect associated with each time-independent covariate, α_j is the logit of baseline hazard function $\lambda_0(X_i|t_j)$, and ε is the error term that follows a binomial distribution (Hosmer and Lemeshow, 2004). We obtain bootstrap estimates corrected for intra-cluster correlations of country–product combinations (Lin and Wei, 1989). This hazard function indicates the extent to which explanatory variables drive the likelihood of time-to-dive in a country, given that it has still not occurred. Results with the discrete-time hazard model can be interpreted when they are expressed as the percentage change in the hazard ratio, which can be calculated from e^{β} by the formula $100 \times (e^{\beta} - 1)$.

We use the discrete-hazard model to predict the peak and the dive. We model first the hazard of a peak in penetration of the current product and then the hazard of a dive by using the hazard of a dive during the overt time-to-dive period as a dependent variable. We label the models as *discrete-time hazard model of peak* and *discrete-time hazard model of dive*, respectively.

The discrete-time hazard model of peak includes eight time-dependent variables and five time-independent covariates. The time-independent variables are uncertainty avoidance, masculinity, individualism, power distance, and the year of introduction of the new substitute product in each country–product combination. The eight time-dependent covariates are population density, Gini index, percentage of rural population in the prior year, GDP per capita at PPP in the prior year, level of penetration of the current and the new product in the prior year, takeoff of the new product, and prior dives in other countries. Note that all the time-dependent variables are lagged except takeoff of the new product and prior dives in other countries.

To measure the intercountry lead-lag effect of a dive, we include a variable for the sum of prior dives in other countries for each country–product combination. We also include two variables representing time and time-squared to control for nonlinearity of time effects on the baseline hazard of a peak and a dive.

The discrete-time hazard model of dive includes two more time-independent variables: first, the relative percentage change in penetration during the five years prior to the peak of the level of penetration of the current product. This measure allows us to ascertain if the late maturity phase of the current product is flat or penetration increases at sustained rates before reaching a peak. Second is the length of the hidden discontinuance period of the current product. This measure allows us to ascertain if the period between the introduction of the new product and the peak of the current product is related to the hazard of a dive. Appendix S4 includes a detailed description of each variable.

A discrete-time hazard model is applied to the data within which the effects of covariates of the five product categories are analyzed simultaneously. The estimation of hazard models is fitted with *lrm* and *bootcov* functions of the *rms* package of R software (R Development Core Team, 2010).

Results

This section reports the results in six subsections: peak and hidden discontinuance period, dive and overt time-to-dive, differences between developed and emerging markets, estimates of the discrete-time hazard models, out-of-sample predictive results, and robustness tests.

Peak and Hidden Discontinuance Period

We refer to the point at which change in the penetration of the current product switches from increase to decrease as the peak in its penetration. Our results show that, on average, when a new product is introduced into the market, the market penetration of the current product continues to grow until the peak. The penetration of the current product starts decreasing many years after a new product has been introduced. We refer to this period, from the introduction of the new product to the peak of the current product, as the hidden discontinuance period. The average hidden discontinuance period is 10.4 years (Figure 3).

The takeoff of the new product occurs prior to the peak of the current product in 95.4% of the cases, the same year as the peak in .8% of the cases, and after the peak in 3.8% of the cases. The peak penetration of the current product occurs at 56% of its own penetration, nowhere near its saturation point.[3] From these statistics, we may infer that the peak is caused by the takeoff of the new product and not any saturation in penetration of the current product.

Dive and Overt Time-To-Dive

A dive occurs in 96% of the cases (283 out of 295 product–country combinations) similar to the frequency of takeoff of a new product that occurs about 96% of cases. This frequency is a robust result present in all the five current product categories (Appendix S5). On average, for the five product–country combinations, a dive occurs at 54% penetration of the current product. The average percentage decline in penetration of the current product during the year of the dive is 2.5% versus .9% growth during the year of the takeoff. Compared with the prior year, the average percentage decline in penetration of the current product at the dive is 286%, and the average percentage increase in penetration of the new product at takeoff is 235%[4] (Figure 2).

Based on these results, we can confirm that a decline in penetration levels of current products will not be a smooth and slow process, but in general it will experience a dramatic decrease, especially when compared against prior growth.

