Strategies for Encroaching on the Low End of Existing Markets

Cheryl T. Druehl
R. H. Smith School of Business
The University of Maryland
College Park, MD 20742
(301) 405-9677
(301) 405-8655 (FAX)
cdruehl@umd.edu

Glen M. Schmidt
The David Eccles School of Business
University of Utah
Salt Lake City, UT
(801) 585-3160
glen.schmidt@business.utah.edu

February 24, 2006

ACKNOWLEDGEMENTS: The authors acknowledge the helpful feedback received from faculty seminars at Purdue University and Georgetown University, and from attendees at the Product and Service Innovation Conference at the University of Utah.

Strategies for Encroaching on the Low End of Existing Markets

ABSTRACT

Kodak helped introduce disruptive innovation into its own market by developing expensive digital cameras. We describe their strategy as one of detached-market low-end encroachment: early digital cameras sold to affluent tech-savvy males who represented a market quite detached from the existing film-camera market, but digitals eventually encroached on the film-camera market starting with point-and-shoot models and moving upward to higher-end SLRs. An alternate strategy for Kodak would have been to pursue what we call fringe-market low-end encroachment: the early digital camera would have instead been a lower-priced, easier-to-use version targeted toward customers on the lower-end fringe of the film-camera market, such as budget-strapped moms, and from there it would have encroached upward on the film camera market. Such an early digital would have carved out a less attractive new market position for Kodak in terms of price, but possibly a more attractive position relative to competition. We compare and contrast the market impact of these two low-end encroachment strategies, and show how they are related to Christensen's notion of disruptive innovation. In doing so we help explain the conundrum of an expensive disruptive innovation. We relate our results to the finding that "willingness to cannibalize" is a key factor in an incumbent firm's growth and survival, and to the "blue ocean strategy."

Keywords: Diffusion, Disruptive innovation, Willingness to cannibalize, Blue ocean strategy, Low-end encroachment.

INTRODUCTION

The typical buyer of an early digital camera was an affluent tech-savvy male who bought the camera as an electronic gadget; a computer accessory. Even as digital sales ramped up to 5 million units per year by the year 2000, sales of film-based cameras remained relatively constant at about 20 million units per year. But at that point digital cameras encroached on (took sales from) the lower end of the existing film camera market, and then moved up-market (digitals first encroached on the point-and-shoot segment with low picture quality and are now moving up to the higher-end SLR segment). Kodak had seemingly been anticipating this since the early 1980s, having invested heavily in digital technology, and in 1995 Kodak followed Apple in introducing a digital camera that worked with a home computer.

The strategy that Kodak chose to pursue is what we call the *detached-market form of low-end encroachment*: the new product first sells to customers that are quite “detached” from the old market in terms of customer preferences (tech-savvy males had quite different preferences as compared to the mainstream market for film cameras). We use the term encroachment to mean that the new product takes sales away from the old product: over time, due to improvements and price reductions in digital cameras, they eventually encroached on the film camera market. Cannibalization is a special form of encroachment where both products are sold by the same firm. By low-end encroachment, we mean the first customers that the new product “steals” are customers whose demand for the traditional dimension of competition is on the lower end (initially, the poor MP rating of the digital camera precluded high-end users of film cameras from discarding their film cameras, particularly in the SLR market).

Kodak seemingly addressed the threat of digital cameras, but in doing so adopted a strategy quite different from the one upon which the company was built. In the early 1900s, Kodak introduced the Brownie, a camera not for the affluent tech-savvy market, but for the average user. The Brownie opened up a new market at the low-end fringe of the old market, and then improved quality over time to move up-market. In our terminology this represents low-end encroachment of the *fringe-market* type: the new product encroaches on the old product from the low end, but after having opened up a new market of customers that were on the fringe of the old market, with preferences more similar to existing customers. Kodak might have pursued the fringe-market strategy by using its considerable know-how in digital technology and its extensive R&D budget to introduce a digital Brownie. This would have initially sold not to tech-savvy males but to a quite different market segment, such as budget-strapped moms. Over time, such a camera probably would have again encroached on the existing market from the low end upward, as picture quality improved. But at the outset, the target market would have been markedly different, and users would have been able to get prints of their pictures more conventionally, rather than having to use a computer. Kodak discusses this alternate strategy in Future Image (2004).

The competitive implications of these two strategies are dramatically different. With the detached-market strategy, Kodak entered a market space that offered the potential for high prices, but also attracted multiple competitors such as Sony, Canon, and others. With the fringe-market strategy, Kodak would have been carving out a less attractive space in terms of price but possibly achieved higher volume (and potentially, higher profit).

Another example of what we call detached-market low-end encroachment is the cell phone. Similar to the digital camera, initially this innovation was very expensive: Rogers (2003) reports early cell phones cost up to $3,000. Also, the monthly subscription price for cellular service was originally much higher than for a land line, the product that the cell phone eventually began to replace. The early cell phone offered poor reception and spotty coverage, but in spite of this some customers were willing to pay the exorbitant price because the cell phone offered portability. The needs of these new customers were "detached" from those of customers in the old-product market.

The cell-phone example is similar to the digital camera illustration in that the price of the innovation came down over time, and its performance along the traditional attribute dimension (the one most highly valued in the existing market) improved over time to the point where the low end of the old market could accept that performance. In the case of cell phones, the first users to drop their land lines in favor of exclusive use of the cell phone were college students, teens, and apartment dwellers. These represent customers at the lower end of the land-line market. Most of us still have land lines as our primary home line and in our office (i.e., land lines still dominate in higher-end applications), in part because reception is generally superior (remember the recent cell-phone commercial that continually asked "can you hear me now?"). But the cell phone seems to be continually encroaching on the land-line market from the low end upward.

In addition to modeling the detached-market low-end encroachment scenario and contrasting it to the fringe-market type, another contribution of our paper is to help resolve an anomaly resulting from Christensen's work on disruptive innovations, that of an expensive disruptive innovation. Note that both the cell phone and the digital camera (as actually introduced) started out very expensive, but at the same time are examples of new-market disruptive innovations, as defined by Christensen (1997), Christensen and Raynor (2003) and Christensen et al. (2004), abbreviated C, CR and CAR, respectively. A disruptive innovation is at first ignored by the existing high-end market because it performs poorly along the traditional performance dimension. Instead, it initially sells to a lower-end or new market that values an alternate dimension along which the innovation (i.e., the new product) outperforms. Over time, however, the new product improves along the traditional dimension and eventually becomes attractive to even the old product's high-end customers. In the case of the early digital camera, it offered poor picture quality, with resolution of less than 1 megapixel (MP). It sold to a new market that highly valued transportability of pictures. Over time, resolution improved.

While the digital camera and cell phone are cases of expensive disruptive innovations, they are anomalies: "We normally think of disruptive innovations as being inexpensive" (CR, p. 60). Also, Christensen et al. (2001) refer to disruptive innovations as "cheaper, simpler, and more convenient products" than the ones they eventually displace (p. 82). CR discuss how the personal computer was far simpler and less costly than a workstation computer, with these differences further magnified as compared to a mainframe. They offer additional examples including Schwab, which offers on-line stock trading that is far less expensive than a broker-initiated transaction, and Toyota, which introduced low-cost economy cars. The work of Christensen and his co-authors is permeated with discussion that emphasizes the low-cost nature of disruptive innovations.[1] Adner (2002) also emphasizes the role of price, stating on p. 686: "Finally, critical to a disruptive outcome is the price at which the invader offers its product. The attacking firm must have the incentive and ability to offer its technically inferior, yet nonetheless satisfactory product at a sufficiently lower unit price to consumers than its rival…" Our detached-market low-end encroachment scenario helps explain these anomalies, thus offering an important extension to the theory of disruptive innovation.

Other authors have interpreted these anomalies differently. For example, Govindarajan and Kopalle (2006b) classify both cell phones and calculators as high-end disruptions. We contend that there are no high-end disruptive innovations (when high-end is defined relative to the existing market) and use Christensen's trajectory curves, which he says are the basis for his theory of disruptive innovation, to support our claim that by definition a disruptive innovation always exhibits low-end encroachment.

We contend that this further understanding of disruptive innovation is critically important if an incumbent is to thwart an entrant and capitalize on the opportunity that they represent. Govindarajan and Kopalle (2006a) similarly make the case that it is critically important to be able to measure disruptive

[1] CR say that all new market disruptions are inexpensive and explain away the example of the cell phone by saying that cell phones were not expensive relative to other products such as CB radios. We agree that customers will always choose the least-costly alternative (in the language of our model, they will buy the product giving them the most surplus) but do not find CR's explanation satisfying – we would like to explain how the cell phone can encroach first on the low end of the *land-line* market in spite of being initially expensive; we are not trying to explain its encroachment on the market for CBs.

innovations, and Markides (2006) and Danneels (2004) also point to the need to sharpen the theory. Our model and terminology enhance the understanding of the different ways in which disruptive innovations diffuse through the market (in contrast to the way sustaining innovations do so).

Effectively, our work extends that of Christensen by showing that new-market disruptive innovations come in multiple forms. One form is the low-priced type associated with fringe-market low-end encroachment. A second type is associated with our detached-market scenario; this type of disruptive innovation can start out as a very expensive product and yet still encroach from the low end. Another way that we add insight into Christensen's work is to describe how disruptive (and sustaining) innovations diffuse through the market. In our discussions with managers, we find that they have preconceived notions as to the meaning of the term "disruptive" which inhibits their understanding of Christensen's meaning. We find managers readily relate to our encroachment terminology.

We also relate our work to that of Kim and Mauborgne (2004, 2005a, 2005b), who suggest firms should introduce a product in a "blue ocean" where there is a lack of competition instead of in a competitive "red ocean." A detached-market or fringe-market innovation as described by our framework is similar to a "blue ocean." For example, if a firm were the only one introducing a product that is detached from the traditional market, that firm would effectively be introducing a blue ocean between itself and its competitors. Our framework suggests such a new product would be able to avoid competition with and/or cannibalization of the old product for a longer period of time than if the new product were introduced to compete at the high end of the old product market.

Further, our work has implications on the findings of Chandy and Tellis (1998) and Govindarajan and Kopalle (2004) who conclude that "willingness to cannibalize" is a key consideration in the successful introduction of innovations by incumbents. Our work suggests there are dramatically different ways that cannibalization can progress, depending on the type of product the firm introduces. Going back to the Kodak example, Kodak was willing to eventually cannibalize through the detached-market low-end encroachment scenario we describe but apparently unwilling to cannibalize in the fringe-market fashion, which in retrospect they seem to regret. If Kodak had adopted a fringe-market low-end encroachment strategy, it likely would have more quickly cannibalized its high margin film and photo-processing businesses as well as its film camera market, but may have established a more favorable market position. Another example is that of Intel, who historically was very willing to cannibalize from the high end with successive generations of Pentium processors. Only when it became willing to cannibalize from the low end with its Celeron did it address a disruptive threat from AMD's lower-end processors.

A brief description of our modeling framework is as follows. We assume each of two products, one old and one new (such as the land line and cell phone, respectively), has a linear reservation price curve. A reservation price curve is a plot of customer willingness-to-pay, with customers ordered from highest willingness-to-pay to lowest (or lowest to highest). A product's reservation price curve is determined by the attributes of the product and heterogeneous customer valuations of those individual attributes. Customers with the highest reservation prices for the old product are identified as its high-end customers, and those with lower reservation prices are lower-end. We find the Nash equilibrium outcomes when different firms offer the old and new products, and find the profit-maximizing outcomes when the same firm offers both. In the current paper we focus on the case of opposite-sloping reservation price curves, which leads to the detached-market scenario of low-end encroachment, and fit data from the phone market to our model to illustrate market outcomes as diffusion progresses. Schmidt and Porteus (2000), abbreviated SP, also use a linear reservation price framework but assume both curves are downward-sloping, leading to the other encroachment scenarios discussed herein.

We next review related literature, and then address the question of whether disruptive innovation can be high end. This is followed by development of the opposite-sloping linear reservation price framework. We go on to use empirical data from the phone industry to corroborate the detached-market low-end encroachment scenario, and end with a discussion of results. Proofs are available from the authors (Druehl and Schmidt 2006).

