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Customer Segmentation, Leapfrogging, Switching, and Cannibalization in the Context of Disruptive Technological Change

Deepa Chandrasekaran, Gerard J. Tellis, and Gareth M. James

Report Summary

All business executives marketing products/technologies should realize that disruptive technologies are always on the horizon. The big dilemma for incumbent firms is to evaluate whether or not to introduce these disruptive technologies and cannibalize their own successful offerings. The challenge for entrant firms is to know who to market these technologies to.

Deepa Chandrasekaran, Gerard Tellis, and Gareth James propose that when evaluating whether or not to introduce new disruptive technologies, and when, it is important to know which adopter segments drive market growth versus cannibalization and what the size is of these segments by category and country. They address the following questions:

1. How can one model the diffusion and growth of successful technologies?
2. Can one estimate sizes of adopter segments from such a model?
3. How do the adopter segments vary in size across categories and countries?
4. How do adopter segments contribute to cannibalization and disruption for incumbents? Can one measure the extent of cannibalization by a new successive technology from the model?

Study

The authors develop a generalized model of the diffusion of successive technologies with partial substitution, tested on large, multi-country datasets of technological succession. Their model includes a separate rate of disengagement from the old technology, which represents the extent to which adopters of the preceding technology abandon it in favor of the new technology. Low disengagement implies low cannibalization. Further, they define and model five new adopter segments of successive technologies that they term pure switchers, bold and doubtful leapfroggers, maven, and cautious innovators.

Findings and Strategic Insights

Key findings are the following:

- Their generalized model of the growth of new technologies provides superior fit to data on both penetration and sales data for successive technologies than existing multi-generational models which are geared towards modeling data on successive generations of the same technology.
- The new segmentation enables estimation of the influence of technology cannibalization on the prior technology’s adoption curve, as well as the influence of leapfrogging vs. switching on the new technology’s adoption curve. In general, the authors find that the composition of the five segments varies by technology, across markets, and even across successive technologies that serve the same basic need.
- The percentage of leapfroggers, in the early life-cycle of the new technology, is significantly higher in developing than developed markets, and vice-versa for innovators.
- Major incumbents often fail during the takeoff of new technologies due to the under-estimation of leapfroggers (opportunity cost) or pure switchers (real cost). Their model and analysis provide a better strategic understanding of how adopter segments for a newer technology may drive sales to marketers. Such analyses can prevent disruption on the emergence of a new technology.

Their findings suggest that senior managers of strategy and managers of new products should be careful not to underestimate cannibalization by switchers and market growth via innovators (especially in developed countries) or leapfroggers (especially in developing countries). Managers should target their marketing efforts appropriately to these consumer segments in these countries.

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CUSTOMER SEGMENTATION, LEAPFROGGING, SWITCHING, & CANNIBALIZATION DURING DISRUPTIVE TECHNOLOGICAL CHANGE

Contents

I. Introduction

In 1975, one of Kodak's engineers, Steve Sasson, invented the digital camera and subsequently Kodak owned most of the patents in digital photography. Yet Kodak delayed introducing the product commercially, clinging in hope of the continued success of analog photography (Tellis 2012). Digital photography was introduced by Kodak's rivals, who ironically licensed Kodak's digital technology. Digital photography took off in 1999. Only in 2001, Kodak made a big push into the digital marketplace, with the Easyshare brand. However, by that time the field was too crowded. Kodak never recovered from the decline of analog photography and the lack of a foothold in digital photography. Kodak stopped selling traditional film cameras in the U.S., Canada, and Western Europe in 2004 and eventually filed for bankruptcy in 2012 (Shreyder 2012). Figure 1 (following the references section) shows the Kodak stock price plunge in the period 1992-2011. Ironically, in the same industry, digital camera incumbents like Nikon, Canon, and Sony later suffered due to an underestimation of cannibalization by smartphones.

Similarly, consider the example of tablets, which disrupted the market for two prior technologies - PCs and laptops. HP dominated the market for laptops and PCs. Even though the tablet, in various forms, was in the works for many years (Stone and Vance 2009), the market took off with the introduction of the Apple iPad. Figure 2 shows HP's decline in stock price after the takeoff of tablets.

Disruptive technologies are always on the horizon. The big dilemma for incumbent firms is to evaluate whether or not to introduce these disruptive technologies and cannibalize their own successful offerings. Incumbents often stumble during technological change (See Table 1 below following references). The challenge for entrant firms is to know whether it is profitable to enter with these technologies and who to market these technologies to. Technological disruption has become such a pressing concern for companies, more so, in the digital age where disruptive technologies affect multiple industries: online video streaming, 3-D printing, ride-sharing services, etc. In fact, companies, big and small, in recent years are pondering the creation of a new role in the C-suite- the 'Chief Disruption Officer', a thought leader who can think strategically about the company, competition, industry and the value chain.

Much of the attention in the academic literature in the context of technological disruption focuses on managing the promotional mix strategies in the age of digital disruption. Businesses focus on organizing the C-suite for change leaders. However, there seems to be a forgotten stakeholder – THE CUSTOMER. Here are some unaddressed issues: How do consumers react to the introduction of a new, successive technology? Which consumers contribute to market growth and which consumer segments drive cannibalization of the previous technology? If one can understand how different consumer segments react to new technologies differently, marketing can be tailored suitably to create value during times of technological turbulence. The issue of understanding customer during technological change is so important that the Marketing Science Institute has established '*Cultivating the customer asset- the customer-technology interface*' as the foremost research priority for 2018-2020.

We add to this dialogue by focusing on the customer-technology interface in the context of disruptive technological change. Specifically, we propose a new consumer segmentation typology for successive technologies: Pure Switchers, Bold and Doubtful Leapfroggers, Cautious and Maven Innovators. We describe these segments below:

1. Pure switchers are consumers in the segment who had already adopted Technology 1 but choose to replace it with Technology 2 after the latter technology is introduced.
2. Bold leapfroggers adopt Technology 2, but would never have adopted Technology 1, and thus present an entirely new consumer segment for the new technology.
3. Doubtful leapfroggers represent the consumer segment who would have adopted the prior technology, but had delayed the decision, and instead end up adopting the new technology.
4. Maven innovators had already adopted Technology 1 but elect to adopt both technologies once Technology 2 is introduced.
5. Cautious innovators represent the consumer segment who would have adopted the prior technology, but had delayed the decision, and end up adopting both technologies.

We propose that pure switchers and doubtful leapfroggers represent a lost market for Technology 1 and thus, its cannibalization (CAN), while bold leapfroggers, and innovators represent market growth (MG). Cannibalization is the extent to which the new technology "eats" into real or potential sales (or adoption) of the old technology. Cannibalization is driven mainly by switching, which occurs when adopters of the old technology replace it with the new technology. That is, switchers who bought Technology 1 disengage from it and buy Technology 2. Market growth, on the other hand, is driven mainly by leapfrogging, which occurs when consumers directly adopt a new technology without adopting the immediately preceding (old) technology in a set of successive technologies serving the same consumer need. Further, a new technology may only partially substitute (in other words, somewhat complement) an older technology, in that some adopters may choose to hold both the older and newer technology at the same time. We term this segment of adopters as innovators. Innovators also contribute to market growth, but not to cannibalization.

Despite the importance of technological leapfrogging, switching, and cannibalization, no model formally captures these phenomena to extract strategic implications. To address this gap, our research addresses the following substantive questions:

1. How can one model the diffusion and growth of successful technologies?
2. Can one identify/estimate sizes of adopter segments from such a model?
3. How do the adopter segments vary in size across categories and countries?
4. How do adopter segments contribute to cannibalization and disruption for incumbents? Can we measure the extent of cannibalization by a new successive technology from the model?

We first develop a generalized model of the diffusion of successive technologies with partial substitution, tested on large, multi-country data-sets of technological succession. Our model has two characteristics: First, it includes a separate rate of disengagement from the old technology, which represents the extent to which adopters of the preceding technology abandon it in favor of the new technology. Low disengagement implies low cannibalization. Second, it decomposes adoption of new technologies into five strategic adopter segments: bold and doubtful leapfroggers, maven and cautious innovators, and pure switchers.

We test the new model on a unique dataset comprising of time series data on the market penetration of seven sets of successive technology pairs across 105 countries (441 technology pair-country combinations), spanning multiple years (earliest data-point of 1947 and the latest data-point of 2016). We also test the robustness of the model on sales of three contemporaneous technology pairs across 40 countries. Additionally, we present an extension of the model to the diffusion of technology triplets (three successive technologies).

The key findings from the research are the following:

- The generalized model of the growth of new technologies provides superior fit to data on both penetration and sales data for successive technologies than existing multi-generational models which are geared towards modeling data on successive generations of the same technology, for example, iPhone 9 and 10. Managers can gain insights on the expected size of adopter segments, cannibalization and market growth over time, across categories and markets, for new successive technologies.
- Our model enables managers to determine the extent of influence of technology cannibalization on the prior technology's adoption curve, as well as the influence of leapfrogging vs. switching on the new technology's adoption curve.
- A key generalization from this research across markets is that the percentage of leapfroggers, in the early life-cycle of the new technology, is significantly higher in developing than developed markets, and vice-versa for innovators.
- Major incumbents often fail during the takeoff of new technologies due to the under-estimation of leapfroggers (opportunity cost) or pure switchers (real cost). See Table 1 below for some examples of firm outcomes during technology transactions. Our findings and analyses suggest that the profit implications of leapfrogging, switching, and cannibalization may vary greatly on which firms market which technology.

This research provides the following implications (See Table 2 below, following the References, for a useful summary). If the incumbent firm markets the old technology and a new entrant markets the new technology, then leapfrogging and switching represent a net loss to the incumbent and a net gain to the entrant. If the incumbent firm markets both technologies and if the margin on the new exceeds the margin on the old, then switching and leapfrogging represent a net gain to the incumbent. However, if multiple firms market each technology or if margins vary, then the extent of switching, leapfrogging, and cannibalization become critical to ascertain profitability. Next, we provide details on the model, data and findings.

II. Evidence

Our proposed model extends the Jiang and Jain (2012) model of multi-generational diffusion to the context of the adoption of successive technologies that each serve the same need. Among the various multi-generational diffusion models proposed in the literature (See Table 3), the Jiang-Jain (2012) model compares favorably on multiple aspects and provides better fit (Jiang-Jain 2012), apart from being the newest published model. Thus, we use the Jiang and Jain model as the starting point. The major difference in our model is that we include a rate of disengagement from the old technology that does not equal the rate of adoption of the new technology.