The time from the peak to dive is 1.8 years (Figure 3). Further, the dive of the current product occurs 12.2 years after the introduction of the new product and 8.4 years after its takeoff. This long period is a robust result present in all the five multigenerational product categories. The takeoff of the new product occurs prior to a dive in the current product in 96% of the cases, the same year as the dive of the current product in .5% of the cases, and after the dive in 3.5% of the cases. From this result, we

[3] Appendix S5 includes detailed key statistics for each product.
[4] When dive and takeoff occur in the first year, the percentage change in penetration compared with the prior year cannot be estimated.

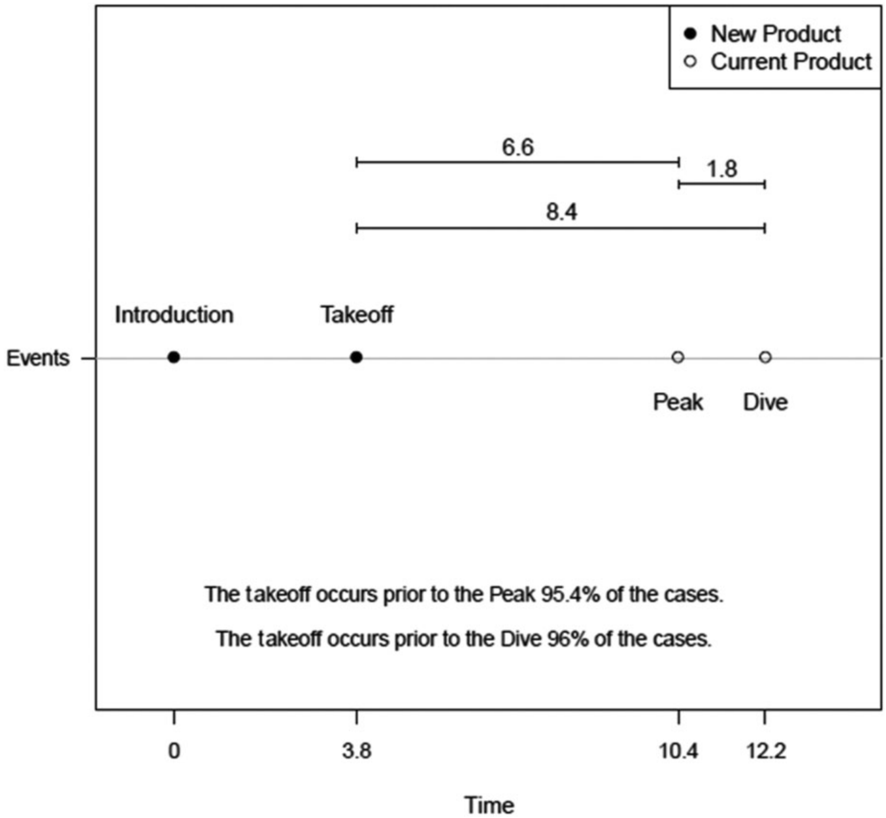

Figure 3. Timeline of Events

may infer that the takeoff of the new product is the primary cause of the dive of the current product.

The overt time-to-dive is the period between the peak and dive in penetration of the current product (Figure 1). Our results show that, on average, overt time-to-dive of the current product is 1.8 years, while time-to-takeoff of the new product is 3.8 years, showing that overt time-to-dive of the current product is about half as long time-to-takeoff of the new product. The difference between the overt time-to-dive and time-to-takeoff are significantly tested for every product category combination with a Mann–Whitney test (Hollander and Wolfe, 1999) (Table 1).

Differences between Developed and Emerging Markets

The hidden discontinuance period and the overt time-to-dive are significantly shorter in emerging markets than in developed ones. On average, the hidden discontinuance period for developed markets is 11.5 years, and for emerging markets is 9.4 years. On average, overt time-to-dive for developed markets is two years and for emerging markets is 1.6 years. For the time-to-takeoff, there is no significant difference between developed and emerging markets (Table 2).[5]

On average, the peak penetration of the current product occurs at a significantly greater penetration of the new product in developed markets (46%) than in emerging markets (14%). The average level of penetration of the current product during the peak is significantly greater in developed markets (71.2%) than in emerging markets (43%). On average, the mean percentage decline in penetration by year of the overt time-to-dive in developed markets is significantly smaller (1.6%) than in emerging markets (2.6%). The average percentage decline in penetration of the current product during the year of the dive is significantly smaller in developed markets (1.8%) than in emerging markets (2.9%). Compared with the prior year, the average percentage decline in penetration compared with the prior year at the dive in emerging markets (309%) is significantly greater than in

[5] Appendix S6 includes detailed key statistics for each product in developed and emerging markets, and Appendix S7 includes a table with the average hidden discontinuance period and average overt time-to-dive for each country, ranked from the shortest to the longest.