RELATED LITERATURE

Innovation has been classified into a variety of types (Gatignon et al. 2002). While we focus on disruptive innovations, other research examines radical and incremental innovations (e.g., Ettlie et al. 1984, Dewar and Dutton 1986). A radical innovation is often defined to be a revolutionary change, while an incremental one is a minor change. Disruptive innovation may be radical or incremental. Dewar and Dutton (1986) empirically find that radical and incremental innovations differ in nature, while Atuahene-Gima and Ko (2001) find that firms with high market and high entrepreneurial orientations tend to be more successful in innovation. Chandy and Tellis (2000) examine a broad range of products and find that incumbents do introduce radical innovations, especially recently. Our model does not address the question of radical versus incremental innovation nor organization effects such as market or entrepreneurial orientation. Instead, we concentrate on how disruptive innovations diffuse through a market and the strategic and managerial implications of these patterns.

Disruptive innovations tend to (but don't necessarily) come from firms not originally serving the disrupted market. Other have examined similar concepts: Foster (1986) discusses the attacker's advantage; Henderson and Clark (1990) examine the entrant's advantage in architectural product changes; Tushman and Anderson (1986) study the entrant's advantage when the new technology is competence destroying (in other words, the established firm's processes must change). Govindarajan and Kopalle (2004) examine the impact of organizational abilities on the introduction of radical and disruptive innovations. They support CR's supposition that a focus on current customers limits a firm's ability to develop a disruptive innovation. In an extensive empirical study of innovation, Sood and Tellis (2005) find that new innovations may attack the existing market from the low or high end, giving qualitative support to our low-end and high-end encroachment scenarios.

We contrast our model with others that lend insight into how disruptive innovations impact the competitive landscape. Adner (2002) models the possible diffusion of one product into a market previously held by a second product, sold by a second firm. While he analyzes firms' decisions regarding whether to pursue diffusion by improving product performance and/or cost, our model focuses on identifying the diffusion pattern as described by the timing of purchases by low-end and high-end customers (we do not make the firms' decisions explicit). Both his model and ours allow for multiple product attributes and multiple customer segments with differing relative preferences for the attributes. However, in his model all customers within a segment have the same willingness-to-pay for a given product, but differ in the minimum performance or net utility a product must offer before being considered for purchase (i.e., differ in purchase thresholds), while in our model, all customers within a segment vary in willingness-to-pay (i.e., reservation price). Adner and Zemsky (2005) identify factors leading to disruption such as performance oversupply and the number of firms using each technology, but do not examine disruption from the perspective of which customers are the first to buy, as we do (in their model, customers in the old product market derive the same utility, net of price, from a new disruptive product as from the old). However, they examine the conditions under which firms choose to innovate, and other related questions that we do not address.

Ghemawat (1991) and Chandy and Tellis (1998) suggest that firms must be willing to cannibalize their own (old) products if they are to become successful with new technologies rather than be displaced. The issues of cannibalization and launch-sequence are examined in Bhattacharya et al. (2003) in a setting where a technology's performance improves over time (as it does in our model), such as with microprocessors. Krishnan and Zhu (2005) propose that a firm might vertically differentiate low-end and high-end products along alternate performance dimensions to mitigate cannibalization. We address cannibalization from the perspective of how the diffusion progresses (from the low end or high end).

INTRODUCTION TO OUR ENCROACHMENT FRAMEWORK, AND HOW THE THEORY OF DISRUPTION MAPS TO IT

Our encroachment framework is grounded in the linear reservation price model briefly described in the Introduction. A related linear reservation price framework was introduced in SP, where the term low-end encroachment was first defined, along with its counterpart, high-end encroachment. To reiterate, low-end encroachment describes the scenario where low-end customers (those with lower willingness-to-pay) are the first to switch from the old product to the new (possibly after the new product first opens up a new market), followed by diffusion of the new product upward toward the high end. High-end encroachment is the scenario where high-end customers (those with highest willingness-to-pay) are the first to buy the new product, followed by diffusion downward to lower-end customers. An example of high-end encroachment is the Pentium IV (P-4) microprocessor encroaching on the Pentium III (P-3) version. The P-4 first sells to customers willing to pay a high price for processing power, which the P-4 offers at an elevated level relative to the P-3.

In the current paper we significantly extend SP by using a linear reservation price framework to identify a new type of low-end encroachment (the detached-market type). We further extend SP by formalizing the relationship between our framework/terminology and the theory of disruptive innovation and by deriving the mapping between the language of disruptive innovation and our encroachment terminology.

Establishing this mapping between terminologies helps frame our later discussion. Thus we delay the formal development of our linear reservation price model and first derive the mapping. As will be shown, disruptive innovation maps to what we call low-end encroachment, and sustaining innovation maps to what we call high-end encroachment. And as discussed earlier, this implies that disruptive innovation can be observed in either the form of fringe-market low-end encroachment, or in the form of detached-market low-end encroachment.

The mapping is presented in Table 1. We derive this relationship below using trajectory charts, because per C/CR/CAR such trajectory charts form the basis for the theory of disruptive innovation. A trajectory chart for the disk drive industry is shown in C (p. 16), while similar charts are presented in CR (pp. 33 and 44), CAR (p. xvi) and Bower and Christensen (1995).

Table 1. Mapping of the Type of Innovation to the Type of Diffusion

Type of Innovation, C/CR/CAR	**Type of Diffusion to which it Maps**	**Description**	**Examples**	**Reservation Price Curves***
Disruptive innovation	**Low-end encroachment**	The new product first encroaches on the low end of the existing market, and then diffuses upward.		
New-market disruption	Fringe-market low-end encroachment	Before encroachment begins, the new product opens up a fringe market (where customer needs are only incrementally different from those of current low-end customers).	5.25-inch disk drive (relative to 8-inch)	Both downward-sloping, New product is B
	Detached-market low-end encroachment	Before encroachment begins, the new product opens up a detached market (where customer needs are quite different than those of current low-end customers).	Cell phones (relative to land lines)	Opposite-sloping, New product is either B or N
Low-end disruption	Immediate low-end encroachment	Low-end encroachment begins immediately upon introduction of the new product.	Discount retailer (relative to high-end retailer)	Both downward-sloping, New product is B
Sustaining innovation	**High-end encroachment**	The new product first encroaches on the high end of the existing market, and then diffuses downward.	Pentium IV (P-4) microprocessor (relative to P-3)	Both downward-sloping, New product is N

* See the next section of this paper for further description of reservation price curves, and for definitions of products B and N.

The charts in CR/CAR are three-dimensional (3-D) in an attempt to show more information, but in turn they lose some of the richness of the original 2-D disk drive chart in C. To show both the richness of the original chart as well as the additional information conveyed in the 3-D charts, we develop the two frames shown in Figure 1. (In their 3-D graphs they only show information at two points along the third dimension, so we can effectively show the same information with just two 2-D frames.) We add some further richness to the charts, which will be justified below when that information is needed.

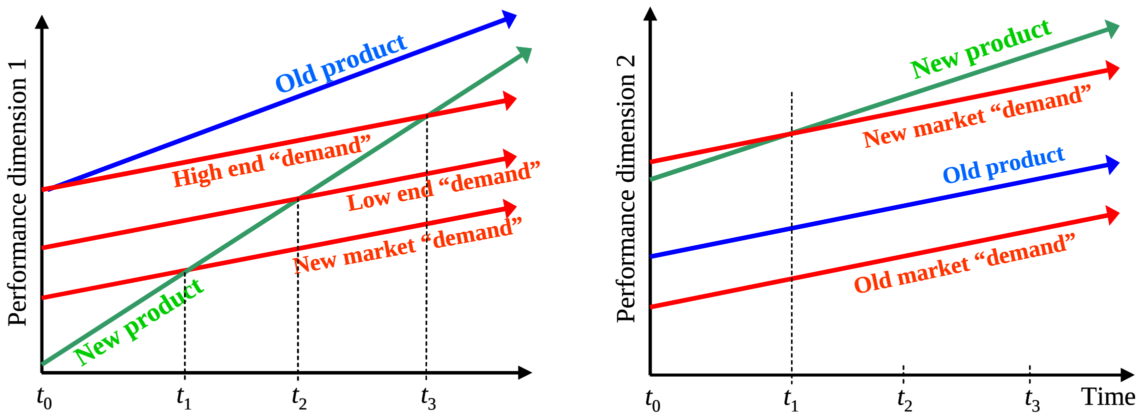

Figure 1. Disruptive innovation theory (adapted from Christensen 1997 p. 16 & CAR p. xvi)

Disruptive innovation theory is described by C/CR/CAR assuming two performance dimensions. The left frame in Figure 1 applies to the first dimension, the one most highly valued by current high-end customers, while the right frame applies to the second dimension, the one highly valued by a new market – that is, if there is a new market. CR distinguish between new-market disruptions which first open up a new market before encroaching on the old market, and low-end disruptions which are simply lower-priced products. In other words, for CR's low-end disruption scenario, the right-hand frame does not apply because there is no new market.

Each graph shows consumer demand[2] and product performance in relation to the given attribute. As illustrated in the left frame, low-end customers have lower demands for the first attribute than high-end customers. It is assumed users will buy a product only if it meets the user's demand along every dimension, but users will not pay extra for an overshoot in performance (i.e., they will buy the product

[2] CR use the term "demand" to denote the performance level usable by the customer, without directly addressing the trade-off a customer generally makes between performance and price. We formalize this trade-off in our linear reservation price model.

that meets their demand by the smallest margin, with the least overshoot).[3] As illustrated in the left frame, the performance of the old product along this dimension meets the demand of both high-end and low-end consumers at time t_0. In contrast, the new product (the disruptive innovation) falls short of the low-end users' demand until time t_2, and falls short of the high-end customers' demand until time t_3 (we will address the demand curve for the new market shortly).

Consider the scenario CR and CAR call new-market disruption. Given our description above, this means the new market's demand curve for the first performance dimension must lie below that of the low-end market, as shown in the left frame of Figure 1 (if it were positioned above the low-end market, then low-end users would buy the new product before the new-market users).[4] Now consider the right-hand frame in Figure 1. CR show two demand curves for the second dimension – we interpret these to be the average demands for the old market and for the new market. Specifically, we interpret the lower curve to apply to the old market and the upper curve to the new market, such that the new market has a higher demand than the old market with regard to the second performance dimension. (Christensen (1992a) shows that when a new smaller disk drive was introduced, it appealed to a new market which highly valued the new smaller size but placed lesser value on storage capacity, whereas the old market didn't place as much value on compactness. In other words, demands for the two performance dimensions were negatively correlated – the high end of the old market strongly demanded capacity but weakly demanded compactness, the low end of the old market less strongly demanded capacity and more strongly demanded compactness, while the new market least strongly demanded capacity and most strongly demanded compactness.) In the right frame of Figure 1 we have drawn the demand curves in the relative positions suggested by these observations.[5]

Given these curves, the purchase decisions are as follows. Up to time t_2 the low-end and high-end users buy the old product (it exceeds both performance demands while the new product fails to meet

---

3 This is not spelled out explicitly in C/CR/CAR, but it is implicit since the "demand curves" as developed in Christensen (1992a) are simply the median disk drive capacities actually purchased by the various market segments. (For example, the high-end market is the mainframe segment.)

4 Technically, we should also consider the demands for the second performance dimension before drawing this conclusion – if we do so using the right-hand frame in Figure 1, this statement still holds.

5 The only possibility is that the "demand curve" for the users of the old product (i.e., the old market demand) lies below the performance curve for the old product (at least during the time period over which they buy the old product, or else they would not buy it). Similarly, the only possibility is that that the performance trajectory for the new product lies above the old market demand curve after the time at which the old market has switched to buying the new product.

demands for performance dimension 1). Up to time t_1 the new-market users buy nothing (neither product meets their performance demands for dimensions 1 or 2) while beyond time t_1 they buy the new product (it meets both demands with the least overshoot). The low-end users switch to the new product at time t_2 and the high-end users switch at time t_3. (Although both products meet their performance demands, the new product has less overshoot.)[6] Accordingly, we have shown that what C/CR/CAR call new-market disruption leads to low-end encroachment: the product first opens up a new market and then encroaches on the low-end market before diffusing up-market to the high end. In SP we illustrate how the new market can be on the low-end fringe of the old market (illustrating the "fringe-market" type) while in the next section of the current paper we formulate the "detached-market" type. That is, we have just shown that new-market disruption maps to low-end encroachment, which we further distinguish as being of either the fringe-market or detached-market type.

Our contention that disruption results in low-end encroachment has been derived above using the trajectory curves of C/CR/CAR. Since the trajectory curves of C/CR/CAR form their basis for their theory of disruptive innovation, we conclude that C/CR/CAR effectively define disruptive innovation to be a low-end encroachment process, not a high-end one. The model presented herein along with those in SP and in Schmidt and Druehl (2005), SD, also support this notion.