Below, we (1) specify our model for the diffusion of two successive technologies, (2) discuss the critical departure from the basic model of multi-generational diffusion, i.e., we provide a more flexible model where we do not force the rate of decline from Technology 1, to exactly match the rate of increase of Technology 2, (3) illustrate the equations to decompose adoption into five adopter segments, falling into the umbrella of leapfroggers, innovators and pure switchers, and (4) specify the model for the case of three successive technologies.

The Model for Diffusion of Two Successive Technologies

We specify the proposed model for the simplest case of the diffusion over time of two successive technologies as follows. Let $S_1(t)$ and $S_2(t)$ respectively represent the penetration rates of Technologies 1 and 2 at each time period t. Then we model $S_1(t)$ and $S_2(t)$ as follows:

$$S_1(t) = m_1 F_1(t)\big(1 - F_{12}(t - \tau_2 + 1)\big) \qquad (1)$$

$$S_2(t) = F_2(t - \tau_2 + 1)\big(m_2 + m_1 F_1(t)\big) \qquad (2)$$[1]

where τ_2 corresponds to the introduction year for Technology 2 and

$$F_g(t) = \frac{p_g\left(1 - e^{-(p_g+q_g)t}\right)}{p_g + q_g e^{-(p_g+q_g)t}}, \quad t \geq 0, \ \ g = 1, 2, or\ 12 \qquad (3)$$

refers to the fraction of adoption for each technology at time t. Here g refers to a technology (rather than a generation of a technology as is typically considered in the literature on multi-generational diffusion). Our model contains eight parameters: $m_1, m_2, p_1, p_2, p_{12}, q_1, q_2$ and q_{12}. The parameter m_1 represents the long-run penetration potential for Technology 1, *if Technology 2 had never been introduced*. Put another way, prior to the introduction of Technology 2, the penetration level for Technology 1 will converge towards m_1 but it will never reach $m_1$because for $t \geq \tau_2$, Technology 2 will start to reduce the market share of Technology 1. Thus, the new Technology 2 begins to take market share from Technology 1 on introduction. Similarly, m_2 represents the *additional* market share for Technology 2 above that of Technology 1, so our model assumes that the long-run penetration for Technology 2 will equal $m_1 + m_2$. The

[1]Note we have added the 1 in Equations 1 and 2 to account for the fact that we are only considering whole years.

parameters $p_1$and p_2 are the *coefficients of innovation* for Technologies 1 and 2 respectively, while $q_1$and q_2 are the *coefficients of imitation* for Technologies 1 and 2 respectively. p_{12} and q_{12} can then be thought of as the coefficients of disengagement. Thus, F_1 describes the rate at which customers adopt Technology 1 prior to the introduction of Technology 2, while F_2 models the rate of adoption of Technology 2 after its introduction. Finally, F_{12} models the rate at which Technology 1 customers disengage upon the introduction of Technology 2.

Note that we make two critical departures in this specification from what is typical of multi-generational diffusion models. Typically, multi-generational diffusion models restrict $F_2 = F_{12}$. The proposed model removes such a restriction for the context of successive technologies. What is the potential advantage of modeling F_2 and F_{12} separately? Multi-generational diffusion models such as Jiang-Jain (2012) assume that the rate of disengagement by current Technology 1 customers exactly matches the rate of adoption by Technology 2 customers. However, in the case of multi-category, multi-country diffusion of *technology pairs*, this assumption is often not valid. In the case of successive technologies, across categories and countries, consumers may in fact hold both technologies simultaneously. For example, many older families have both a landline and a mobile phone. In addition, both technologies may grow simultaneously among different customer segments. Hence, one of our innovations in developing a corresponding model to fit the context of successive technologies is to allow$F_{12} < F_2$, which corresponds to people adopting Technology 2 at a faster rate than they leave Technology 1. If $F_{12} = 0$ then there is no substitution effect. When F_{12} is large, there is a large substitution effect. This is a strength of the model because we can directly measure the substitution effect rather than forcing $F_2 = F_{12}$. We carry out both in and out of sample predictive performance of the model on a large cross-country, multi-category dataset of technology pairs. The analysis indicates that the proposed model fits and predict the data on successive technologies and predicts better than the use of existing multi-generational models that force perfect substitution ($F_{12} = F_2$). We subsequently show robustness of the fit results to the use of sales rather than penetration.

Second, an important distinction from prior models is that we also do not constrain p_1= p_2 or q_1= q_2, as is typically done in multi-generation diffusion models. The constraint is suitable when the changes between the two generations are incremental, as in multi-generational diffusion models, but not when the technology is discontinuous (Mahajan and Muller 1996).

Overall, however, our model is a generalized model that can apply to both generational diffusion and technology diffusion. When the disengagement rate F_{12}=F_2, it reduces to a generational diffusion model.

Model Estimation

Let S_{ig} represent the observed yearly penetration level of Technology g at time t_i. Then estimating the eight parameters in (1), (2), and (3) can be achieved using non-linear least squares. In particular, we select $m_1, m_2, p_1, p_2, p_{12}, q_1, q_2$ and q_{12} as the values that minimize

$$\sum_{i=1}^{n} \Big(S_{i1} - m_1 F_1(t_i)\big(1 - F_{12}(t_i - \tau_2 + 1)\big)\Big)^2$$

$$+ \sum_{i=1}^{n} \Big(S_{i2} - F_2(t_i - \tau_2 + 1)\big(m_2 + m_1 F_1(t_i)\big)\Big)^2, \qquad (4)$$

where n represents the number of years of observation. We minimize (4) using the NLS function in the statistical software package R. However, a variety of non-linear least squares algorithms can be fit using standard software packages. Once the parameters have been estimated, it is a simple matter to plug the estimates back into (1) and (2) in order to predict future penetration levels for Technologies 1 and 2.

Computing Cannibalization, Leapfrogging and Switching Adoption for Two Successive Technologies

Next, we divide the adopters of Technology 2 into five major segments. *Pure switchers* (PS) are consumers in the segment who had already adopted Technology 1 but choose to replace it with Technology 2 after the latter technology is introduced. *Bold leapfroggers* (BL) adopt Technology 2, but would never have adopted Technology 1, and thus present an entirely new consumer segment for the new technology. *Doubtful leapfroggers* (DL) represent the consumer segment who would have adopted the prior technology, but had delayed the decision, and instead end up adopting the new technology. *Maven innovators* (MI) had already adopted Technology 1 but elect to adopt both technologies once Technology 2 is introduced. *Cautious innovators* (CI) represent the consumer segment who would have adopted the prior technology, but had delayed the decision, and end up adopting both technologies.

Pure switchers and doubtful leapfroggers represent a lost market for Technology 1 and thus, its cannibalization (CAN), while bold leapfroggers, and innovators represent market growth (MG). Hence, the penetration for Technology 2 at time t, $S_2(t)$, is composed of the sum of pure switchers, leapfroggers and innovators, i.e.,

$$S_2(t) = MG_2(t) + CAN_2(t) = \underbrace{BL_2(t) + MI_2(t) + CI_2(t)}_{Market\ Growth} + \underbrace{PS_2(t) + DL_2(t)}_{Cannibalization} \quad (5)$$

Similarly, the penetration for Technology 1 at time t, $S_1(t)$, is composed of the initial market for this technology (BL_1) less cannibalization from Technology 2, i.e.,

$$S_1(t) = BL_1(t) - CAN_2(t) = BL_1(t) - \underbrace{(PS_2(t) + DL_2(t))}_{Cannibalization} \quad (6)$$

We define the various consumer segments as follows:

$$BL_1(t) = m_1 F_1(t),\ BL_2(t) = m_2 F_2(t - \tau_2 + 1) \quad (7)$$

$$PS_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_1(\theta - 1)\big(F_{12}(\theta - \tau_2 + 1) - F_{12}(\theta - \tau_2)\big) \quad (8)$$

$$DL_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_{12}(\theta - \tau_2 + 1)\big(F_1(\theta) - F_1(\theta - 1)\big) \quad (9)$$

$$MI_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_1(\theta - 1)\left(\tilde{F}_2(\theta - \tau_2 + 1) - \tilde{F}_2(\theta - \tau_2)\right) \quad (10)$$

$$CI_2(t) = m_1 \sum_{\theta=\tau_2}^{t} \tilde{F}_2(\theta - \tau_2 + 1)\big(F_1(\theta) - F_1(\theta - 1)\big) \quad (11)$$

where $\tilde{F}_2(t) = F_2(t) - F_{12}(t)$.

See Technical Appendix A before the references for the intuition for these definitions. Technical Appendix B provides details about estimation and extraction of the sizes of the segments over time for three successive technologies.

Model Benefits

In sum, the proposed model allows us to extract the sizes of adopter segments, specifically, bold leapfroggers, doubtful leapfroggers, maven innovators, cautious innovators and pure switchers for each year and technology pair in each country, using the above equations. Our model has several additional desirable characteristics. First, the model parameters have natural interpretations. For example, F_g corresponds to the rate that individuals would adopt technology g in the absence of any competing technologies, while $F_{g-1,g}$ represents the rate that individuals disengage from technology g-1 in order to adopt technology g. Second, by setting $F_{g-1,g} = F_g$ our model reduces to that of Jiang and Jain (2012) so their model can be seen as a special, but more restrictive version of our approach. Our empirical results suggest that our model provides a significantly more accurate fit to the data. Third, we can estimate the level of market growth and cannibalization associated with each new technology. Market growth generated by a particular technology can be easily computed as the sum of BL, MI and CI above, while cannibalization can be computed as the sum of PS and DL (See Technical appendices below for the equations). Note that cannibalization includes pure switching and doubtful leapfrogging but not bold leapfrogging or innovators because the former quantities subtract from the old technologies market while the latter quantities correspond to a net increase in the market. Fourth, we do not place any restriction on the size of adopter segments. Thus, market growth can be positive or negative. The latter case occurs when the total market size actually declines with the introduction of a new technology, possibly indicating disruption by yet another technology. While not the norm, our empirical results suggest that market growth can at times be negative when a newer technology emerges for which we do not have data. The next section examines the results from the empirical applications of the model and key findings from our research.

Data

To test the fit of the model and applicability of data to the diffusion of technology pairs, we use three sets of rich, time-series, cross-country data on technological succession. First, we assembled a large, historical, yearly, time-series data-set on the market penetration of multiple technology pairs (seven pairs of old-new technologies) spanning 105 countries (441 technology pair-country combinations). These technology pairs represent both historic and contemporary successive technologies across video and communications categories (Telephone-Mobile phone, Dial-up Internet-Broadband, Black and white TV-Color TV, VCR-DVD player/recorder, DVD player-Blu Ray player, Personal computer-Laptop, and Laptop-Tablet) for which we were able to collect market penetration data over time.