Table 1. Overt Time-to-Dive versus Time-to-Takeoff

Overt Time-to-Dive	Time-to-Takeoff	
Current products	New products	Mann–Whitney test
1.8 years, $n = 283$	3.8 years, $n = 238$	p-value < .01
Black-and-white television sets	Color television sets	
2 years, $n = 52$	9.8 years, $n = 4$	p-value < .01
Cassette-radio players	CD players	
1.9 years, $n = 59$	3 years, $n = 54$	p-value < .01
Videocassette recorders	DVD recorders	
1.7 years, $n = 62$	4.2 years, $n = 65$	p-value < .01
Landline telephones	Mobile telephones	
1.7 years, $n = 49$	3.3 years, $n = 53$	p-value < .01
CD players	Internet personal computers	
1.6 years, $n = 61$	4 years, $n = 62$	p-value < .01
CD players	CD players	
1.6 years, $n = 61$	3 years, $n = 54$	p-value < .01

developed markets (261%) (Figure 2). Emerging markets reach a lower penetration than developed markets and tend to have a higher percentage decline during the dive (Table 2).

Discrete-Time Hazard Model

This section reports the results of predicting two critical events in the life cycle of the current product: the peak in penetration and the dive. We use a discrete-time hazard model to do so for each event. We pool over all five product categories and all 57 countries. First, we display results for the discrete-time hazard model of peak. Second, we present the discrete-hazard model of dive.

Discrete-Time Hazard Model of Peak

Table 3 presents the results of the discrete hazard model to predict the peak in penetration of the current product. Population density, the level of penetration of current products, prior dives, and the year of introduction of a new product are significantly associated with the hazard of a peak in penetration (p-value < .05). Time is significantly associated with the hazard of peak of penetration (p-value < .05), but not time-squared (p-value > .05). Based on the estimates of these two variables, the baseline hazard of a peak is in Appendix S8 (Figure S2). Overall, the hazard model explains 45.1% of the variation of the hazard of a dive (pseudo R-square = .45).

Based on the model in Table 3, each additional unit of population density (people divided by land area in square kilometers) is associated with a .02% increase on the odds of the hazard of a peak in penetration ($\beta = .0002$, p-value < .05). That is, the hidden discontinuance period tends to be shorter in those countries that have more people per unit of land area. Each additional percentage increase in the level of penetration of current product is associated with a 2.4% increase in the odds of a peak ($\beta = .02$, p-value < .05). Therefore, controlling for other

Table 2. Significant Differences between Developed Markets and Emerging Markets

	Developed Markets	Emerging Markets	Mann–Whitney Test
Time-to-takeoff	3.5 years, $n = 120$	4 years, $n = 118$	p-value > .05
Hidden discontinuance period	11.5 years, $n = 120$	9.4 years, $n = 127$	p-value < .01
Overt time-to-dive	2 years, $n = 120$	1.6 years, $n = 163$	p-value < .01
Penetration of new product (at peak of penetration of current product)	45.5%, $n = 127$	14.1%, $n = 168$	p-value < .01
Peak of penetration of current product	71.2%, $n = 127$	43.4%, $n = 168$	p-value < .01
Average percentage decline in penetration of dive	1.8%, $n = 120$	2.9%, $n = 163$	p-value < .01
Average increase in penetration of takeoff	1.1%, $n = 120$	.7%, $n = 118$	p-value < .01
Relative percentage decline in penetration compared with prior year of dive	261%, $n = 89$	309.2%, $n = 95$	p-value < .05
Relative percentage increase in penetration compared with prior year of takeoff	274%, $n = 118$	196.5%, $n = 118$	p-value > .05

Note: The difference between time-to-takeoff of developed and emerging markets is significant by using a Student's t-test.