To complete our mapping, we next address Christensen's categorizations of low-end disruption and sustaining innovation. Low-end disruption can be described as follows (since there is no new market in this case, we ignore the right frame in Figure 1 and the new-market demand curve in the left frame). At time t_0 both the low-end and high-end users buy the old product, as the new product falls short of their demand. At time t_2 the low-end users switch to the new product as it catches up with their demand, and at time t_3 the high-end users switch. We have just described what we call low-end encroachment – the new product first sells to the low end and then diffuses upward to the high end. We call this the *immediate* form of low-end encroachment because there is no new market – the encroachment on the old market is immediate CR use the example of discount retailers encroaching on high-end retailers. The analysis of SP also applies to the immediate form.

Next we discuss the diffusion pattern for a sustaining innovation. CAR's discussion of "undershot

---

6 The trajectory for the new product in shown to start at t_0 but since no one buys until t_1 in this case we interpret this to mean the product is effectively introduced at time t_1.

customers" suggests that sustaining innovations are repeatedly successful when customer demands are rapidly increasing relative to the rate of advancement in any given innovation. We use the familiar example of subsequent generations of Pentium microprocessors to illustrate this phenomenon. In the 1990s Intel would introduce a new generation of Pentium processor, and before long, because of further software upgrades by Microsoft, customers would be clamoring for more processing power (to date, the market for a new generation of MP3 player relative to the previous generation also fits this description, in that customers flock to a new model that stores more songs). We interpret this type of situation to mean that the users' demand curve is steep relative to the product's performance curve, as shown in Figure 2. We again provide more detail in this trajectory chart than do C/CR/CAR, by inferring added detail from CAR's discussion of "undershot customers".[7]

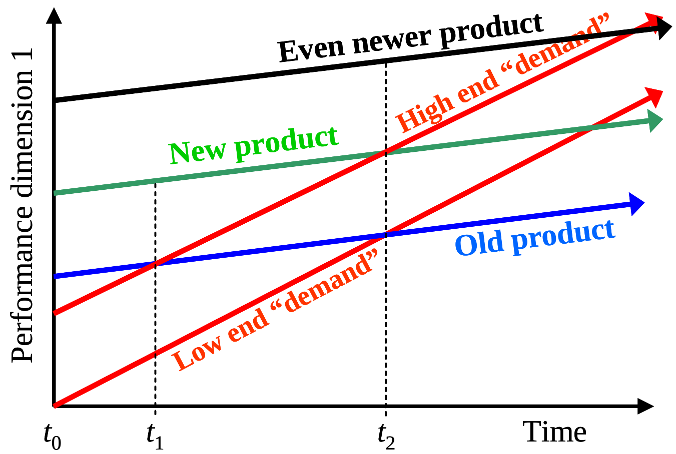

Figure 2. Trajectory chart for a sustaining innovation

As suggested by Figure 2, from time t_0 to t_1 both low-end and high-end users buy the old product, as it meets their demands with the least amount of overshoot. At time t_1 the high-end market switches to the

---

[7] We interpret the trajectory chart on p. xvi in C as follows. After a disruptive innovation is introduced, such as a smaller disk drive, it is immediately and continually upgraded with an infinite number of infinitesimal sustaining innovations. This is what gives it the upward performance trajectory along the first performance dimension – this upward trajectory can only be achieved by sustaining innovations. This is why C's performance curve for the disruptive innovation is labeled "progress due to sustaining innovations." With regard to a sustaining innovation, there does not seem to be formal recognition of a discrete sustaining innovation (such as a new generation of microprocessor). Similar to what happens to a disruptive innovation after its introduction, the "non-disruptive" product (to which the trajectory chart on the left in C, p. xvi applies) simply undergoes an infinite number of infinitesimal sustaining innovations over time (the left trajectory is similarly labeled "progress due to sustaining innovations"). See also the trajectory chart on p. xvi in CAR with the curved arrows – in the context of the microprocessor we would interpret these to represent upgrades in a generation of microprocessor over time, such as from 500 to 600 to 700 MHz.

new product as the old product no longer meets their needs (this implies the new product isn't introduced in the market until time t_1), while the low-end market does not switch to the new product until time t_2, at which point the high-end market moves on to an even newer product (another sustaining innovation, introduced, technically, at time t_2). Thus we infer sustaining innovation leads to high-end encroachment, where the new product diffuses downward from the high end of the existing market. Going back to the microprocessor example, a new generation of Pentium offers more of what current high-end customers want, processing power. It starts out high priced, selling first to high-end customers, diffusing downward.

A MODEL OF DETACHED-MARKET LOW-END ENCROACHMENT

In this section we develop the model that results in detached-market low-end encroachment. To solidify the link between this encroachment scenario and the theory of disruptive innovation, we build the model assuming there is a new product which exhibits the characteristics of a disruptive innovation relative to the old product. We first show that this setup can lead to opposite-sloping reservation price curves, and then derive the market outcomes that result from these curves. We use the example of cell phones later in this section to motivate the analysis, and to prepare for fitting the model to phone data in the next section.

Technical Basis for Opposite-Sloping Linear Reservation Price Curves

Characteristics of a disruptive new-market innovation are that it initially performs poorly along a key dimension valued by mainstream customers, but performs better than the old product along an alternate dimension valued by new customers (a new market). We model these characteristics using the concept of part worths and reservation prices. A reservation price is the most a customer is willing to pay for a product, and is assumed to be the sum of a customer's part worths for the individual product attributes. (Similarly, a reservation price curve is a plot of all reservation prices.) The notions of part worths and reservation prices are inherent in marketing tools such as conjoint analysis (Green and Srinivasan 1978 and 1990, Dahan and Srinivasan 2000).

We assume there are two products (the old and the new), and consider how customers value each product's attributes. There are assumed to be two such attributes, the one highly valued by mainstream customers (not highly valued by the new market) and the one highly valued by the new market (not highly valued by the old market). We assume the old and new markets are heterogeneous, in that the customers vary in their willingness-to-pay (i.e., their part worths). This assumption is consistent with the notion of different demands for low-end and high-end customers in CR/CAR's trajectory charts. We further assume the two products are differentiated substitutes for each other (if they weren't, then there would be no potential for the innovation to encroach on the old product).

Starting with the first attribute (the one highly valued by existing customers), and the old product, we order the existing customers in decreasing order of part worths for the primary (first) attribute. We plot the part worths, assuming customers are numerous such that we can consider the plot (which we call a part-worth curve) to be continuous as opposed to consisting of discrete points for each customer. See the left-hand side of the top frame in Figure 3 (the labeling for the *x*-axis at the bottom suggests the left side applies to the old market). A customer's part worth determines her "type," denoted by θ (again, see the labeling of the *x*-axis along the bottom). We denote the number of customers in the old-product market by s_1. The old product's high-end customers are those with the highest part worths for the first product attribute (as will be shown, they also have the highest reservation prices for the old product).

Continuing to consider only customers in the old market, we plot their part worths for the new product. Since a characteristic of a disruptive new product is that it is de-rated along the dimension highly valued by existing customers, we assume these customers have much lower part worths for the new product's first attribute, in proportion to their part worths for the old product.

Now consider customers in the new market and their part worths for the second attribute. Refer to the right-hand side of the middle frame in Figure 3. In this case we order the new customers in increasing order of part worths. We again denote (potential) customers by type θ and identify the interval over which they reside by s_1 to s. The new-market customers with the highest part worths for the second attribute are denoted as the new product's top-end customers. (We avoid using the term high-end to avoid confusion with the high-end customers of the old market.) We plot their part worths for the new and old products: since the old product does not perform well along this alternate dimension, we assume the part worths for it are much lower, in proportion to the part worths for the new product.

To this point we have discussed the left-hand half of the top frame in Figure 3, and the right-hand half of the middle frame. To complete the frames, we base our reasoning on Christensen (1992a), where he found that preferences for the two dimensions of product performance were negatively correlated across customers. This justifies drawing the downward-sloping part-worth curves shown in the right-hand half of the top frame (the part worth for the first attribute goes down in that graph as the part worth for the second attribute goes up in the frame below it). Similarly, this justifies drawing the upward-sloping part-worth curves shown in the left-hand half of the middle frame (the part worth for the second attribute goes up in that graph as the part worth for the first attribute goes down in the frame above it). For convenience we assume the part-worth curves of the old and new markets are connected at s_1 and assume the slopes of a product's part-worth curves are the same for customers in $[0, s_1]$ as in $[s_1, s]$.

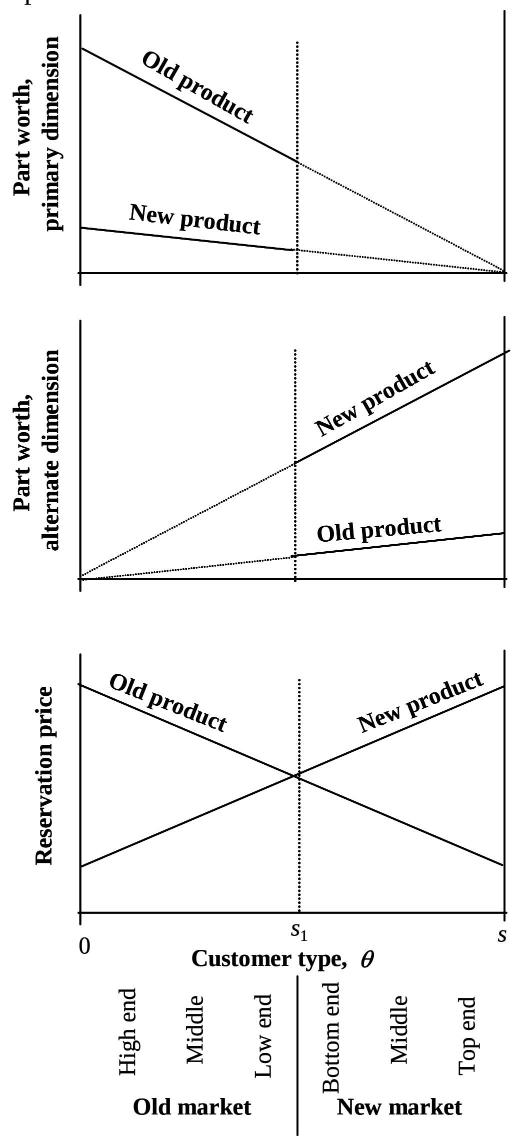

Figure 3. Adding part-worth curves to yield opposite-sloping reservation price curves

Next we add the two part-worth curves to obtain the reservation price curves for the old and new products as shown in the bottom frame of Figure 3. Thus starting from the theory of disruptive innovation, we have qualitatively illustrated how disruptive innovation can result in opposite-sloping reservation price curves. (The case where both reservation price curves are downward sloping would also be possible if, for example, the slopes of the part-worth curves were shallower in the middle frame – that scenario is analyzed in SP and SD.) In Appendix A, we formalize the development of opposite-sloping reservation-price curves and show how they might specifically apply in the case of cell phones. In doing so we go on to somewhat relax our assumptions of only two product attributes and the assumption that the preferences of the two attributes must be perfectly negatively correlated across customers.

Assumptions and Notation Pertaining to the Reservation Price Curves

In our vernacular the term "customers" includes all potential buyers, not merely those who actually purchase. It is important to recognize that a single person can represent multiple customers if she considers purchasing more than one unit. For example, she may desire multiple phones; one for office use, another for the home, and another for "mobile" use. This person may be looking for different attributes in each of her potential purchases, and thus the three customers that she represents may each have a different willingness-to-pay for a given product.

Similar to Norton and Bass (1987), we assume a customer would like to buy one unit per time period. For example, with phones, this can be interpreted as a monthly subscription. Hereafter, when we refer to "cell phones" and "land lines" we refer to the monthly phone subscription. We assume that at any given time a customer will buy at most one product (but a person may buy multiple products if she represents multiple customers), the one that offers her the most positive surplus, or nothing if both surpluses are negative, where surplus is defined as the difference between her current reservation price and the current selling price. Similar to Adner (2002), we assume that at each point in time, firms consider only current reservation price curves and costs in setting price, and that a customer considers only her current reservation prices and the current sales prices in her purchase decision.

A customer's part worths, and hence her reservation prices, may vary with time. For example, a part worth may go up because the product quality improves over time, or it may go down because the customer's expectation rises. Changes in reservation prices over time, along with possible changes in production costs over time, lead to the diffusion of a new product: a customer that preferred (in terms of surplus) the old product at a previous time may switch to buying the new product or a customer that previously bought nothing may later buy a product.

In Figure 4 we show the (hypothetical but plausible) reservation price curves for cell phones and land lines as derived in Appendix A, circa 1985. The primary performance dimension (highly valued by customers of the old product, land lines) is assumed to be phone reception (being able to reliably and clearly connect to the other party). The alternate dimension (assumed to be highly valued by cell-phone customers) is portability (being able to take the phone with you). In Appendix A we go on to consider a third performance dimension, that of status (in addition to the dimensions of reception and portability).