To test the fit of the model and applicability of data to the diffusion of technology triplets, we use time-series penetration data on two *technology triplets*, across 45 countries, for the period 1977 to 2016 for two categories: (1) Computers and peripherals, comprising of Personal computers – Laptops – Tablet and (2) Home video comprising of VCRs – DVD players – Blu Ray players. As such, this represents the largest database covering the penetration of *triplets of contemporaneous* consumer technologies. The model exhibits good fit to the case of the data on technology triplets.

Finally, to address the question - does the model fit sales data well, we assemble a cross-country database of sales of contemporaneous technologies. We were able to gather data for 40 countries for the yearly sales of three contemporary technology pairs (Laptops-Tablets, DVD players-Blu Ray players, and Digital Cameras-Smartphones), with 92 product-country combinations in total for the years 1990-2017.

We compiled this data from Euromonitor Passport, a leading provider of syndicated data on industries, economies and consumers.

Key Findings

Before we present the results, we summarize the key findings from our model and its empirical applications on the data-sets that we assembled.

- The generalized model of the growth of new technologies with a separate disengagement parameter that we develop provides superior fit to data on technological succession (technology pairs or triplets) than existing multi-generational models that do not include a separate rate of disengagement. The model provides excellent fit to penetration and sales data for successive technologies. Further, an added benefit of the generalized model is that by setting $F_{g-1,g} = F_g$ our model reduces to a model of multi-generational diffusion. This model can be estimated using R or similar software packages.

- Second, the generalized model estimates the sizes of five segments of adopters of successive technologies over time from the commercialization of a new successive technology: bold and doubtful leapfroggers, maven and cautious innovators and pure switchers. Thus, the model allows us to estimate the extent of cannibalization of the prior technology's adoption curve, as well as the influence of leapfrogging vs. switching on the new technology's adoption curve. In general, we find that the composition of the five segments varies by technology, across markets, and even across successive technologies that serve the same basic need.
- For marketers interested in cross-country analyses, the key generalization is that we find the percentage of leapfroggers to a new successive technology, in the early life-cycle of the new technology, is significantly higher in developing than developed markets, and vice-versa for innovators. Specifically, bold leapfroggers form a dominant component of adoption in the early life cycle of a new technology in developing markets, compared to other segments. Maven innovators form a dominant component of adoption in the early life cycle of a new technology in developed markets, compared to other segments.
- Major incumbents often fail during the takeoff of new technologies due to the under-estimation of leapfroggers (opportunity cost) or pure switchers (real cost). Our model and analysis provides a better strategic understanding of how adopter segments for a newer

technology may drive sales to marketers. Such analyses can prevent disruption on the emergence of a new technology.

We present evidence for each of these key findings below.

Model Fit

Recall that our first research question was: does a model of diffusion of successive technologies fit data for technological succession better than one for multiple generations of one technology? Overall, the proposed model fits the penetration data on technology pairs and technology triplets, and sales data for the three technology pairs very well. Please see Technical Appendix C for a discussion of fit statistics.

Estimation of Sizes of Consumer Segments

Our model allows us to decompose adoption data for technology pairs into the five constituent adopter segments. In this section, we will briefly describe the results of decomposition. First, let us examine how the decomposition works for Technology 1, Technology 2 and the overall market. Consider the example of the decomposition results from our model for the telephone-mobile phone technology transition in India, using our model, presented in Figure 3 below, following the references section. Panel 1 shows the projected adoption BL1 of Technology 1, the old technology (i.e., India-Telephone) if the new technology (mobile phone) were absent. Panel 1 also shows the effect of cannibalization from technology 2 (BL1 – cannibalization due to pure switchers + doubtful leapfroggers), which is represented by S1, the estimated adoption curve for technology 1. We can see the size of the switchers and doubtful leapfroggers increasing over time. Panel 2 shows the breakdown of the adoption curve (S2) for Technology 2 (mobile phone in India) into bold leapfroggers, pure switchers, doubtful leapfroggers, maven innovators, and cautious innovators. Panel 3 shows the evolution of the overall market (S1+S2) due to market growth from technology 2 (bold leapfroggers + innovators) compared to the market in the presence of only Technology 1 (BL1). All figures are plotted over the lifetime of available data for Technology 1. In this example, the adoption of Technology 2 (Mobile phone) was dominated by bold leapfroggers initially, followed by cannibalization. That is, the mobile phone initially attracted an entirely new market of consumers. Figure 4 below similarly shows the decomposition of adoption curves of telephone technologies in another country - Kenya, into adopter segments.

Figure 5 below shows the decomposition of successive technology curves into adopter segments and their sizes over time, using our model using sales data for select countries for three newer categories. In Vietnam, the sales of laptops were cannibalized by a growing percentage of switchers and doubtful leapfroggers (and we can estimate the size of this cannibalization over time) to tablets. However, the growth of Tablets was also fueled by an entirely new market of adopters- the bold leapfroggers. Both technologies however were sustained by the presence of the maven and cautious innovators who end up holding both technologies, and thus the sales decline for laptops is not as steep as it might have been otherwise. Similarly, we can observe decompositions for smartphones/digital cameras in Italy and Blu ray/DVD players for Malaysia.

Do the Adopter Segment Decompositions for Technology Pairs Vary by Category?

Next, we present the decomposition results, based on our model, at 10 years from the commercialization of the new technology, across the 441 technology pair-country combinations, indicate that adopter segments vary by category and country. Figure 6 below presents the average size of the three most dominant adopter segments (bold leapfroggers, maven innovators and pure switchers) across categories. Notice, for the transition from Dial-up to Broadband, on average across countries, pure switchers form the dominant category in terms of market penetration (8%), followed by bold leapfroggers (6%), rather than maven innovators. In terms of validity, these results make sense as most adopters are unlikely to hold both dial-up and broadband.

Further, our results indicate that on average, growth of Technology 2 derived from *cannibalization* of Technology 1 due to pure switchers and doubtful leapfroggers is greater than from *market growth* due to bold leapfroggers and cautious and maven innovators for the Blu Ray and Broadband markets. On the other hand, market growth is greater than cannibalization for the other technology pairs, indicating that the effects of leapfrogging, switching and cannibalization across technologies varies across categories.

We also have preliminary evidence that adopter segments may vary across successive technologies serving the same need. Figure 6 below provides a contrast of adopter segments between the VCR-DVD player transition (dominated by maven innovators) and DVD player-Blu Ray player transition (dominated by pure switchers) as of year 10 after new technology commercialization.

More specifically, looking at individual countries, we also see further evidence for example, in the case of the transition from PC to Laptops in the USA, where maven innovators comprised the major adopter segment for laptops. However, in the case of the transition from laptops to tablets in the US, bold leapfroggers dominate the adoption of tablets, suggesting that the tablets were predominantly attracting an entirely new adopter segment to the market, compared to the laptop. These preliminary findings lead to the following proposition:

P1: The effects of leapfrogging, switching and cannibalization vary across categories as well as across successive technologies serving the same need.

How does the Decomposition Vary across Developing and Developed Countries?

We use the analytical classification provided by the World Bank that we gather from various historical reports since income classifications are rigorous and contemporaneous. We refer to low and low-middle income countries as developing, and middle and high-income countries as developed. We present the following results using data from 323 technology pair-country combinations, where we were able to identify the country income classification as of year 10 from new technology commercialization. Figure 7 below examines the mean percentage of leapfroggers across categories in low-income countries versus upper-income versus high-income countries, and similarly for innovators and switchers. On average, the percentage of leapfroggers, especially bold leapfroggers is significantly higher in low-income compared to upper-middle and high-income countries. In contrast, the percentage of innovators is significantly higher in high-income versus low-income countries.

Figures 7a and 7b below provide a specific illustration of this finding in the case of the telephone-mobile phone transition for USA versus India, where bold leapfroggers dominate in India (the green dashed line) and maven innovators dominate in the USA (purple dashed line).

A key empirical generalization from our analysis is that:

P2: *Developing countries exhibit a higher percentage of leapfrogging adoption than developed countries in the early life cycle of the new technology. Developed countries, in contrast exhibit a higher percentage of adoption by innovators than developing countries in the early life cycle of the new technology.*

How do Adopter Segments Contribute to Cannibalization and Disruption of Incumbents?

When technological change occurs, incumbent firms marketing the old technology may fail or lose much market share. We provide evidence for this assertion applying our model to sales data from the U.S. market to examine four practical cases: the decline and bankruptcy of Kodak with the rise of digital photography, the fall of Nikon, Canon and Sony with the rise of smartphones, the decline and split of HP with the rise of tablets, and the success of Sony with the rise of DVD technology. We hypothesize that what happens in the U.S. repeats itself round the world, but we do not have data to test that hypothesis.

Digital versus analog photography. Let us consider the examples we presented in the introduction. Eastman Kodak dominated the market for analog cameras. However, it failed to capitalize on its patents in digital photography and eventually lost substantial market share after Digital photography took off in 1999. Figure 8 shows the decomposition of sales using our model in corresponding periods (1994-2013) once the digital camera took off. The figure shows the predicted sales of analog cameras (Technology 1) and the decomposition of predicted sales of digital cameras (Technology 2) in the U.S. The solid blue line shows the decline in sales of analog cameras as digital photography took off. The dotted blue line shows the predicted sales of analog cameras, if the digital camera were not introduced. Which adopter segments of digital cameras contributed to the decline for analog cameras? The decomposition shows that analog camera sales are cannibalized primarily by the growth in pure switchers to digital cameras (solid red line). Other segments, such as bold leapfroggers, also contributed to the growth of digital cameras (green line). In not promptly embracing digital photography, Kodak may have underestimated the real cost of lost sales from pure switchers (red line) and the opportunity cost of lost sales from bold leapfroggers (green line). While prior research examines cultural factors that determine willingness to cannibalize (e.g. Chandy and Tellis 1998), our research decomposes the adopter segments that accounts for such cannibalization. Managers may use the model and such analyses, predicting several years into the future to plan proactively and avoid disruption when a new technology emerges.

Smartphones versus digital photography. Likewise, digital camera incumbents like Nikon, Canon, and Sony may have also underestimated the pure switchers and bold leapfroggers to smartphones. Figure 9 below (following references) shows the decomposition of sales for the U.S. photography market after the introduction of smartphones using our model. It indicates that the sales of the older technology - digital cameras (blue line) suffered due to an increase in the number of pure switchers (red line) from digital cameras to the newer technology - smartphones. In this case, the primary segment for smartphones is bold leapfroggers (green line) and only secondarily pure switchers, who used smart phones for photography.