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Table 3. Discrete-Time Hazard Model of Peak

Variables	Coefficients	Standard Error	z-Statistic	*p*-Value
Intercept	**−14.04**	**1.74**	**−8.09**	**.00**
Time	**.69**	**.14**	**5.02**	**.00**
Time squared	.00	.01	.14	.89
Uncertainty avoidance	.00	.01	.81	.42
Power distance	.01	.01	.85	.40
Masculinity	−.01	.00	−1.52	.13
Individualism	−.01	.01	−1.35	.18
Gini index (lagged)	.00	.01	.06	.96
Population density (lagged)	**.0002**	**.00**	**2.02**	**.04**
Levels of penetration of the new product (lagged)	.00	.01	−.70	.48
Levels of penetration of the current product (lagged)	**.02**	**.01**	**4.56**	**.00**
GDP per capita (lagged)	−.02	.01	−1.73	.08
Percentage of rural population (lagged)	.00	.01	−.48	.63
Takeoff of new product	−.80	.43	−1.88	.06
Number of prior dives	**−.06**	**.01**	**−7.64**	**.00**
Year of introduction of new product	**.43**	**.04**	**10.18**	**.00**
Likelihood ratio chi^2	−493.25			
Pr(>chi^2)	<.0001			
Number of observations	2131			
Number of events	195			
Pseudo *R*-square	**.45**			

Notes: 195 clusters of country–product combinations. Bootstrapped model 10,000 times. Significant covariates are presented in bold.

variables, the hidden discontinuance period tends to be shorter for those products with higher levels of penetration. Each additional increase in the number of prior dives is associated with a decrease of 5.8% in the odds of a peak ($\beta = -.06$, p-value < .05). Each additional increase in the calendar year of introduction of the new product is associated with a 54.3% increase in the odds of the hazard of peak of a current product ($\beta = .43$, p-value < .05). The remaining control variables of our model did not show significant results.

Based on the above results, we present the out-of-sample prediction of the peak in a subsequent section. Once the peak in penetration has been reached, at the end of the hidden discontinuance period, companies may predict the hazard of a dive including information about this period, such as the length of the hidden discontinuance period and the relative percentage change in penetration of the current product during the late maturity phase before reaching this peak.

Discrete-Time Hazard Model of Dive

Results from this discrete-time hazard model are in Table 4. As hypothesized, the takeoff of new products, prior dives, and the year of introduction of new products are significant, and in line with H1, H2b, and H3 (p-value < .05), respectively. The year of introduction of a new product, the hidden discontinuance period, and the relative percentage change in penetration during the late maturity phase of the current product are also significant (p-value < .05). The hazard of dive is related with time, (p-value < .05), but not with time-squared. Based on these two estimates, the baseline hazard of a dive is in Appendix S8 (Figure S3). Overall, the hazard model explains 50.9% of the variation of the hazard of a dive (pseudo R-square = .51).

Based on the model in Table 4, the takeoff of the new product is associated with a 157.2% increase on the hazard of a dive. Each additional increase in the number of prior dives is associated with a decrease of 7.2% in the hazard of a dive. Each additional year increase in introduction of the new product is associated with a 21.5% increase in the hazard of a dive. Each additional year increase in the hidden discontinuance period is associated with a 30.5% increase in the hazard of a dive. Each relative percentage increase in penetration during the late maturity phase period is associated with a 5.8% increase on the hazard of a dive.

In an international context, the takeoff of a new product, prior dives of the current product, the year of introduction of the new product, and the percentage change in penetration during the late maturity phase are associated with the hazard of a dive. Consistent with H1, the takeoff of the new substitute product increases the

Table 4. Discrete-Time Hazard Model of Dive

Variables	Coefficients	Standard Error	z-statistic	p-value
Intercept	−6.05	3.78	−1.60	.11
Time	**4.02**	**1.49**	**2.69**	**.01**
Time squared	−.62	.34	−1.84	.07
Uncertainty avoidance	−.01	.01	−1.25	.21
Power distance	.00	.01	−.26	.79
Masculinity	.01	.01	1.30	.19
Individualism	.00	.01	.07	.94
Gini index (lagged)	−.02	.02	−.81	.42
Population density (lagged)	.00	.00	.35	.73
Levels of penetration of the new product (lagged)	.00	.01	−.13	.90
Levels of penetration of the current product (lagged)	−.02	.01	−1.71	.09
GDP per capita (lagged)	−.04	.04	−1.18	.24
Percentage of rural population (lagged)	.00	.01	.02	.98
Takeoff of new product	**.94**	**.49**	**1.93**	**.05**
Number of prior dives	**−.07**	**.02**	**−3.78**	**.00**
Year of introduction of new product	**.19**	**.10**	**1.97**	**.05**
Hidden discontinuance period	**.27**	**.14**	**1.96**	**.05**
Change in penetration in late maturity phase	**.06**	**.02**	**2.55**	**.01**
Likelihood ratio chi2	195.94			
Pr(>chi2)	<.0001			
Number of observations	408			
Number of events	190			
Pseudo *R*-square	**.51**			