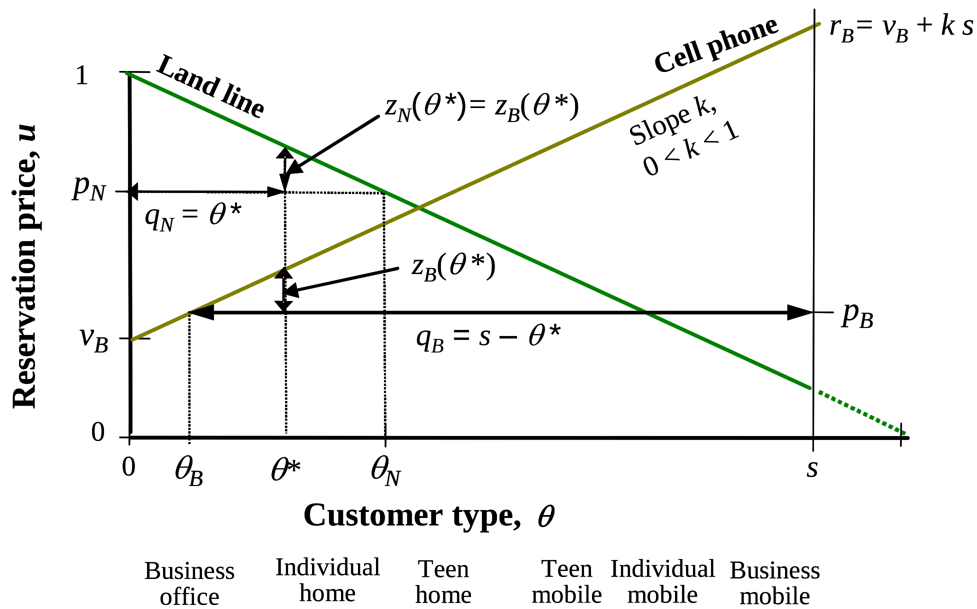

Figure 4. Reservation price curves for the opposite-sloping case (parameters are shown without time dependencies to avoid clutter –curves are assumed to apply circa 1985, but, prices, quantities, and surpluses are not meant to suggest 1985 levels)

A number of customer segments are loosely identified in Figure 4: from left to right these are the business office through the business mobile segments. See Table 2 for a summary of notation: customer type θ identifies the market segment to which the customer belongs and more specifically, identifies that customer's exact reservation prices.[8] Time is denoted by t and a number of parameters are functions of t as they may change over time (e.g., cell-phone reception gets better which enhances reservation price over time). Reservation price, or utility, is a function of both θ and t and is denoted by $u_j(\theta, t)$, where $j \in \{N, B\}$ denotes the product (N and B to be defined shortly).

Refer in Figure 4 to the reservation price curve labeled "land line," representing monthly subscription reservation prices. Relative to other customer segments, the business office users with θ close to zero have the highest relative reservation prices for the land line: we assume these users very

[8] We assume heterogeneity within each segment such that, for example, the business office customer with the lowest reservation price has "the same" willingness-to-pay as the individual home user with the highest reservation price. This allows us to achieve linear reservation price curves as shown.

highly value reliable reception, which the land line offers. But the business office users have low relative reservation prices for an early cell phone, because of its poor reception.

Table 2. Summary of Notation (in order as defined in the text)

θ =	Customer type (indicates willingness-to-pay for the product).
t =	Time: t_0 denotes time of introduction of the new product.
$u_j(\theta,t)$ =	*Reservation price* (or utility) of customer θ for product *j* at time *t*: $u_j(\theta,t)=v_j(t)+k_j(t)\theta$.
$s(t)$ =	Number of customers (potential buyers) at time *t*.
Product N =	Product with niche appeal (its reservation price curve has the steeper slope).
Product B =	Product with broad appeal (its reservation price curve has the shallower slope).
$k_j(t)$ =	Slope of reservation price curve for product *j* at time *t*, $j \in \{N,B\}$.
$k(t)$ =	*Breadth factor*. Relative slopes of res. price curves at time *t*: $k(t)=k_B(t)/k_N(t)=k_B(t)$.
$v_j(t)$ =	*y*-axis intercept of reservation price curve for product *j*, $j \in \{N,B\}$, at time *t*.
$r_B(t)$ =	Maximum reservation price for product B at time *t*: $r_B(t)=v_B(t)+k(t)s(t)$.
$c_j(t)$ =	Unit production cost of product *j* at time *t*, $j \in \{N,B\}$
$m_j(t)$ =	*Depth* (maximum plausible markup depth) for product *j* at time *t*, $j \in \{N,B\}$: $m_N(t)=1-c_N(t)$, $m_B(t)=r_B(t)-c_B(t)$.
$m(t)$ =	*Depth ratio* at time *t*: $m(t)=m_j(t)/m_J(t)$, where *j* is the new product (and *J* the old).
$p_j(t)$ =	Sales price of product *j* at time *t*, $j \in \{N,B\}$.
$z_j(\theta,t)$ =	Surplus for product *j* of customer type θ at time *t*, $j \in \{N,B\}$.
$\theta_j(t)$ =	Customer type indifferent between buying product *j* and nothing at time *t*, $j \in \{N,B\}$.
$\theta^*(t)$ =	Customer type indifferent between buying product N or B at time *t*, if such customer exists.
$q_j(t)$ =	Rate of sales for product *j* at time *t*, $j \in \{N,B\}$.
$\pi_j(t)$ =	Rate of profit derived from product *j* at time *t*, $j \in \{N,B\}$.
$S_j^i(t)$ =	Ratio of market share for product *j* to that of *J* at time *t*, given market type *i*, $i \in (D,\ M,\ B)$, where *D* denotes duopoly, *M* detached monopoly, and *B* benign duopoly: $S_j^i(t)=q_j(t)/q_J(t)$.
d =	*Coefficient of depth*. Magnitude of change in depth ratio $m(t)$ per unit time.
b =	*Coefficient of breadth*. Magnitude of change in breadth factor $k(t)$ per unit time.
σ =	*S-coefficient*. Degree of non-linearity in change in $m(t)$ and $k(t)$ over time.

Conversely, the business mobile users (e.g., construction managers traveling from site to site) with θ close to $s(t)$, where $s(t)$ denotes potential size of the entire market, have the highest reservation prices for a cell phone: they most highly value portability, which the cell phone offers, but have low reservation prices for the land line because of its poor portability. (Since each person may represent multiple customers, a business office user may be the very same person as a business mobile customer.)

Customers with θ close to zero (the business office users) are the high-end customers for the old product. Customers with θ close to $s(t)$ are willing to pay a lot for the new product, but are "detached" from high-end customers for the current product in that their preferences are very different. (Also, in Figure 4 these two sets of customers are detached in the sense that they are on the opposite ends of the *x*-axis.) This confirms the basic intuition behind the notion of opposite-sloping reservation price curves: different market segments (customer types) have vastly different evaluations of the old and new products.

In Figure 4 we show additional market segments: the individual home segment is much like the business office segment except that willingness-to-pay for land lines isn't quite as strong as for business users, and the teen home segment has even less willingness-to-pay (these are second lines in homes for which willingness-to-pay is typically less than for the primary line). Similar intuition explains the lower reservation prices of the individual mobile and teen mobile segments with regard to cell phones, as compared to business mobile users. In Appendix A we show why reservation prices for cell phones of individual home and teen home users are higher than for business office users (and why the reservation prices for land lines of individual mobile and teen mobile users are higher than for business mobile users): this result stems from consideration of all three attributes (reception, portability, and status).

The slopes of the reservation price curves are denoted by $k_B(t)$ and $k_N(t)$: we label the product whose reservation price curve has a shallower slope as product B, for broad appeal, such that $|k_B(t)| \le |k_N(t)|$ (a shallower slope indicates the product appeals similarly across a broader set of customers as compared to a steeper slope), and we label the product with the steeper slope as product N, for niche appeal. Either the old or new product can be product B, and we make no assumptions as to whether one reservation price curve lies above the other or whether they cross.

Let $v_j(t)$ denote the reservation price that a customer of type $\theta = 0$ holds for product *j*, $j \in \{N, B\}$. We normalize reservation prices such that $v_N(t) = 1$ is the maximum reservation price for product N, and normalize the slopes of the reservation price curves such that $k_N(t) = -1$, suggesting $0 < k_B(t) \le 1$. Define $k(t) := -k_B(t)/k_N(t) = k_B(t)$, and further define $r_B(t) := v_B(t) + k(t)\,s(t)$, such that $r_B(t)$ is the maximum reservation price for product B, held by the customer with type $s(t)$. We assume $s(t) \le \min\left(1,\ r_B(t)/k(t)\right)$, indicating all reservation prices are positive. (Our analysis holds if some reservation prices are negative, but we rule this out to avoid implying that the firm has to "pay" a consumer to take a product.) Thus after normalization, we have $u_N(\theta, t) = 1 - \theta$ and $u_B(\theta, t)$ = $r_B(t) - k(t)(s(t) - \theta)$. The curves in Figure 4 apply to the market at t_0, the time of cell-phone introduction, where we assume $u_N(\theta, t_0) = 1 - \theta$ and $u_B(\theta, t_0) = 0.314 + 0.9\ \theta$ (see Appendix A).

Along with knowledge of each product's reservation price curve, we assume firms know the normalized product costs $c_j(t)$, $j \in \{\text{N, B}\}$, at each time *t*, and that there are no economies or diseconomies of scale. We assume $1 - 2s(t) < c_N(t) < 1$ and $2v_B(t) - r_B(t) < c_B(t) < r_B(t)$, insuring a product's monopoly price falls strictly between its minimum and maximum reservation prices.

A product's maximum reservation price minus its cost is denoted by $m_j(t)$, $j \in \{N, B\}$, and is called its *depth of maximum plausible markup* (or simply its *depth*). That is, $m_N(t) := 1 - c_N(t)$ and $m_B(t) := r_B(t) - c_B(t)$. Actual markup, though, likely differs from depth. Further, define $m(t) =$ $m_j(t)/m_J(t)$ as the *depth ratio* at time *t*, where *j* is the new product (and *J* the old), j and $J \in \{N, B\}$.

Let $p_j(t)$ denote the price of product *j* at time *t*, $j \in \{N, B\}$, and let $z_j(\theta, t) := u_j(\theta, t)$ – $p_j(t)$ denote the surplus a customer of type θ holds for product *j*. Let $\theta_j(t)$ denote the customer who is indifferent between buying product *j* or nothing: $z_j(\theta_j, t) = 0$. Let $\theta^*(t)$ denote the type of customer who is indifferent between buying product N or B, if such type exists: $z_B(\theta^*, t) = z_N(\theta^*, t)$.

We next derive market outcomes given opposite-sloping, linear reservation price curves.

Market Outcomes in Terms of Prices, Quantities, and Profits

For brevity, we omit the time-dependencies in this section (e.g., $c_N(t)$ is abbreviated c_N). In the case of different firms selling the old and new products (i.e., products N and B, but not necessarily respectively), we find the Nash equilibrium prices for each product. If the same firm sells both products, then we find that firm's profit-maximizing prices. In either case, the prices p_j, $j \in \{N, B\}$, in turn determine the quantities sold, q_j, and the profits derived from the products, $\pi_j = (p_j - c_j)q_j$.

Two Competitive Firms Sell Products B and N, Respectively

Figure 5 portrays the formal results given in Theorem 1 in Appendix B. The first possible market outcome is that there are *detached monopolies*, where each product sells at its monopoly price to a segment at one end of the potential market. That is, products N and B sell to customers in the intervals $(0, \theta_N)$ and (θ_B, s), respectively, where $\theta_N \le \theta_B$. This result holds when neither product commands wide coverage (when both depths are "low"). Effectively, each firm's product caters to customers at one end of the potential market, with customers in the "middle" left unserved (the non-buying segment may actually be toward one end, but lies between the two buying segments). The two markets are "detached."