Tablets versus laptops. Consider the example of tablets that we also mentioned in the introduction. Figure 10 below (following references) shows the decomposition of tablet sales based on our model (Tech 2). In this case, tablet sales are fueled primarily by bold leapfroggers (green line), who adopt tablets without having adopted PCs and laptops. However, pure switchers (red line) from laptops (or PCs) to tablets and maven innovators (orange line) are also major influencers or tablet sales. Apple gained by attracting maven innovators who wanted to use both technologies, while also capturing an entirely new adopter segment base, bold leapfroggers.

DVD players versus VCRs. In contrast, let us examine the technology transition in the DVD player market. Figure 11 shows the decomposition of sales of VCRs as and after DVD players take off using our model. The sales of DVD players is fueled in the initial years by maven innovators (orange line), who hold both technologies, followed subsequently in time by pure switchers (red line). Because maven innovators buy and use both technologies, the VCR market is initially on “neutral zone” with a slow sales decline between 1996 and 2000 (See Figure 11, blue line). The VCR market begins a steep decline from 2001 once pure switchers to DVD players take off, cannibalizing VCR sales.

In this industry, Sony dominated the market for VCRs and introduced and dominated the market for DVD players. The presence of maven innovators (orange) may have provided Sony with breathing room to make the transition to DVD players before it cannibalized the VCR market.

In sum, our findings from the analysis of sales data on technology pairs suggest that:

P3: Failure of incumbents during technological change may be due to a failure to understand and properly estimate cannibalization of the older technology products by pure switchers and growth of new technology products from leapfroggers.

III. Conclusions and Strategic Implications

Our findings and analyses suggest that the profit implications of leapfrogging, switching, and cannibalization may vary greatly on which firms market which technology. The major strategic implications from the above sets of analysis are the following (also see Table 2):

- Our analysis shows which of various segments cause the most gains to marketers of the new technology and the losses to the old: pure switchers cause cannibalization of the old technology while maven innovators and bold leapfroggers contribute to market growth from the new technology.

- Bold leapfroggers are only an opportunity loss for incumbents but pure switchers are a real loss to incumbents.
- All segments represent a real gain for entrants. For the entrant introducing the new technology (Apple in tablets), the takeoff of the new technology is always a win.
- For the incumbent, not introducing the new technology (Kodak, HP), the takeoff of the new technology is always a loss. Particularly, if the incumbent firm markets the old technology and a new entrant markets the new technology, then leapfrogging and switching represent a net loss to the incumbent and a net gain to the entrant.
- For the incumbent introducing the new technology (Sony in DVD players), the takeoff of the new technology is a win if competitors would have introduced it or if the new technology has a higher margin than the old technology.
- If the incumbent firm markets both technologies and if the margin on the new exceeds the margin on the old, then switching and leapfrogging represent a net gain to the incumbent. However, if multiple firms market each technology or if margins vary, then the rate of switching, leapfrogging, and cannibalization become critical to ascertain profitability.
- Senior managers of strategy and managers of new products should be careful not to underestimate cannibalization by pure switchers and market growth via maven innovators (especially in developed countries) or bold leapfroggers (especially in developing countries). Managers should target their marketing efforts appropriately to these consumer segments in these countries.

Limitations and Future Directions

This study suffers from several limitations primarily due to the limitations of collecting historical data across so many countries. First, we used aggregate data for the purpose of testing the model and getting rich insights about adopter segments across countries, categories and over time. Future research could replicate these analyses with disaggregate data. Second, future analysis would need to complement these data sets with surveys of the adopter types to determine the characteristics of adopters. It may seem at first blush that age or generational cohorts (millennials, etc.), level and variety of use of a technology, exposure to prior technology and income may be determinants of which adopter segment a consumer may be classified as. However, this determination would require an entirely new study and data. All these remain fruitful areas of future research and managerial collaboration.

Technical Appendices

Technical Appendix A: Intuition behind Derivations of the Five Segments

Our generalized model of the diffusion of successive technologies helps estimate the size of five adopter segments as defined earlier and in Table 2. We define the various consumer segments as follows:

$$BL_1(t) = m_1 F_1(t),\ BL_2(t) = m_2 F_2(t - \tau_2 + 1) \tag{7}$$

$$PS_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_1(\theta - 1)\big(F_{12}(\theta - \tau_2 + 1) - F_{12}(\theta - \tau_2)\big) \tag{8}$$

$$DL_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_{12}(\theta - \tau_2 + 1)\big(F_1(\theta) - F_1(\theta - 1)\big) \tag{9}$$

$$MI_2(t) = m_1 \sum_{\theta=\tau_2}^{t} F_1(\theta - 1)\left(\tilde{F}_2(\theta - \tau_2 + 1) - \tilde{F}_2(\theta - \tau_2)\right) \tag{10}$$

$$CI_2(t) = m_1 \sum_{\theta=\tau_2}^{t} \tilde{F}_2(\theta - \tau_2 + 1)\big(F_1(\theta) - F_1(\theta - 1)\big) \tag{11}$$

where $\tilde{F}_2(t) = F_2(t) - F_{12}(t)$.

To provide some intuition on these definitions, first consider $BL_2(t)$. Recall that m_2 represents the total potential additional market for Technology 2 above that of Technology 1, while F_2 provides the fraction of potential customers who have actually adopted the new technology. Hence, $BL_2(t)$ corresponds to the total number of additional Technology 2 adopters who would never have adopted Technology 1. Next consider $DL_2(t)$ and $CI_2(t)$. Note that $m_1(F_1(\theta) - F_1(\theta - 1))$ represents the number of customers who would be expected to adopt Technology 1 in time period θ. However, F_{12} of these customers switch directly to Technology 2, while $\tilde{F}_2 = F_2 - F_{12}$ customers purchase both technologies. Hence, summing from τ_2 up to t gives the total number of doubtful leapfroggers (Equation 9) and cautious innovators (Equation 11).

Finally, the pure switchers and maven innovators correspond to the remaining adopters of Technology 2, which can be shown to correspond to Equations (8) and (10). At $\theta = \tau_2$ these equations are fairly intuitive because $m_1 F_1(\tau_2 - 1)$ represents the current number of Technology 1 adopters and $F_{12}(t)$ represents the fraction of potential customers who drop Technology 1 to adopt Technology 2 in period $\theta = \tau_2$. Similarly $\tilde{F}_2(1) = F_2(1) - F_{12}(1)$ represents the fraction of potential customers who keep Technology 1 and adopt Technology 2 in period $\theta = \tau_2$. Hence, (8) and (10) assume current customers of Technology 1 switch to Technology 2 at the same rate as non-customers of Technology 1. However, for $\theta > \tau_2$ the intuition becomes more complicated since the number of Technology 1 customers will be less than $m_1 F_1(t-1)$ as a result of prior switching.

Technical Appendix B: The Model for the Diffusion of Technology Triplets

In markets characterized by excessive turbulence, a third technology is often introduced in quick succession to the second technology. We can extend our model to account for $G \geq 2$ different technologies, $S_1(t), S_2(t), \ldots, S_G(t)$ as follows:

$$S_g(t) = \left(m_g + H_g(t)\right) F_g\left(t - \tau_g + 1\right)\left(1 - F_{g,g+1}(t - \tau_{g+1} + 1)\right), \quad g < G \tag{12}$$

$$S_G(t) = \left(m_G + H_G(t)\right) F_G(t - \tau_G + 1), \tag{13}$$

where $H_g(t) = \sum_{k=1}^{g-1} m_k \prod_{l=k}^{g-1} F_l(t - \tau_l + 1)$ for $g > 1$ and $H_1(t) = 0$.

Here, successive technologies cannibalize the market of earlier technologies. If we set G=2 we get $H_2(t) = m_1 F_1(t)$ so (12) and (13) reduce exactly to our two-technology model given by (1) and (2)[2]. In the $G = 3$ technology case (12) and (13) reduce to

$$S_1(t) = m_1 F_1(t)\big(1 - F_{12}(t - \tau_2 + 1)\big) \tag{14}$$

$$S_2(t) = \big(m_2 + m_1 F_1(t)\big)F_2(t - \tau_2 + 1)\big(1 - F_{23}(t - \tau_3 + 1)\big) \tag{15}$$

$$S_3(t) = \big(m_3 + m_2 F_2(t - \tau_2 + 1) + m_1 F_1(t) F_2(t - \tau_2 + 1)\big)F_3(t - \tau_3 + 1). \tag{16}$$

Analogously, we can decompose $S_g(t)$ into

$$S_g(t) = \underbrace{BL_g(t) + MI_g(t) + CI_g(t)}_{Market\ Growth\ of\ Tech\ g} + \underbrace{PS_g(t) + DL_g(t)}_{Cannibalization\ by\ Tech\ g} - \underbrace{(PS_{g+1}(t) + DL_{g+1}(t))}_{Cannibalization\ by\ Tech\ g+1} \tag{17}$$

where

$$BL_g(t) = m_g F_g\big(t - \tau_g + 1\big) \tag{18}$$

$$PS_g(t) = \textstyle\sum_{\theta=\tau_g}^{t} H_g(\theta - 1)\left(F_{g-1,g}\big(\theta - \tau_g + 1\big) - F_{g-1,g}\big(\theta - \tau_g\big)\right) \tag{19}$$

$$DL_g(t) = \textstyle\sum_{\theta=\tau_g}^{t} F_{g-1,g}\big(\theta - \tau_g + 1\big)\left(H_g(\theta) - H_g(\theta - 1)\right) \tag{20}$$

$$MI_g(t) = \textstyle\sum_{\theta=\tau_g}^{t} H_g(\theta - 1)\left(\tilde{F}_g\big(\theta - \tau_g + 1\big) - \tilde{F}_g\big(\theta - \tau_g\big)\right) \tag{21}$$

$$CI_g(t) = \textstyle\sum_{\theta=\tau_g}^{t} \tilde{F}_g\big(\theta - \tau_g + 1\big)\left(H_g(\theta) - H_g(\theta - 1)\right) \tag{22}$$

$$CAN_g(t) = PS_g(t) + DL_g(t) \tag{23}$$

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[2] Note $\tau_1 = 1$ by definition.

and $\tilde{F}_g(t) = F_g(t) - F_{g-1,g}(t)$. (24)