Note: 199 clusters of country–product combinations. Bootstrapped model 10,000 times. Significant covariates are presented in bold.

hazard of a dive of the current product ($\beta = .94$, p-value < .05). Consistent with H2b, prior dives in other countries tend to decrease the hazard of a dive in a target country ($\beta = -.07$, p-value < .05). Consistent with H3, the year of introduction of the new product increases the hazard of a dive ($\beta = .19$, p-value < .05). The higher the relative change in penetration of the current product during the late maturity phase, the higher the hazard of a dive ($\beta = .06$, p-value < .05). The longer the hidden discontinuance period, the higher the hazard of a dive ($\beta = .27$, p-value < .05).

Out-of-Sample Predictive Ability

The true test of a hazard model is its ability to predict events for an out-of-sample target category. So we evaluate the predictive ability of the model by using a jackknife technique following Golder and Tellis (1997). We first hold one target product–country combination, reestimate the model with all other product–country combinations, and then use the estimated coefficients to predict the peak and the dive of the target product–country combination using the values of the variables of the latter. We predict both the peak and the dive to occur in the year when the probability of no event, referred to as survival probability, falls below 50%.

Table 5 displays the resulting predictions for the three models. The average predicted survival probability of the event of a peak with the discrete-time hazard model of peak is .79 and ranges from 0 to 1. The discrete-time hazard model of peak predicts 61.5% of all peaks and predicts 87.1% of nonpeaks. The false positive rate is 12.9% and the false negative rate is 38.5% of the periods.

Table 5. Predictive Results of Peak and Dive by Discrete-Time Hazard Model

	Percentages			
	True Positives	True Negatives	False Positives	False Negatives
Peak	61.5	87.1	12.9	38.5
Dive	82.1	60.6	39.4	17.9

The average predicted survival probability of the event of a dive with the discrete-time hazard model of dive is .44 and ranges from 0 to 1. The discrete-time hazard model of dive predicts 82.1% of all dives and 60.6% of nondives. The false positive rate is 39.4% and the false negative rate is 17.9% of the periods.

Robustness of Results

To measure possible intercorrelations of variables, we present correlation matrices of the variables included in the discrete-time hazard model in Appendix S9. We test multicollinearity via a variance inflation factor (VIF) test. The VIF of independent variables is according to accepted standards. We also bootstrap the discrete-hazard models 10,000 times and conclude that results are highly robust. To test the robustness of the predictive ability, we also fit the models applied to the data without cultural dimensions of countries, for which data are only available on 57 countries. The hazard model without cultural variables includes 79 countries. We also model them separately for developed and emerging markets, and include their predictive results in Appendix S10. The prior results are fairly robust to all these tests.

Discussion

This section summarizes the key findings, discusses implications, and suggests directions for future research.

Summary of Findings

The major findings of this study are as follows:

- Most current products reach a peak at about 56% of market penetration. Subsequently, they suffer a dramatic decrease in relative penetration of 286%, which we call the dive.
- A dive occurs in 96% of current products in five categories across 86 countries between 1977 and 2011.
- The introduction and takeoff of a new product are the primary causes of the peak in penetration and the dive of the current product. On average, the time from takeoff of new product to a peak in penetration of current product is 6.6 years and to the dive of the current product is 8.4 years. The overt time-to-dive (from peak to dive of the current product) is 1.8 years, much shorter than time-to-takeoff.
- The decline in the rate of penetration of the current product starts much after the introduction of a new product because the current product continues to win late adopters even as it loses early adopters. We call this period the hidden discontinuance period. On average, the hidden discontinuance period is 10.4 years.
- Both the hidden discontinuance period and the overt time-to-dive are shorter in emerging economies than in developed ones. The peak penetration of the current product is lower and occurs at a lower penetration of the new product in emerging markets than in developed ones. The dive suffers a more dramatic decrease in penetration in emerging markets than in developed ones.
- The hazard of a peak increases with an increase in penetration of the current product, the population density of the country, and the introduction of the new product. The hazard of the peak decreases with prior dives in other countries.
- The hazard of a dive increases with the takeoff of a new product, introduction of a new product, a longer hidden discontinuance period, and an increase in the growth of penetration during the late maturity phase of the current product. The hazard of a dive decreases with an increase in prior dives in other countries.
- The discrete-time hazard model of dive predicts the occurrence of a dive with a true positive rate of 82% and a true negative rate of 61%. And the discrete-time hazard model of peak predicts the occurrence of a peak with a true positive rate of 62% and a true negative rate of 87%.