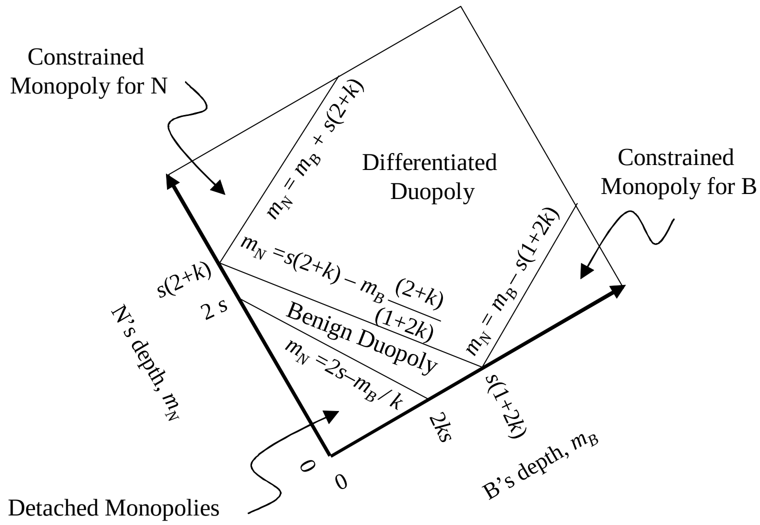

Figure 5. Outcomes when products B and N are sold by different firms (time dependencies omitted)

If we do not find detached monopolies, then the market is covered in one of several possible ways (because we assume a product's cost is less than its maximum reservation price, there is no chance of only one product having a monopoly on one end of the market with the other end uncovered). Product N covers the market interval $\left(0,\ \theta^*\right)$, while product B covers the remaining segment $\left(\theta^*,\ s\right)$.

If the depth of one product is sufficiently high, while that of the other is sufficiently low, then the one with the sufficiently higher depth can take the entire market. This is a *constrained monopoly* because even though only one product obtains strictly positive sales, that firm is constrained to charging less than the monopoly price. Product B has a constrained monopoly selling to the entire market when $\theta^* = 0$. Alternately, if $\theta^* = s$, then product N has a constrained monopoly.

Another possibility is that the two products split the covered market (although not necessarily equally) in one of two ways: at θ^* the surpluses are either both zero or they are both positive (and equal). We call the region where they are both positive a *differentiated duopoly*. In this region the depth of each product is relatively large, such that if either firm were a monopolist instead of a duopolist, its market would be relatively large and would extend into the "middle" of the interval (0, *s*). As monopolists, both firms would sell to customers in the middle, and thus as duopolists both firms are willing to compete somewhat aggressively for these customers in the middle. As a result the two firms price aggressively, to the extent that the customer at θ^* gets a positive surplus.

If the surpluses are both zero at θ^*, we call the outcome a *benign differentiated duopoly* (or benign duopoly for short – the effect of one differentiated product on the other is relatively benign). The product depths are large enough so that if you separately calculate each firm's monopoly market, the two monopoly markets would overlap only slightly, so in this case firms do not want to aggressively compete for customers in the middle. In the benign duopoly we find a continuum of equilibria. To gain some intuition, consider what would happen if one firm sets price first (as a Stackelberg leader) in this region. Say firm N (the firm selling product N) is the leader – it will price as a monopolist and achieve monopoly sales and profit, while the follower (firm B) will react by setting its price low enough to take the rest of the market but no lower (i.e., it sets price at the lowest reservation price of the remaining customers). This defines one end of the continuum of equilibria, while the other end is set by the analogous outcome achieved when firm B is the leader. Everywhere in between, if one firm sets price, the other firm's non-aggressive reaction is to simply price low enough to take the rest of the market but no lower. But since we do not define either firm to be a Stackelberg leader, we find the continuum of equilibria.

As this discussion and Theorem 1 suggest, except in the case of detached monopolies, each product encroaches on the low end of the competitive product's market. That is, each firm would like to extend its market at its low end, but is restrained from doing so by the competitive product. Also note that broad appeal is "good" – product B with broad appeal has an advantage in the sense that it can achieve a constrained monopoly "more easily" than product N. (Compare in Figure 5 the intercept of the boundary to B's constrained monopoly region on the *x*-axis, $s(1+2k)$, to the intercept of the boundary of N's constrained monopoly region on the *y*-axis, $s(2+k)$, and note that $s(1+2k) < s(2+k)$.) The advantage of broad appeal is also illustrated by the way product B "reaches over" to encroach on product N earlier. (Compare the intercept of the boundary to the detached monopolies region on the *x*-axis, $2ks$, with this boundary's intercept on the *y*-axis, $2s$, and note that $2ks < 2s$.)

A Monopolist Sells Both Products N and B

When a single firm (a monopolist) offers both the old and new products, both products may be sold in a *joint detached monopoly* with each product taking one end of the potential market (as in the detached monopolies region of the two-firm case), one product may sell to the entire potential market *s*, or there may be a *joint covered monopoly* where the entire market is covered, with each product getting a strictly positive quantity to a segment at one end. See Theorem 2 in Appendix B.

As might be expected, in the detached monopoly region both products are sold at their individual monopoly prices. In the joint covered monopoly, the monopolist sets the surplus for the customer of type θ^* equal to zero (every other customer has a strictly positive surplus for the product purchased). Each product is priced above its individual monopoly price – by selling two differentiated products the firm can target each product to one end of the potential market and raise its price as compared to the monopoly price charged when it is the only product sold. When one product claims the entire market, it is priced at its minimum reservation price.

A picture showing the various market regions would be similar to Figure 5 in that the joint detached monopoly region matches that of the detached monopolies. Further, the joint covered monopoly region in Theorem 2 is similar to the differentiated duopoly region in Theorem 1 (Figure 5), and the one-product monopoly regions in Theorem 2 are similar to the one-product constrained monopoly regions in Theorem 1 (Figure 5) except as follows: The joint covered monopoly region abuts the joint detached monopoly region (there is nothing equivalent to the benign duopoly) and the boundaries between the joint covered monopoly region and one-product monopoly regions are parallel to the boundaries between the differentiated duopoly and the one-product constrained monopoly regions shown in Figure 5, but the *x*-axis and *y*-axis intercepts are at 2 k s and 2 s, respectively.

FITTING THE DETACHED-MARKET MODEL TO PHONE DATA

We use the results of the previous section to analyze the diffusion/substitution process involving wireless telephony. Figure 6 shows our empirical data, the number of subscriptions for cell phones and land lines for 1985 to 2003, obtained from CTIA (2003) and FCC (2005), respectively.

Cell-phone size has been reduced, coverage has been greatly enhanced, and cost has come down over time, which in turn change the product depths and breadths. Costs may have fallen over time due to economies of scale and/or learning curve effects (Hatch and Dyer 2004, Macher and Mowery 2003, Schmidt and Wood 1999), for instance. Per our results of the previous section these changes in depths and breadths will impact the market outcomes along with sales prices, quantities, and profits.

Assume that at time $t_0 = 0$ a new product B (the cell phone) is introduced into a marketplace involving old product N (the land line). We do not precisely know the phone depths and breadths but proceed by assuming plausible numbers in an attempt to gain insight. We assume the reservation price curves from Figure 4 (but not the prices and quantities sold shown there) reflect the market at t_0, with a breadth factor of $k(t_0)$ = 0.9, and product depths of $m_N(t_0)$ = 0.6 and $m_B(t_0)$ = 0.005, such that the depth ratio is $m(t_0) = 0.00833$. We normalize the number of customers to $s(t)$ = 0.5 for all *t*. Note in Figure 5 that these depths would represent a point just inside the detached monopolies region. Given these values, and using the multi-firm results of the previous section we find the market outcome shown in the left frame of Figure 7: sales of land-line subscriptions extend across the business office, individual home, and teen home markets, while cell-phone subscriptions start close to zero. (The width of the rectangle labeled "Sales of land lines" indicates subscription sales volume, and the height of the rectangle reflects sales price, such that the area represents sales revenue volume. Similarly for cell phones.)

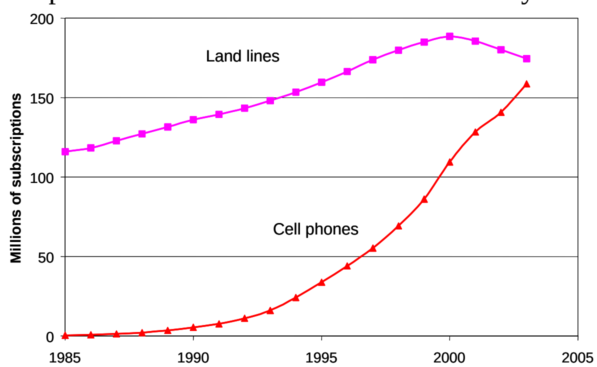

Figure 6. Sales of cell-phone and land-line subscriptions

These results show that upon introduction of cell phones the markets are "detached," in that initially cell phones and land lines sell to opposite ends of the market in detached monopolies. There is a wide "blue ocean" between the products in the terminology of Kim and Mauborgne (2004, 2005a, 2005b). The cell phone has not yet encroached on the land line and cell phones are priced significantly higher than land lines.

The middle and right frames of Figure 7 show the market progression over time, 10 years and 19 years after introduction of the cell phone, respectively. These figures were obtained by fitting the empirical data for cells phones to our model. First we qualitatively describe these results as portrayed in the middle and right frames, then we explain how we derive these results from the empirical data.

During their first 10 years, cell phones were upgraded, wireless coverage was enhanced, and costs were reduced, increasing cell-phone depths and breadths (as defined earlier). As a result, the price of cell-phone subscriptions comes down (as indicated by the diminishing height of the rectangle labeled "sales of cell phones"), and the market expands significantly, as shown in the middle frame of Figure 7. The market for cell phones expands beyond business mobile users to individual mobile users. The market for land lines is unaffected. As shown in the right frame of Figure 7, after 19 years (the 2003 data point) price is further reduced, and the market expands to teen mobile users. Furthermore, at this point cell phones begin encroaching on the sales of land lines. But note that the encroachment is from the low end of the land-line market: teen home users (and college students who might have otherwise had land lines in dorm rooms) are the first to adopt the cell phone in favor of the land line. The higher-end user segments, (the business office and individual home segments) continue to use the land line. Qualitatively, this description fits the outcome that has been observed to date in the actual market.[9]

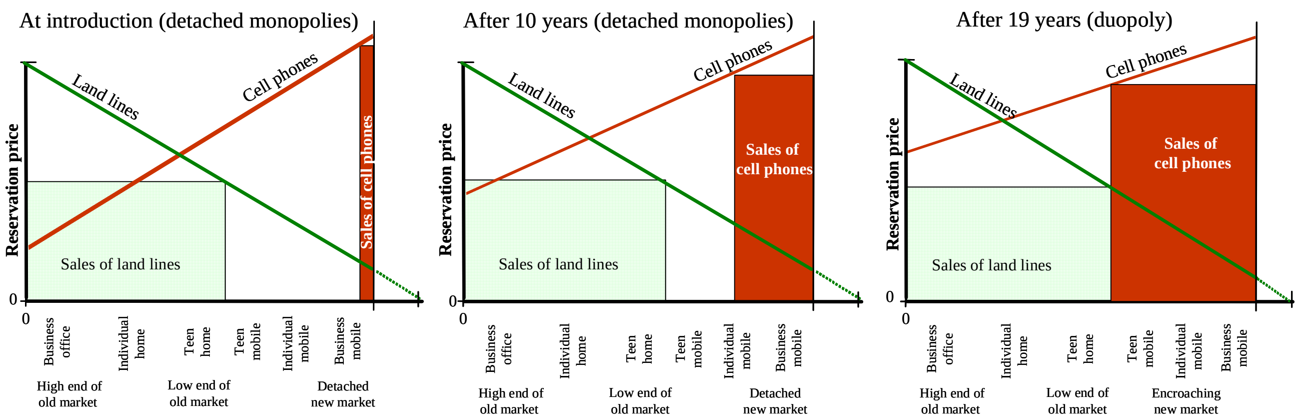

Figure 7. Outcomes as depths and breadths change

As suggested earlier, these market outcomes were obtained by fitting empirical data to our model. The process of fitting data to our model is analogous to fitting empirical data to the Bass (1969) diffusion model, where one finds the best-fit coefficients of innovation and imitation. Instead, we find the best-fit coefficients of depth and breadth, and S-coefficient (all defined shortly). See SD for a similar approach.

The Bass diffusion model fits actual unit sales of a new product to predicted unit sales, ignoring sales of the old product. In contrast, we take into account sales of both products by fitting the logarithms of actual market share ratios to the logarithms of predicted market share ratios. The market share ratio is simply the number of cell-phone subscriptions divided by land-line subscriptions: we use the logarithm because, as Fisher and Pry (1971) show, a plot of the logarithm of the market share ratio versus time is often approximately linear (such a plot is called a substitution curve).