For $G = 3$ technologies this reduces to

$$S_1(t) = BL_1(t) - CAN_2(t) = BL_1(t) - \underbrace{\left(PS_2(t) + DL_2(t)\right)}_{Cannibalization\ by\ Tech\ 2} \quad (25)$$

$$\begin{aligned} S_2(t) &= MG_2(t) + CAN_2(t) - CAN_3(t) \\ &= \underbrace{BL_2(t) + MI_2(t) + CI_2(t)}_{Market\ Growth\ of\ Tech\ 2} + \underbrace{PS_2(t) + DL_2(t)}_{Cannibalization\ by\ Tech\ 2} \\ &- \underbrace{\left(PS_3(t) + DL_3(t)\right)}_{Cannibalization\ by\ Tech\ 3} \end{aligned} \quad (26)$$

$$\begin{aligned} S_3(t) &= MG_3(t) + CAN_3(t) \\ &= \underbrace{BL_3(t) + MI_3(t) + CI_3(t)}_{Market\ Growth\ of\ Tech\ 3} + \underbrace{PS_3(t) + DL_3(t)}_{Cannibalization\ by\ Tech\ 3} \end{aligned} \quad (27)$$

Technical Appendix C: Model Fit

Appendix Table A1 below presents comparisons on the penetration data using both mean-squared and median-squared errors of our proposed model for four technology pairs with the separate disengagement parameter, compared to the reduced form model using the simplifying assumption $F_2 = F_{12}$, such as in multi-generational diffusion models (for example Jiang-Jain 2012). Our proposed model gets much smaller error rates than the latter model applied to the same technology data. The mean errors in the *training*, or in sample data, are based on excluding the last time point for each curve, fitting each of the two competing models to the remaining time points and calculating the mean of squared errors between the observed and predicted points for each technology pair across countries. Since our model has an extra parameter, we would expect that our model fits, in sample, better than the model without the disengagement parameter. In contrast, the *test*, or out of sample, results are also based on excluding the last time point from each curve and fitting the models to the remaining time points. However, now the mean squared error is calculated using the squared difference between the final year's observed and predicted points and calculating the overall average error across countries, for each technology pair. Overall, our model fits much better out of sample as well, which is the true test for better performance of our model. The median error rate refers to the in-sample and out-of- sample error rate across the different countries, using the median instead of the mean, to account for the fact that some countries may greatly influence the averages.[3]

Does the improvement in fit come from old or new technologies? The results in Appendix Table A1 further break down the results into older and newer technologies as well as the average error across both technologies. Our proposed model with the separate disengagement parameter that varies across countries and categories performs better than a model without such a parameter on the statistical criteria across the four technology pairs.

Similarly, we calculate fit statistics for the *sales* data for the three contemporary technology pairs (laptop-tablet, DVD player-Blu ray players, digital cameras- smartphones), by technology as well as overall, for both technologies. Again, our model fits the data well. Figures A1 and A2 present sample fit plots for selected technology pairs based on the sales curves, as well as, what is most relevant to managers- how the overall curves can be decomposed into adopter segments.

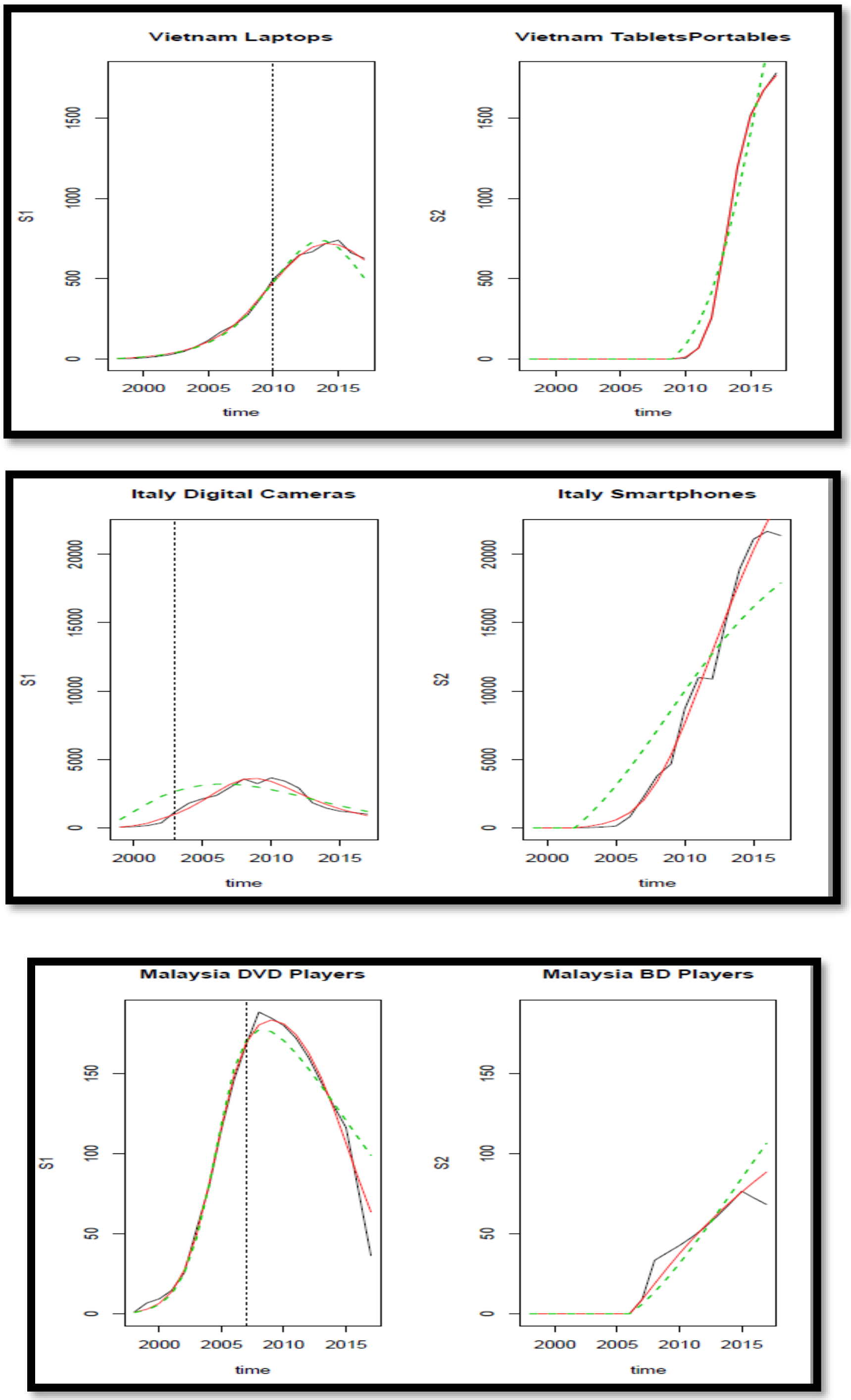
[3] All the raw numbers for this analysis were standardized using the largest observed penetration level within each country to provide for a valid comparison across countries.

Table A1:

IN AND OUT SAMPLE FIT STATISTICS FOR TECHNOLOGY PAIRS USING PENETRATION DATA

Training Errors on Model without Disengagement Parameter							
Tech 1	Tech 2	Tech 1 Mean	Tech 2 Mean	Overall Mean	Tech 1 Median	Tech 2 Median	Overall Median
Laptop	Tablet	0.0043	0.0009	0.0026	0.0006	0.0001	0.0003
PC	Laptop	0.0123	0.0016	0.0070	0.0018	0.0003	0.0010
DVD Player	Blu ray	0.0015	0.0001	0.0008	0.0004	0.0000	0.0002
VCR	DVD Player	0.0032	0.0082	0.0057	0.0012	0.0056	0.0018
Test Errors on Model without Disengagement Parameter							
Tech 1	Tech 2	Tech 1 Mean	Tech 2 Mean	Overall Mean	Tech 1 Median	Tech 2 Median	Overall Median
Laptop	Tablet	0.0324	0.0134	0.0229	0.0030	0.0012	0.0023
PC	Laptop	0.0390	0.0131	0.0260	0.0031	0.0017	0.0025
DVD Player	Blu ray	0.0491	0.0073	0.0282	0.0013	0.0034	0.0020
VCR	DVD Player	0.0096	0.1223	0.0659	0.0025	0.0567	0.0089
Training Errors on *Our* Method with a Separate Disengagement Parameter							
Tech 1	Tech 2	Tech 1 Mean	Tech 2 Mean	Overall Mean	Tech 1 Median	Tech 2 Median	Overall Median
Laptop	Tablet	0.0014	0.0002	0.0008	0.0003	0.0000	0.0001
PC	Laptop	0.0024	0.0004	0.0014	0.0013	0.0000	0.0005
DVD Player	Blu ray	0.0011	0.0000	0.0006	0.0004	0.0000	0.0001
VCR	DVD Player	0.0008	0.0014	0.0011	0.0004	0.0005	0.0005
Test Errors on *Our* Method with a Separate Disengagement Parameter							
Tech 1	Tech 2	Tech 1 Mean	Tech 2 Mean	Overall Mean	Tech 1 Median	Tech 2 Median	Overall Median
Laptop	Tablet	0.0072	0.0017	0.0045	0.0012	0.0001	0.0003
PC	Laptop	0.0084	0.0035	0.0059	0.0012	0.0003	0.0007
DVD Player	Blu ray	0.0530	0.0033	0.0281	0.0023	0.0009	0.0014
VCR	DVD Player	0.0027	0.0622	0.0325	0.0006	0.0053	0.0015

Figure A1: Sample Fit Plots for New Technology Pairs (Sales Curves)



Notes: Displayed above are the fit plots for sample technology pairs. The black lines are the real data, red line is plotted using our model with a separate disengagement parameter and the green dashed line is without the disengagement parameter.

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Table 1

FIRM FAILURES DURING TECHNOLOGY TRANSITIONS

Old Technology	**New Technology**	**Incumbent leaders that stumbled or failed**	**Incumbents that Maintained Leadership**	**Entrants that gained**
Telephone	Mobile phone	AT&T, Verizon		Motorola, Nokia, Blackberry
Dial Up	Broadband	Earthlink, AOL, Netzero, Compuserve		Comcast, AT&T, Verizon
VCR	DVD player		Sony	
DVD player	Blu ray		Sony	
Laptop	Tablet	HP		Apple
CD player	MP3 player	Sony		Apple
Camera	Digital camera	Kodak		Canon, Nikon, Sony

Table 2

ADOPTER SEGMENTS, CONSUMER ADOPTION BEHAVIOR, FIRM AND MARKET OUTCOMES IN THE PRESENCE OF MULTIPLE TECHNOLOGIES

Adopter Segments	Consumer Adoption Behavior on the Introduction of Technology 2	Market Outcome on the Introduction of Technology 2	Firm Type: Incumbent marketing Technology 1*	Firm Type: Entrant marketing Technology 2*	Firm Type: Incumbent marketing Technology 2**
Single Technology Holders: Leapfroggers + Pure Switchers					
Bold Leapfroggers	Would never have adopted Technology 1 but adopted Technology 2	Market growth	Neutral	Win	Win
Doubtful Leapfroggers	Would have adopted Technology 1 but instead adopted Technology 2	Cannibalization	Lose	Win	Neutral
Pure Switchers	Had already adopted Technology 1 but replaced it with Technology 2	Cannibalization	Neutral/Lose***	Win	Neutral
Dual Technology Holders: Innovators					
Cautious Innovators	Would have adopted Technology 1 but end up adopting both technologies	Market growth	Neutral	Win	Win
Maven Innovators	Had already adopted Technology 1 but adopted both technologies	Market growth	Neutral	Win	Win

Notes: * Assumes that incumbent (or incumbents) dominated the market for the old technology, while entrants pioneered the new technology. **Assumes that the incumbent chooses to enter the new technology market rather than wait in the sidelines.