Implications

These findings have important implications for managers:

First, the dive represents a sudden and steep decline in the penetration of a current product. Managers need to adapt to the new market characteristics very quickly either by generating new uses for the current product, improving the technology, or switching to the new technology. In the latter case, they will need to move R&D expenditure, manufacturing capacity, inventory, staff, and marketing efforts from the current to the new product. Our predictive model of the hazard of the peak and dive of the current product can help in such planning.

Second, the identification of two key events allows managers some wiggle room for planning their strategy. A dive usually occurs after a long hidden discontinuance period. So managers of the current product have some time to decide which strategy to follow before the onset of the dive. Their strategy will depend on the market orientation of their company. Once the current product reaches peak penetration, the dive follows quickly, and it may be too late to choose their optimal strategy. Yet very few firms are future-oriented and aggressive enough to expedite the dive. Indeed, those businesses invested in the current product may take a defensive position when faced with a promising new product for three reasons (Tellis, 2013). First, they hope the new product may not take off. Second, the profits are more from the current product and they want to keep it alive. Third, they are emotionally wedded to the current product. So they work to enhance their current technology to be able to better compete with the new product. This is known as the sailing-ship effect (Bayus, Kim, and Shocker, 2000; De Liso and Filatrella, 2008; Gilfillian, 1935). Whether the same manufacturer or marketer introduces both the new and the current product or not, our predictive model can guide managers as to when such a defensive strategy may be fruitful and when it may be futile.

Third, both, marketers and consumers of the current product in lag countries may learn how to extend the life cycle of the current product from lead countries. Marketers can do so by improving the current product and creating new promotions. Consumers can do so by being more responsive to these offers and improvements. Our model can help managers decide if their global growth strategies will be effective, either by extending its life cycle or by expediting its dive.

Fourth, our model suggests that for an exit strategy, firms should withdraw current products faster in countries in which takeoff of the new product occurred (Harrigan, 1980). By identifying those countries where the new product takes off, firms may then create optimal strategies of exit for the current product.

Fifth, the trend of more rapid technological change is causing shorter life cycles, more rapid substitution of old products, and shorter hidden discontinuance periods. In such a scenario, all the above recommendations are becoming more important, and the accurate prediction of a peak, dive, and the hidden discontinuance period from our model becomes more valuable.

Limitations

Several limitations of this study provide fruitful avenues to enhance our current knowledge of the adoption dynamics of new-current product substitution.

First, our data include five pairs of durable new products. Extension to more and wider variety of new product pairs would enable generalizations of the findings. Second, we include only successful new products. It would be helpful to study new products that were introduced in the market but did not take off. Third, we do not include marketing mix variables because of the large number of countries and years covered. Obtaining such data would be valuable for managers. Fourth, our data are at the annual level. Disaggregate data (monthly, weekly, or daily) should provide more granular findings. Fifth, we did study the effect of distance between countries and regional factors, such as trade agreements between countries for deeper insights into lead-lag effects of dive. Sixth, we did not include other measures of national culture, such as long-term orientation and indulgence (Hofstede, Hofstede, and Minkov, 2010), or the GLOBE measures (House, Hanges, Javidan, Dorfman, and Vipin, 2004). All these remain useful avenues for future research.

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Supporting Information

Additional Supporting Information may be found in the online version of this paper:

Appendix S1. Country–Product Combinations.
Appendix S2. Threshold for Takeoff.
Appendix S3. Modifications of the Original Threshold Rule for the Measurement of a Dive.
Appendix S4. Description of Variables.
Appendix S5. Key Statistics.
Appendix S6. Key Statistics for Developed Markets and Emerging Markets.
Appendix S7. Rankings of Countries.
Appendix S8. Baseline Hazard.
Appendix S9. Correlation Matrices of Independent Variables.
Appendix S10. Predictive Results for Discrete-Time Hazard Models.