As suggested above, we fit logarithms of the actual ratios of market shares to predicted ratios of

9 We readily admit that our stylized model fails to account for all aspects of the market.

market shares, using the 19 data points denoted by circles in Figure 8. The market share ratios that are predicted by our model are determined, at any point in time, by the two product depths and the breadth factor $k(t)$. We show in Appendix B the equations for the ratio of market shares.

For simplification, we assume the old product's depth $m_N(t)$ is constant over time, since land lines have not changed significantly since the introduction of cell phones. We assume changes in depth and breadth are smooth and continuous over time per a logistic (i.e., S-curve) specification, based on empirical evidence that technology improvements follow an S-curve (a technology improves slowly at first, then more rapidly as the technology becomes better understood, then the rate falls off again because the technology has matured to a point where further improvements are harder to achieve). See Christensen (1992b), for example. Our logistic model specification is $m(t) = m(t_0) + d\ y(t)$ and $k(t) = k(t_0) + b\ y(t)$, where $y(t) = a + \beta \big/ \left(1 + \mathrm{e}^{-\sigma(t-\delta)}\right)$, where *d* denotes the *coefficient of depth* and *b* denotes the *coefficient of breadth*, representing the change in depth and breadth per unit time, respectively. The S-coefficient σ effectively determines the rates of acceleration (and deceleration) in improvements, δ is the "midpoint" or time about which the curve is symmetric, β is a multiplier that scales (magnifies or shrinks) the *y*-values and *a* shifts the curve up (or down).

When cell phones were introduced the market share ratio started close to zero. When cell-phone and land-line subscriptions are equal the ratio will equal one: we refer to this as the "midpoint" of the substitution process and normalize time[10] to denote the midpoint by δ = 0.5. We assume the diffusion process is symmetric around this midpoint but do not assume cell phones will eventually totally displace land lines (they may or may not). Note that *y*(0) = 0 and *y*(0.5) = 0.5, yielding $a = -\gamma \big/ (1 - 2\gamma)$ and $\beta = 1 \big/ (1 - 2\ \gamma)$ where $\gamma = 1 \big/ \left(1 + e^{\sigma/2}\right)$. This leaves σ, *b*, and *d* (the S-, breadth and depth coefficients) as the only unknowns. In reality, we only have two unknowns as the coefficients of depth and breadth are interrelated (if one is specified, the other is automatically determined).[11]

---

10 From Figure 6 it appears equal sales for the two products will occur at about 20 years, which is normalized to a value of 0.5.

11 Recall that at introduction of the new product, its market share starts near zero, with the two products selling in detached monopolies. The market then progresses to the benign duopoly stage, followed by the differentiated duopoly stage which is where the model suggests we are today. With our assumption of symmetry, we assume that if cell phones completely displace land lines this will occur at a normalized time of $t = 1$. At such point of complete displacement the market would be on the boundary of a transition from a differentiated duopoly to a constrained monopoly for new product B. Thus at *t* = 1 we assume $m_N(t) = m_B(t) - s(t)\left(1 + 2\ k(t)\right)$, as dictated at this boundary by Theorem 1 in Appendix B.

Using this specification we find the best-fit depth and breadth coefficients and S-coefficient that minimize the sum of the squared errors between empirical results and model predictions. We search over values of *b*, *d*, and σ to find the coefficients that minimize the sum of the squared errors between the actual logarithms and those given by our model via equations (1) through (3) given in Appendix B. We find the best-fit coefficients are $b = 0.022$, $d = 3.362$, and $\sigma = 12.4$. Results are plotted in Figure 8. The R^2 is 0.95 (F = 154.2) and results are significant at the 0.005 level.

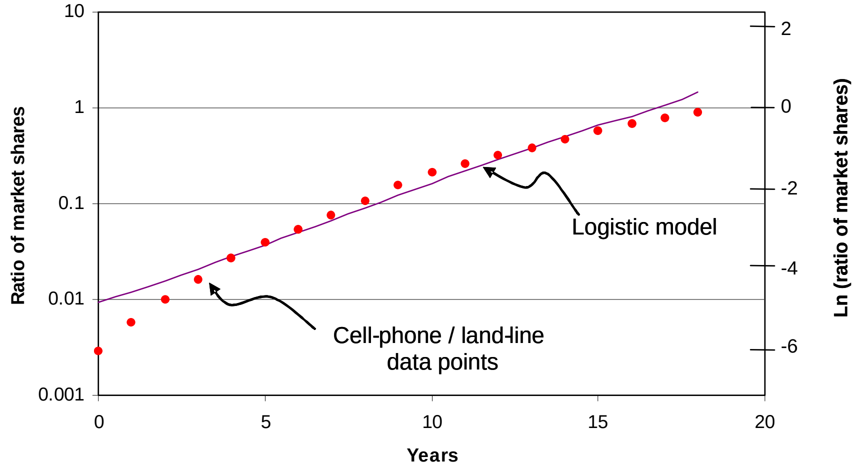

Figure 8. Fitting the model to empirical phone data using substitution curves

What the model is suggesting is that cell-phone reception is improving such that stationary customers progress to view the cell phone more favorably as compared to land lines. (Note in Figure 7 that the cell phone's reservation price curve elevates over time.)

To summarize, Figure 7 shows low-end encroachment of the detached-market type: first we observe detached monopolies, but eventually cell phones start to encroach on land lines from the low end (teens and college students). This progression is obtained from fitting our model to the empirical data in Figure 6. Contrast Figure 7 with Figure 9, where we illustrate fringe-market low-end encroachment as exemplified by a new smaller disk drive (e.g., the 5.25 inch as compared to the 8 inch), and with Figure 10, where we illustrate high-end encroachment as illustrated by a new Pentium processor. Here we show only the qualitative nature of these encroachment types – see SP and SD for more details.

Note in the left frame of Figure 9 that the new 5.25-inch drive first opened up a new market for desktops. This was a market on the low-end fringe of the old market for mid-range computers in that the desktop market required only incrementally smaller size (if the new market at that point in time had been laptops or specialty PDAs, who wanted dramatically smaller size, then we would have classified it as a "detached" market). As the new 5.25-inch drive gained capacity, it then encroached from the low end upward, as shown in the progression to the middle and right frames of Figure 9. Note in the right frame that our results concur with Adner's (2002) insight that the new drive overtakes the old due, in part, to reduced price (the height of the rectangle for sales of the new drive is below that for the old drive).

The immediate form of low-end encroachment is similar to the detached-market form except that there is no new market; expansion occurs (if at all) from the price impact of the new low-end product.

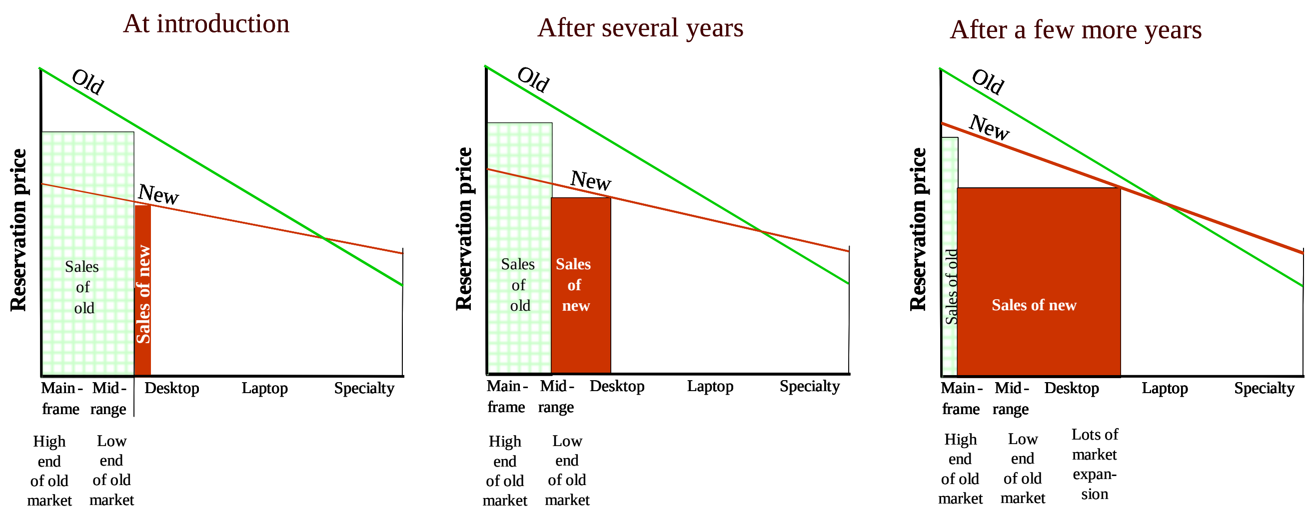

Figure 9. Fringe-market low-end encroachment (e.g., the 5.25" disk drive generation relative to the 8")

Figure 10 depicts high-end encroachment. The new Pentium first sells to the high-end customers, and then as shown in the progression from the left to right frames in Figure 10, it encroaches downward. While in Figure 9 and Figure 10 we show the new product eventually drives sales of the old product to zero, we do not mean to imply that encroachment necessarily always progresses to this extent.

Note that together, Figure 7, Figure 9, and Figure 10 corroborate the mapping in Table 1.

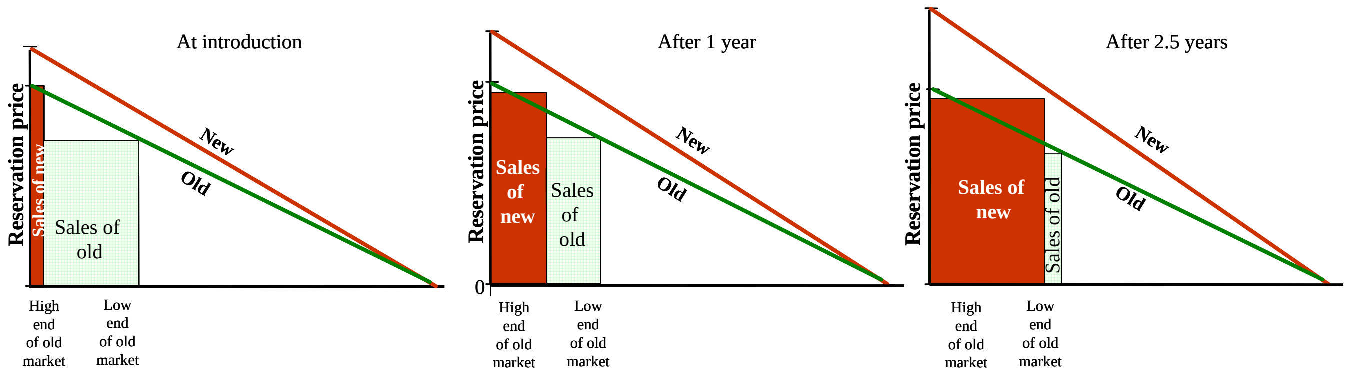

Figure 10. High-end encroachment (e.g., a new Pentium generation relative to the old)

DISCUSSION

A key contribution of our work is to delineate the detached-market low-end encroachment strategy, and compare and contrast the strategic implications of this approach as compared to other possible encroachment scenarios. Refer back to Table 1 (the second column from the left) for a list of the various types. While a firm might use any of the strategies we have outlined to open up new markets and eventually encroach on existing markets (i.e., cannibalize or take market share from existing markets), these various strategies have dramatically different market outcomes over time.

If a firm chooses the detached-market strategy (see Figure 7), then it initially targets a market segment with needs quite different from the existing market. This gives the entrant firm the potential to sell the new product at a high price without necessarily breeding an immediate competitive reaction from the firm selling the old product (or, if the incumbent offers the new product, it avoids immediate cannibalization while simultaneously realizing the potential for charging high prices). This may help explain why many incumbent firms in the land-line market were willing to compete in wireless. However, the high prices might also entice other competitors into this new detached market, as it seemingly did in the case of digital cameras.

This contrasts with what we call fringe-market low-end encroachment (see Figure 9), where initially the firm targets consumers with needs only incrementally different from the existing low-end customers. Because these fringe low-end customers are not willing to pay as much as the firm's most valued high-end customers, the firm offering the old product may more easily concede these customers. However, the margins initially achieved by pursuing this strategy may be relatively lower. This is the more traditional story of disruptive innovation. Thus a contribution of our work is to distinguish between these noticeably different disruptive scenarios.

The detached-market scenario also contrasts dramatically with high-end encroachment (see Figure 10). In this case the encroachment on the old product is immediate and dramatic since the new product first "attacks" the high end of the old market, and thus an entrant may face a swift and aggressive response from the incumbent (or if the incumbent is the one introducing the new product, cannibalization will be direct).