***Neutral for adoption/lose if sales is instead considered.

Table 3
COMPARISON TO RELATED LITERATURE ON GENERATIONAL GROWTH

Paper	Evidence base (Data)	Separate rate of Dis-engagement*	Leapfrogging phenomenon considered?
This paper	**Penetration data on 441 technology pair-country combinations (across 100+countries); Penetration data for two technology triplets across 45 countries; and Sales data for three technology pairs across 40 countries (92 product-country combinations)**	**Yes**	**Yes (Bold+Doubtful leapfroggers plus considers switchers, maven and cautious innovators)**
Jiang and Jain 2012	Two generations of 1 category in 1 country; Three generations of 1 category in 1 country	No	Yes
Stremersch et al. 2010	39 technology generations in 12 product markets	No	Assumes no leapfrogging (no upgrading beyond the subsequent generation)
Goldenberg and Oreg 2007	54 products (Not specifically successive generations)	N/A	Yes
Danaher et al. 2001	Two generations of 1 category in 1 country	No	Yes
Kim et al. 2000	One technology market in 2 countries	No	No
Jun and Park 1999	Successive generations of 2 technology categories, not multi-country	No	Not specifically
Mahajan and Muller 1996	Successive generations of 1 technology category	No	Yes
Norton and Bass 1987	Successive generations of 1 technology category	No	N/A

* From previous generations/prior technologies;

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Figure 1

KODAK STOCK PRICE AFTER THE DIGITAL CAMERA

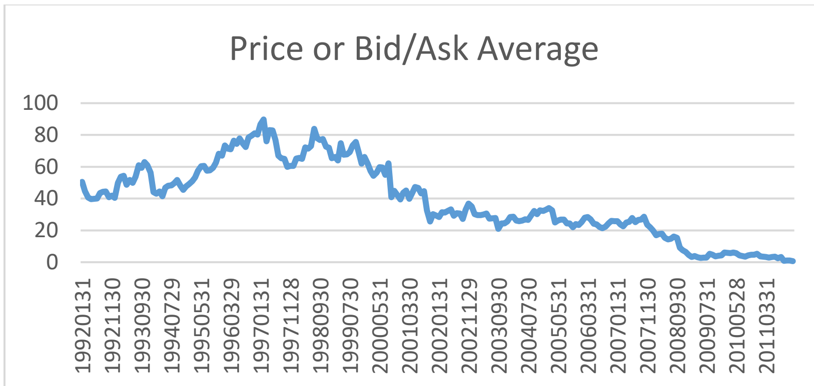


Figure 2

HP STOCK PRICE AFTER TAKEOFF OF TABLETS

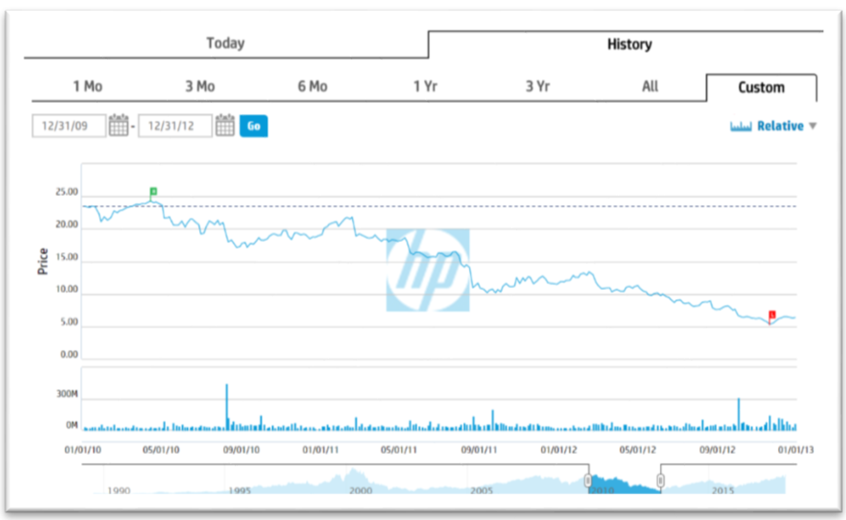
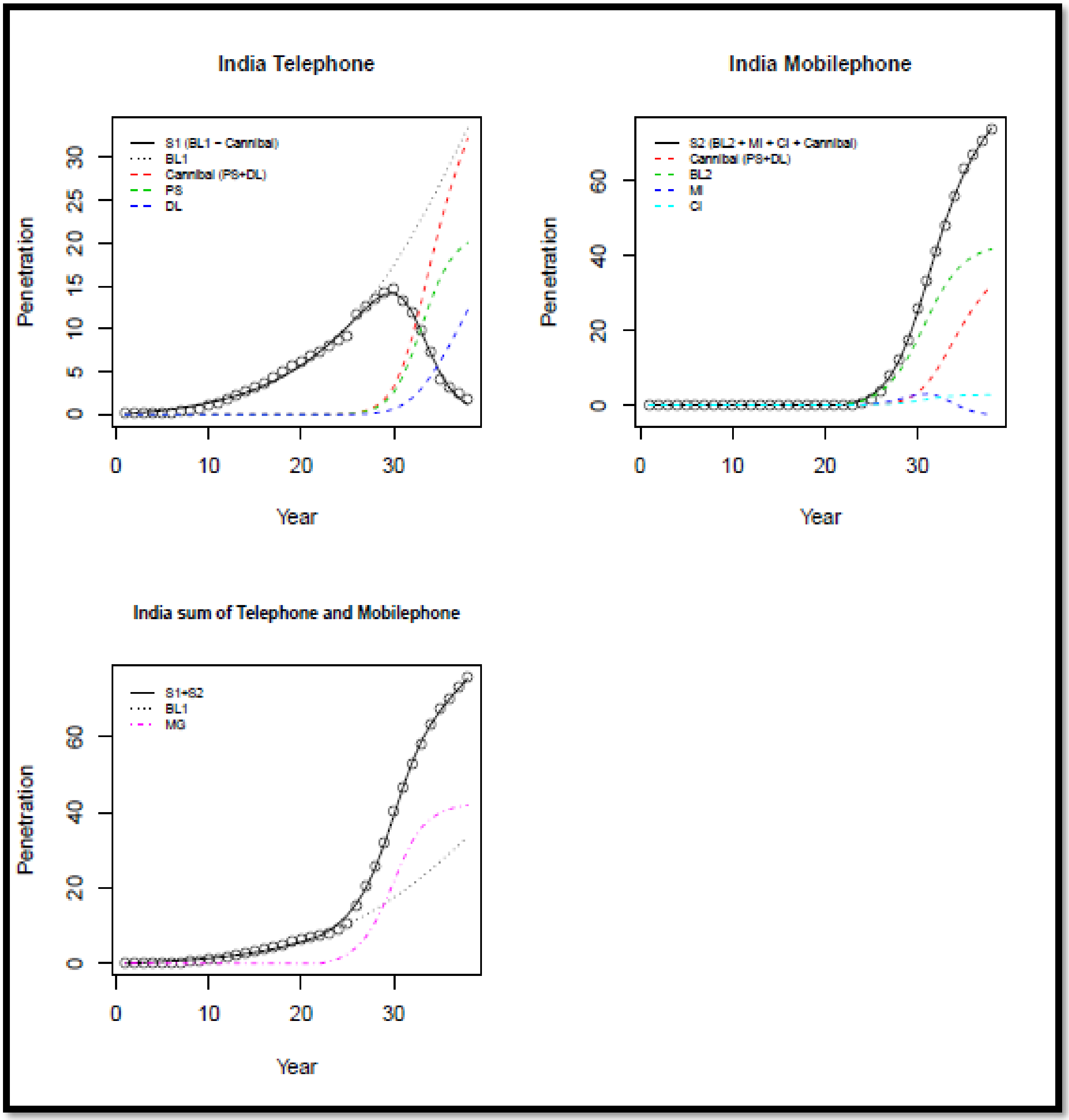


Figure 3

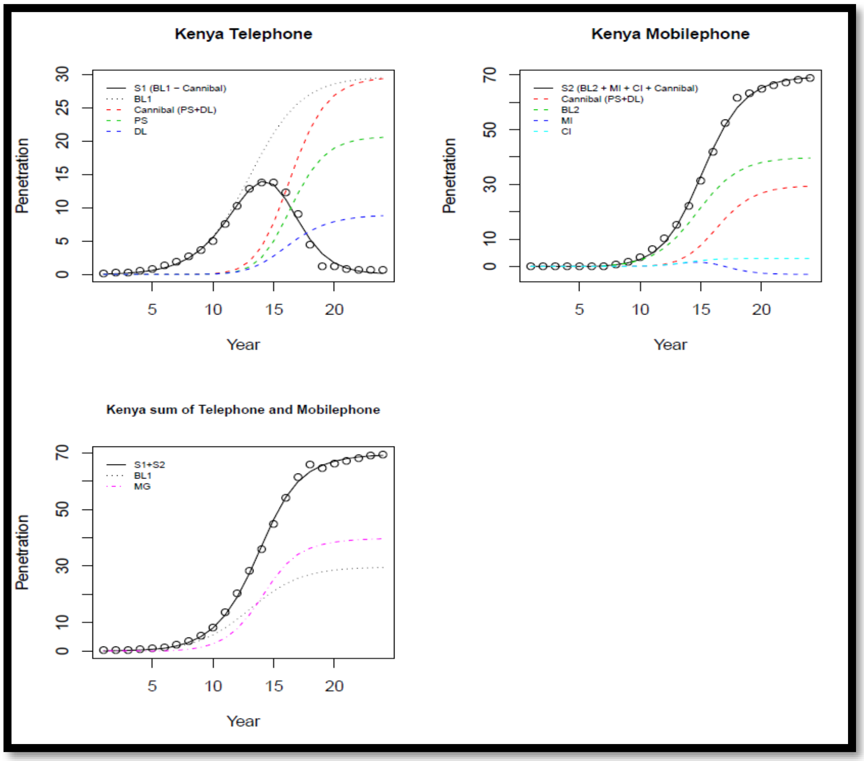
DECOMPOSITION OF SUCCESSIVE TECHNOLOGIES IN INDIA



Notes: Panel 1 shows the projected adoption BL1 of Technology 1 (India Telephone) if the new technology- mobile phone were absent. It also shows the effect after cannibalization from Technology 2 (Pure switchers + doubtful leapfroggers), which is represented by S1, the estimated adoption curve. Panel 2 shows the breakdown of the adoption curve (S2) for Technology 2 (mobile phone in India) into bold leapfroggers, pure switchers, doubtful leapfroggers, maven innovators and cautious innovators. Panel 3 shows the evolution of the overall market (S1+S2) due to market growth from Technology 2 (bold leapfroggers+ innovators) compared to the market in the presence of only technology 1 (BL1). All figures are plotted over the lifetime of available data for Technology 1.

Figure 4

DECOMPOSITION OF SUCCESSIVE TELEPHONE TECHNOLOGIES IN KENYA



Notes: Panel 1 shows the projected adoption BL1 of Technology 1 (Telephone) if the new technology- mobile phone were absent. It also shows the effect after cannibalization from Technology 2 (Pure switchers + doubtful leapfroggers), which is represented by S1, the estimated adoption curve. Panel 2 shows the breakdown of the adoption curve (S2) for Technology 2 (mobile phone) into bold leapfroggers, pure switchers, doubtful leapfroggers, maven innovators and cautious innovators. Panel 3 shows the evolution of the overall market (S1+S2) due to market growth from Technology 2 (bold leapfroggers+ innovators) compared to the market in the presence of only technology 1 (BL1). All figures are plotted over the lifetime of available data for Technology 1.

Figure 5

DECOMPOSITION FOR SELECTED TECHNOLOGY PAIRS USING SALES DATA

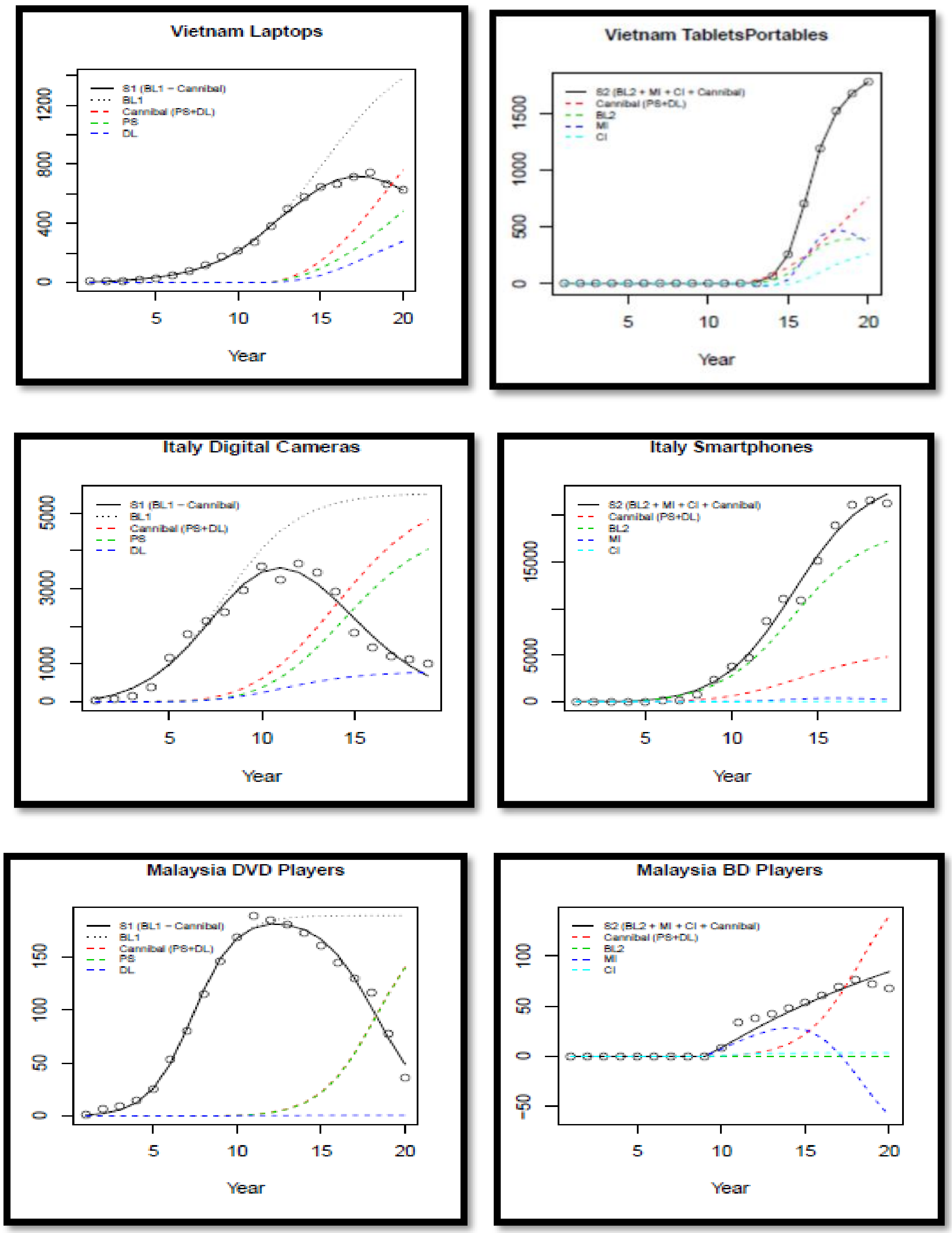


Figure 6

RESULTS FROM DECOMPOSITION BY ADOPTER SEGMENTS FOR TECHNOLOGY PAIRS

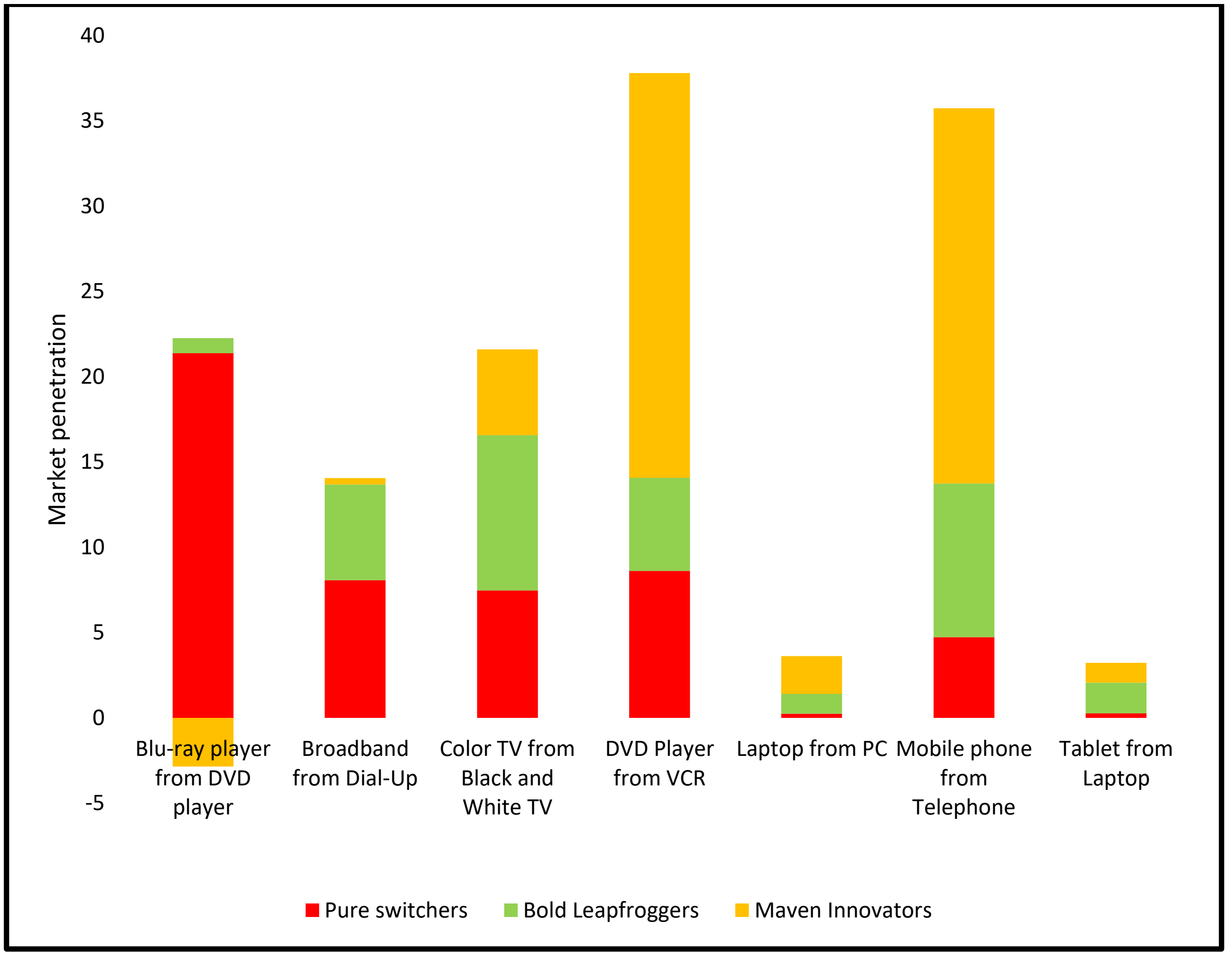
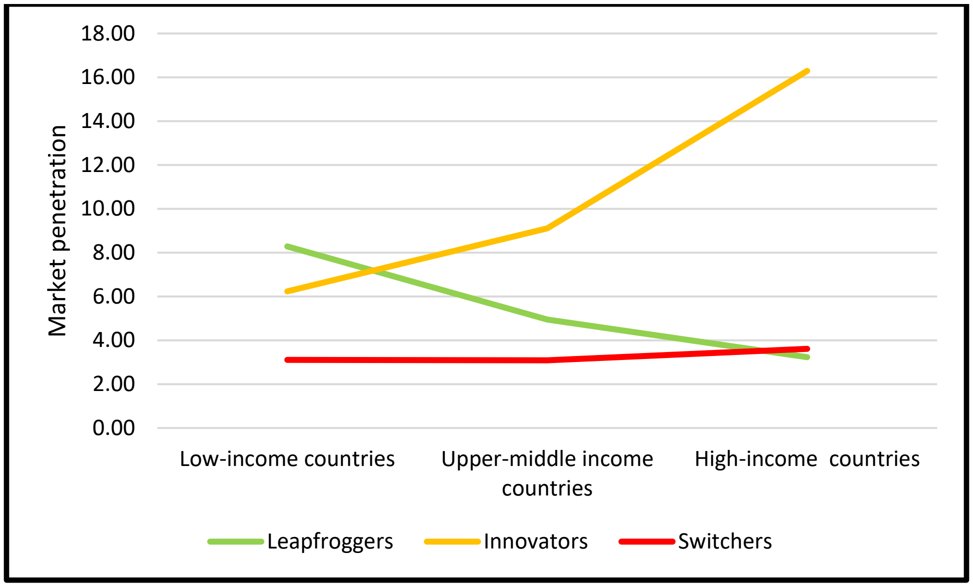