A firm's choice of an encroachment strategy may be limited by technology, as well as by its competitive position. For example, with regard to cell phones, it may not have been technically feasible to produce a low-priced phone that would have encroached as a fringe-market product, so the detached-market scenario may have been the only low-end encroachment alternative. In other cases the fringe-market scenario may be the only low-end alternative. For example, in the 1980s when the 5.25 inch disk drive was introduced it may not have been feasible to make a viable 1.8 inch drive – if such a drive had been introduced back at that point in time it might have opened up an earlier market for primitive PDAs, even before laptop computers became prevalent. The PDA market would have been "detached" from the desktop market (the progression from desktop to PDA would have "gapped over" the laptop). Further, the rate at which a firm is able to make technological improvements will also impact its strategy, given the implication of our model that diffusion relies on changes in reservation prices and costs over time.

Chandy and Tellis (1998), along with Govindarajan and Kopalle (2004), find that "willingness to cannibalize" is a key factor in an incumbent firm's growth and survival. As we have shown in Table 1, cannibalization can occur in several ways: cannibalization can be immediate and from the high end (as with a new Pentium microprocessor), or the new product can first open up a new market on the low-end fringe before encroaching on the old product from the low end upward (as with a smaller disk drive), or the new product can first open up a new "detached" high-end market such that there is a rather lengthy delay before the new product encroaches on the old market (as in the case of cell phones encroaching on the land-line market). Thus "willingness to cannibalize" may not be a descriptive enough prescription for an incumbent to avoid disruption.

That is, different forms of cannibalization may be called for in different settings. Intel initially relied on a high-end encroachment strategy until it realized that to hold off AMD it needed to be willing to cannibalize on the low-end fringe by introducing the Celeron. Kodak executives have noted that it may have been a mistake to initially be unwilling to cannibalize via what we call the fringe-market scenario (with a digital Brownie). More recently Kodak has since been fairly successful in continuing to drive the progression of detached-market low-end encroachment for digital cameras. In 2001, it introduced the EasyShare line, redefining "ease of use" for digitals (www.kodak.com). Recent market results show the success of this strategy: Kodak had the highest U.S. market share, 24.9%, in 2005 (Dobbin 2006).

Our framework also complements the notion of "blue and red oceans" as described by Kim and Mauborgne (2004, 2005a, 2005b). They develop "strategy canvases" for various products, showing how a new product may create an "ocean" between itself and a competitive product. Our reservation price framework effectively starts with the development of the strategy canvas (we rate each product with regard to the various attributes to develop the part-worth curves), and then proceeds to examine how various customer segments value the assortment of attributes portrayed on the canvas. In turn we calculate Nash equilibrium prices, and determine which market segments a product sells to in what quantities (recognizably, though, our setting is more simplistic than many real life situations).

Among the examples discussed by Kim and Mauborgne (2005b) we find fringe-market low-end encroachment ([yellow tail]), high-end encroachment (GM relative to Ford in the early auto industry), and growth of a detached-market (Cirque du Soleil – we stop short of calling this low-end encroachment as we do not observe such encroachment on the low end of the conventional circus market, and it may never encroach in such fashion). An insight from our analysis is that some oceans may be "broader" or "deeper" than others: for example, the detached-market scenario may allow firms to protect the old product from competition or cannibalization inherent in the other scenarios, at least for some period of time. But competition may also spawn in the detached market: in the digital camera example, the detached-market was itself a "red ocean" in that Apple and Sony were early competitors along with Kodak. If Kodak had followed the fringe-market strategy, it would have created a blue ocean by redefining ease of use, price and digital photo printing.

An insight that has apparently gone unrecognized to now, but suggested by our formal analysis of the trajectory curves which form the basis of the theory of disruptive innovation, is that a disruptive innovation cannot begin as a high-end product with respect to the old product market. However, our detached-market model shows how it can start as an expensive product but yet eventually encroach on the old product market from the low end upward (see Figure 7). This helps resolve a conundrum observed in Christensen's work; that of an expensive disruptive innovation. (But importantly, this does not mean that an expensive product that displaces an incumbent's product is necessarily disruptive!)

Govindarajan and Kopalle (2006b) do not concur with our conclusion. They categorize cellular phones relative to wired phones and the calculator relative to the slide rule as high-end disruptions.[12] But we contend their examples of high-end disruption are either detached-market low-end encroachment, or are high-end encroachment which does not map to disruptive innovation. Specifically, we suggest the

[12] p. 14: "Digital cameras relative to analog cameras, cellular phones relative to wired phones, iPod relative to Walkman, and electronic calculators relative to slide rules are examples of disruptive innovations…"

cell-phone / land-line example is quite different from the case of the calculator / slide rule: we contend the calculator / slide rule example does not meet any of the five criteria that Govindarajan and Kopalle (2006b) list for a disruptive innovation.[13] We categorize this as a case where an entrant succeeded with high-end encroachment,[14] similar to the case of fuel injection relative to carburetion (Snow 2004).

We hypothesize innovations may often be categorized incorrectly as disruptive simply because the innovation goes on to make the old product and/or the incumbents obsolete, or because the person has some other preconceived notion of "disruptive." This prejudice against the precise definition may be so strong that it overshadows an attempt to convey the intended meaning.[15] Our encroachment terminology is an attempt to more directly convey the meaning of disruptive innovation: it encroaches from the low end, possibly after first opening up a new fringe market or detached market. We suggest that use of our encroachment terminology might help other researchers in their categorizations and survey measures.

We make many assumptions that would be interesting to relax in future work. For example, we assume linear reservation price curves – it would be interesting to see if our results hold in the face of other formulations. If we allow a reservation price curve to achieve its minimum (or maximum) somewhere inside the interval $(0, s(t))$, we may find additional forms of encroachment, such as where the new product first sells to a detached market and then encroaches on the high end of the existing market before the market is covered. To more accurately reflect market conditions, it would be interesting to consider multiple firms selling each product. Further, our framework may need to be extended to

---

[13] 1) calculators *overperformed* on the attributes mainstream customers valued (speed and accuracy of calculation), 2) calculators did not offer any substantive features *not* valued by mainstream customers, 3) calculators that replaced slide rules were neither cheaper nor dramatically easier to use (remember reverse Polish notation?), 4) early calculators did not appeal to a low-end, price-sensitive customer segment, and 5) the improvements in calculators over time served not to entice high-end mainstream customers to buy their *first* calculator, but rather to make high-end customers continually upgrade to an even better calculator from their previous one.

[14] Christensen also categorizes the cell-phone/land-line example differently than the calculator/slide example. In CR cell phones are discussed as disruptive, while Christensen (2006, p. 50) refers to the calculator / slide rule example and other similar situations where incumbent firms have been displaced with high-end encroachment, such as the carburetor being displaced by fuel injection (Snow 2004) by stating: "Some have suggested that these are instances of high-end disruption. I resist labeling these phenomena as disruptions, because I am trying to give specific meaning to the term, independent of the outcome. Another mechanism of action causes the leaders to have missed these high-end innovations… These are not low-end or new-market disruptions, as I have defined the terms."

[15] As Christensen (2006, p. 50) implies in the above quote, his definition of "disruption" has nothing to do with whether the incumbent is displaced (it is "independent of the outcome"). Of course, it may be the case that incumbents tend to more often be displaced by disruptive innovations and successful with sustaining ones, but definition of the term itself is "independent of the outcome."

accommodate products that have more than two or three pertinent attributes.

Other limitations of our model are that we consider only the case where two firms each offer a single product or a monopolist offers two products; thus we do not address the issues of product variety and product line extensions. See for example Ramdas (2003). We also do not consider brand competition within a product category as Krishnan et al. (2000) do; instead we focus on the competition between different products that can substitute for one another. Also, further work is needed to link what we have found regarding diffusion to the rich literature surrounding the impact of firm capabilities on the ability of firms to innovate (Cohen and Levinthal 1999, Henderson 2006, Ofek and Sarvary 2003, Schmidt and Porteus 2006, Teece et al. 1997, Wernerfelt 1984) and to consider whether firms rationally decide the type of encroachment process to pursue (Gilbert 2005, Gilbert and Bower 2002).

Summarizing, a key insight we gain from the model detailed in this paper is that a new product can initially sell at a high price to a market that is quite "detached" from the existing market in terms of customer willingness-to-pay. This type of new product is typically grossly de-rated (as opposed to being incrementally de-rated) with regard to performance demanded by the old market but offers dramatically improved (as opposed to incrementally improved) performance with regard to some other attribute(s). Instead of opening up a fringe market "adjacent to" the old market, the new market is "detached." But eventually, as the new product improves along the traditional dimension, it again first meets expectations of the old product's low-end market and from there encroaches upward. This detached-market type of low-end encroachment helps explain the anomaly of an expensive disruptive innovation.

The strategic implications of this detached-market diffusion pattern differ quite dramatically from those of the other diffusion patterns we have contrasted it against. It is critically important that firms recognize these various patterns, so that incumbents and entrants may better recognize market threats and opportunities. Our model represents a step toward this understanding.

REFERENCES

Adner R. 2002. When are technologies disruptive? A demand-based view of the emergence of competition. *Strategic Management Journal* **23**(8): 687-688.

Adner R, Zemsky P. 2005. Disruptive technologies and the emergence of competition. *Rand Journal of Economics* **36**(2): 229-254.

Atuahene-Gima K, Ko A. 2001. An empirical investigation of the effect of market orientation and entrepreneurship orientation alignment on product innovation. *Organization Science* **12**(1): 54-74.

Bass FM. 1969. A new product growth model for consumer durables. *Management Science* **15**(5): 215-227.

Bhattacharya S, Krishnan V, Mahajan V. 2003. Operationalizing technology improvements in product development decision-making. *European Journal of Operational Research* **149**(1): 102-130.

Bower JL, Christensen, CM. 1995. Disruptive technologies: Catching the wave. *Harvard Business Review***73**(1): 43-54.

Christensen CM, Bower JL. 1996. Customer power, strategic investment, and the failure of leading firms. *Strategic Management Journal* **17**(3): 197-218.

Chandy R, Tellis GJ. 1998. Organizing for radical product innovation: The overlooked role of willingness to cannibalize. *Journal of Marketing Research* **35**(4): 474-487.

Chandy R, Tellis GJ. 2000. The incumbent's curse? Incumbency, size, and radical product innovation. *Journal of Marketing* **64**(3): 1-17.

Christensen CM. 1992a. The innovator's challenge: Understanding the influence of market environment on processes of technology development in the rigid disk drive industry. Unpublished doctoral dissertation, Harvard Business School.

Christensen CM. 1992b. Exploring the limits of the technology S-curve. Part I: Component technologies. *Production and Operations Management* **1**(4): 334-357.

Christensen, CM. 1997. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business School Press: Boston, MA.

Christensen CM. 2006. The ongoing process of building a theory of disruption. *Journal of Product Innovation Management* **23**(1): 39-55.

Christensen CM, Anthony SD, Roth EA. 2004. *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*. Harvard Business School Publishing: Boston, MA.

Christensen CM, Craig T, Hart S. 2001. The great disruption. *Foreign Affairs* **80**(2): 80-95.

Christensen CM, Raynor M. 2003. *The Innovator's Solution*. Harvard Business School Press: Boston, MA.

Cohen WM, Levinthal DA. 1994. Fortune favors the prepared firm. *Management Science* **40**(2): 227–251.

CTIA (Cellular Telecommunications & Internet Association). 2003. Semi-Annual Wireless Industry Survey.

Dahan E, Srinivasan S. 2000. The predictive power of Internet-based product concept testing using visual depiction and animation. *Journal of Product Innovation Management* **17**(2): 99-109.

Danneels, E. 2004. Disruptive technology reconsidered: A critique and research agenda. *Journal of Product Innovation Management* **21**(4): 246-258.

Dewar RD, Dutton JE. 1986. The adoption of radical and incremental innovations: An empirical analysis. *Management Science* **32**(11): 1422-1433.

Dobbin, B. 2006. Kodak tops U.S. digital-camera market again. *The Ithaca Journal* February 10.

Druehl CT, Schmidt GM. 2006. Technical appendix to "Strategies for Encroaching on the Low End of Existing Markets." Available at http://www.smith.umd.edu/faculty/cdruehl/.

Ettlie JE, Bridges WP, O'Keefe RD. 1984. Organizational strategy and structural differences for radical versus incremental innovation. *Management Science* **30**(6): 682-695.

FCC (Federal Communications Commission). 2005. Trends in Telephone Service. Industry Analysis and Technology Division, Wireline Competition Bureau.

Fisher JC, Pry RH. 1971. A simple substitution model of technological change. *Technological Forecasting and Social Change* **3**(1): 75-88.