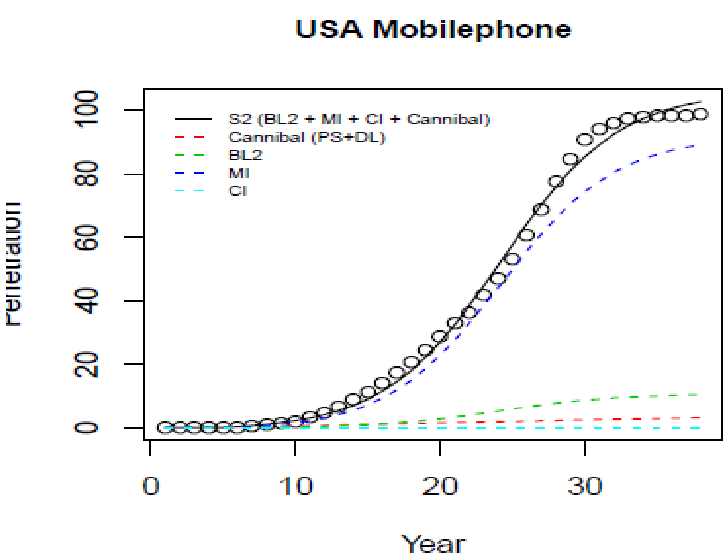
Figure 7

DECOMPOSITION ACROSS INCOME CLASSIFICATIONS OF COUNTRIES



Figures 7a and 7b

DECOMPOSITION ACROSS COUNTRIES IN DIFFERENT INCOME GROUPS FOR MOBILE PHONE



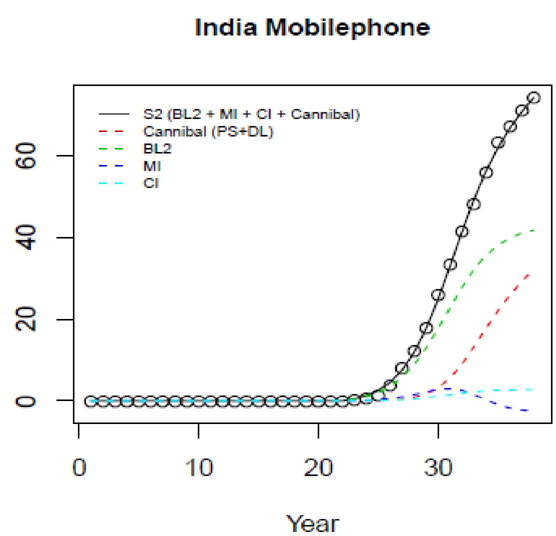


Figure 8

ANALOG-DIGITAL CAMERA SALES DECOMPOSITION IN USA

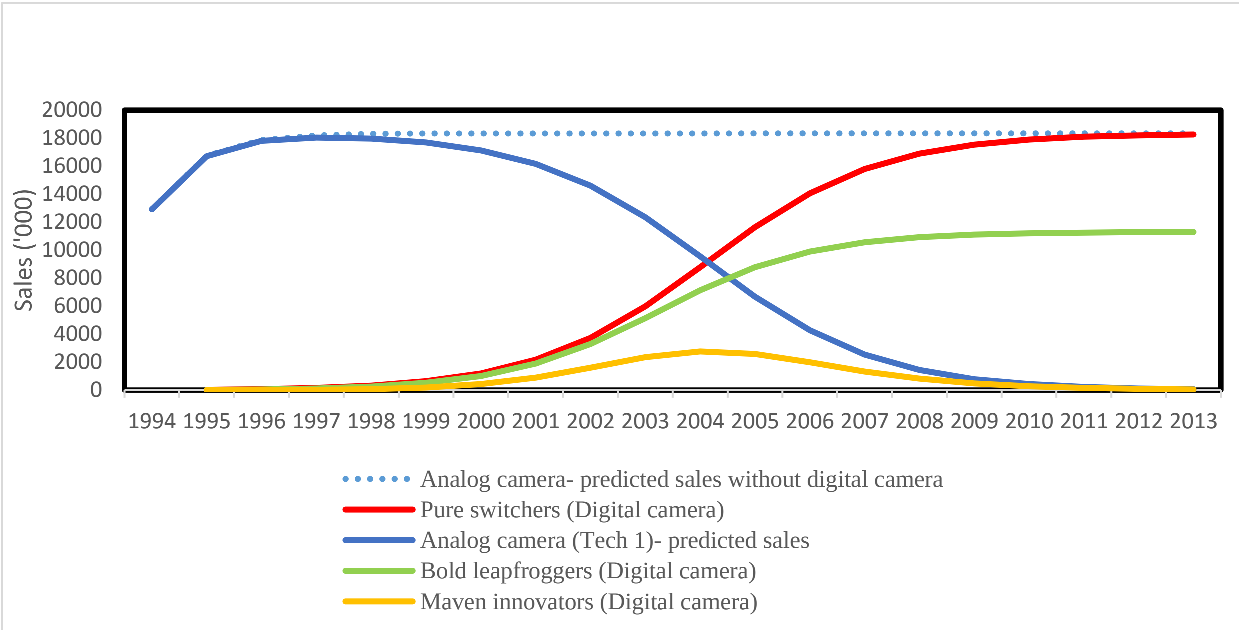


Figure 9

DIGITAL CAMERA- SMART PHONE SALES DECOMPOSITION IN USA

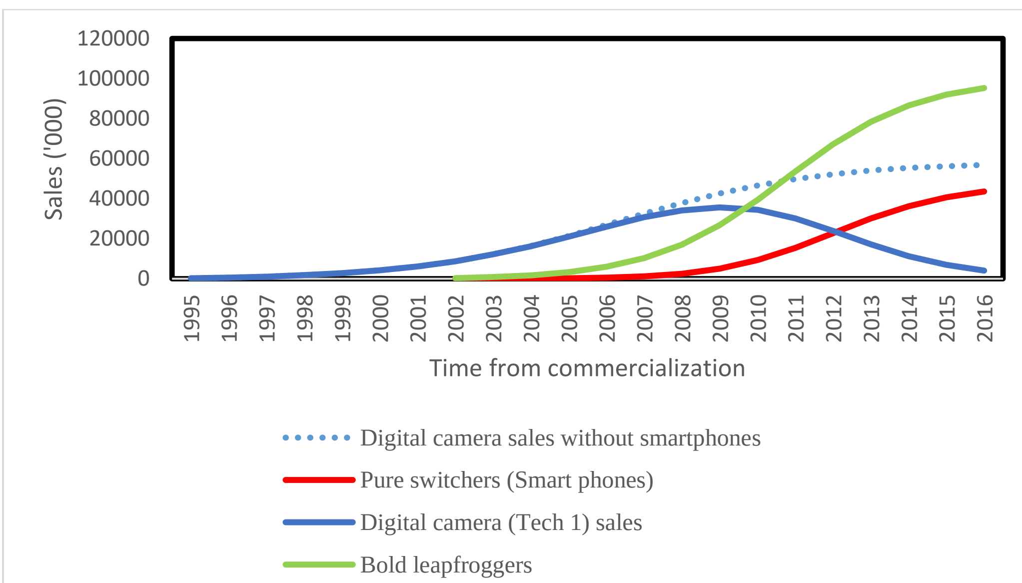


Figure 10

LAPTOP- TABLETS SALES DECOMPOSITION IN USA

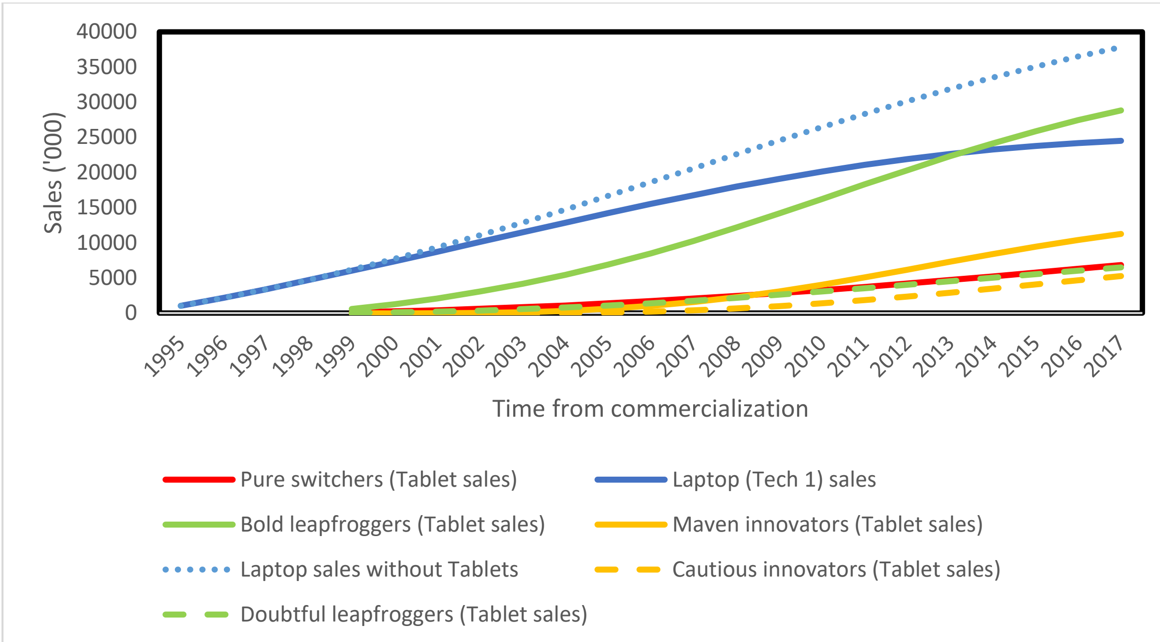


Figure 11

VCR-DVD PLAYER SALES DECOMPOSITION