Foster RJ. 1986. *Innovation: The Attacker's Advantage*. Summit Books: New York, NY.

Future Image Inc. 2004. Digital Cameras: Strategies to Reach the Late Majority. http://www.researchandmarkets.com/reportinfo.asp?report_id=44894&t=o&cat_id=5.

Gatignon H, Tushman ML, Smith W, Anderson P. 2002. A Structural Approach to Assessing Innovation: Construct Development of Innovation Locus, Type, and Characteristics. *Management Science* **48**(9): 1103–1122.

Ghemawat P. 1991. Market incumbency and technological inertia. *Marketing Science* **10**(2): 161-171.

Gilbert C. 2005. Unbundling the structure of inertia: Resource vs. routine rigidity. *Academy of Management Journal* **48**(5): 741–763.

Gilbert C, Bower JL. 2002. Disruptive change: When trying harder is part of the problem. *Harvard Business Review* **80**(5): 94–101.

Govindarajan V, Kopalle PK. 2004. Can incumbents introduce radical and disruptive innovation?. *Marketing Science Institute*. Working Paper Series 04-001.

Govindarajan V, Kopalle PK. 2006a. Disruptiveness of innovations: Measurement and an assessment of reliability and validity. *Strategic Management Journal* **27**(2): 189-199.

Govindarajan V, Kopalle PK. 2006b. The usefulness of measuring disruptiveness of innovations ex post in making ex ante predictions. *Journal of Product Innovation Management* **23**(1): 12-18.

Green PE, Srinivasan V. 1978. Conjoint analysis in consumer research: Issues and outlook. *Journal of Consumer Research* **5**(2): 103.

Green PE, Srinivasan V. 1990. Conjoint analysis in marketing: New developments with implications for research and practice. *Journal of Marketing* **54**(4): 3–19.

Hatch NW, Dyer JH. 2004. Human capital and learning by doing as a source of sustainable competitive advantage. *Strategic Management Journal* **25**(12): 1155-1178.

Henderson RM. 2006. The innovator's dilemma as a problem of organizational competence. *Journal of Product Innovation Management* **23**(1):3: 5-11.

Henderson RM, Clark KB. 1990. Architectural innovation: The reconfiguration of existing systems and the failure of established firms. *Administrative Science Quarterly* **35**(1): 9-30.

Kim WC, Mauborgne R. 2004. Blue ocean strategy. *Harvard Business Review* **82**(10): 76.

Kim WC, Mauborgne R. 2005a. Blue ocean strategy: From theory to practice. *California Management Review* **47**(3): 105-121.

Kim WC, Mauborgne R. 2005b. *Blue Ocean Strategy*. Harvard Business School Press: Boston, MA.

Kodak. 2006. www.kodak.com.

Krishnan TV, Bass FM, Kumar V. 2000. Impact of a late entrant on the diffusion of a new product/service. *Journal of Marketing Research* **37**(2): 269-278.

Krishnan V, Zhu W. 2005. Designing a family of development-intensive products. Working paper, University of Texas, Austin, TX.

Macher JT, Mowery DC. 2003. "Managing" learning by doing: An empirical study in semiconductor manufacturing. *Journal of Product Innovation Management* **20**(5): 391-410.

Markides C. 2006. Disruptive innovation: In need of better theory. *Journal of Product Innovation Management* **23**(1): 19-25.

Norton JA, Bass FM. 1987. A diffusion-theory model of growth and substitution for successive generations of high-technology products. *Management Science* **33**(9): 1069-1086.

Ofek, E, Sarvary, M. 2003. R&D, marketing, and the success of next-generation products. Marketing Science **22**(3): 355-370.

Ramdas K. 2003. Managing product variety: An integrative review and research directions. *Production and Operations Management* **12**(1): 79-101.

Rogers EM. 2003. *Diffusion of Innovations*, 5th Edition. The Free Press: New York, NY.

Schmidt GM, Druehl CT. 2005. Changes in product attributes and costs as drivers of new product diffusion and substitution. *Production and Operations Management* **14**(3): 272-285.

Schmidt GM, Porteus EL. 2000. The impact of an integrated marketing and manufacturing innovation. *Manufacturing and Service Operations Management* **2**(4): 317-336.

Schmidt GM, Porteus EL. 2006. Where do your operational competences position you for a competitive challenge in product development?. Working paper, University of Utah.

Schmidt GM, Wood S. 1999. The growth of Intel, and the learning curve. Stanford University Graduate School of Business, Case Study S-OIT-27.

Snow DC. 2004. Extraordinary efficiency growth in response to new technology entries: The carburetor's "last gasp." Best Paper Proceedings of the 2004 Academy of Management conference series.

Sood A, Tellis GJ. 2005. Technological evolution and radical innovation. *Journal of Marketing* **69**(3): 152-168.

Teece DJ, Pisano G, Shuen A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal* **18**(7): 509-533.

Tushman ML, Anderson P. 1986. Technological discontinuities and organizational environments. *Administrative Science Quarterly* **31**(3): 439-465.

Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* **5**(2): 171-180.

APPENDIX A: Development of Opposite-Sloping Reservation Price Curves for Cell Phones

In this appendix we develop hypothetical part-worth curves for cell phones, to illustrate how they might result in opposite-sloping reservation price curves. (The new and old products are monthly cell-phone and land-line subscriptions, respectively.) At their introduction around twenty years ago, denoted by time t_0, cell phones were quite expensive and very bulky. Furthermore, reception was so poor that early users frequently lost contact with the party to whom they were speaking. But poor performance along this traditional dimension of quality (reception) was overlooked by early users because they more highly valued performance along an alternate dimension, which we call portability. In addition, phones can be thought of as conferring social status on the user. For example, in 1985, teens might have envied a peer who had her own individual land line. Similarly, an early cell-phone user might have purchased that phone in part because it called attention to her when the phone rang in public.

We assume reception, portability and status are the only features of significance for phones (cell or land line). Thus the number of attributes, denoted by n, is n = 3. We posit that various customers held (and continue to hold) vastly different willingness-to-pay for these attributes. For example, Rogers (2003) suggests early cell-phone users were business executives such as building contractors who highly valued phone portability in going from job to job. Such a user really represented multiple customers, because she still relied on a land line for basic service, with a uniquely different willingness-to-pay for a land line as compared to a cell phone.

We assume $s(t)$ consists of w distinct customer segments of size $s_\alpha(t)$, $\alpha \in \{1,...,w\}$; for phones we assume w = 2, representing the stationary (α = 1) and mobile (α = 2) segments. Stationary customers use a phone in a relatively fixed location, such as in an office or a home. Mobile customers need a phone while on the go. Since from Figure 6 we see that cell phones seem to encroach on the land-line market before their sales equal the sales of land lines, we assume $s_1(t) = 2\, s_2(t) = 2\, s(t)/3$.

Starting with segment 1 and attribute 1, we order the customers from highest to lowest part worth, and assume the resulting part-worth curve is continuous and linear. This effectively identifies each customer's "type," denoted by $\theta_1 \in [0,\ s_1(t)]$. Using this same ordering of customers within segment 1, we plot the part-worth curves for all other attributes and assume all part-worth curves are linear. We then proceed to each subsequent segment and again order customers from highest to lowest willingness-to-pay for some given attribute, such that customer type in segment α, $\alpha \in \{2,...,w\}$, is denoted by $\theta_\alpha \in \left[\sum_1^{\alpha-1} s_\alpha(t),\ \sum_1^{\alpha} s_\alpha(t)\right]$. Again, we assume the plot is continuous and linear, and assume the plots of the part-worth curves for all other attributes are linear within each customer segment.

For cell phones, $\theta_1 \in [0,\, 2s(t)/3]$ and $\theta_2 \in [2s(t)/3,\ s(t)]$ denote stationary and mobile customers, respectively. We divide each segment into three sub-segments called business, individual, and teen. First consider the stationary customer segment. We assume that customers in the stationary business sub-segment are contemplating the purchase of an office (business) phone, stationary individual customers are considering a primary line for their homes, and teen customers are considering a second line for the home (other uses for a second line, such as for Internet access, will also fall under this sub-segment). First consider the attribute of reception. We assume business users have the highest part worths, followed by individuals, followed by teens. The logic is that an office user typically expects and demands a "perfect" connection. An individual home user expects this as well but is a bit more price sensitive. And a home user is typically willing to pay more for the first line than the second line, such that the part worth for the teen user (i.e., for the second home line) is lowest. These assumptions yield reception part-worth curves for stationary customers as shown in the left portion of Figure A-1. Customers are ordered from highest to lowest in terms of part worth for the reception attribute at time t_0, the time of introduction of the cell phone (roughly 1985). As suggested by the *x*-axis, business customers are of lowest type θ_1 followed by individuals followed by teens. We assume $s(t_0)$ = 3,750,000 and plot the part worths for land lines and cell phones.

We denote the slope of the part-worth curve at time *t* by $k_{i,\alpha}^j(t)$ and the intercept by $v_{i,\alpha}^j(t)$, where $j \in \{N, B\}$ denotes the product (the two products are identified as products N and B, where N is for niche appeal and B is for broad appeal, $i \in \{1,...,n\}$ the attribute, and $\alpha \in \{1,...,w\}$ the segment. Thus the part-worth (i.e., utility) curve is $u_{i,\alpha}^{j}(\theta_\alpha, t) = v_{i,\alpha}^{j}(t) + k_{i,\alpha}^{j}(t)\theta_\alpha$. We label reception as attribute 1, the land line as product N, and the cell phone as product B. We assume the land-line part-worth curve for reception for stationary customers in 1985 is $u_{1,1}^{N}(\theta_1, t_0) = v_{1,1}^{N}(t_0) + k_{1,1}^{N}(t_0)\theta_1 = 450 - 0.00013\,\theta_1$. (Note that these numbers represent hypothetical but plausible part worths.) All these customers consider the reception offered by a land line in 1985 to be worth more than that offered by a 1985 cell phone (product B). Hence, we assume $u_{1,1}^{B}(\theta_1, t_0) = 53 - 0.0000015\,\theta_1$.

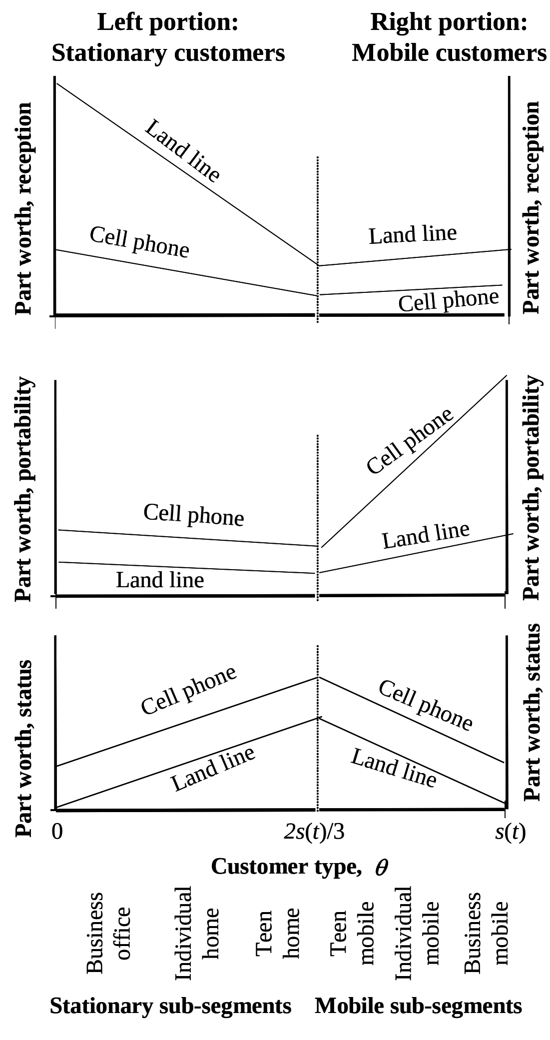

Figure A-1. Hypothetical part-worth curves for the phone example, circa 1985

Our framework thus accommodates the existence of multiple sub-segments assuming linear variation in willingness-to-pay within a sub-segment and that the sub-segments touch. For example, the “first” stationary teen customer is virtually identical to the “last” stationary individual customer.

Maintaining the same ordering of customers within the segment, we similarly plot the part-worth curves for all other attributes, and assume each part-worth curve is linear. To illustrate with phones, next consider the part worths that stationary customers ascribe to the attribute of portability, attribute 2 (see the left portion of the middle frame of Figure A-1), assuming the same ordering of customers as for reception. This attribute is not nearly as highly valued by stationary customers as reception, but part worths for business users are still higher than those of teen users because of the need for productivity, for example. We assume that for a land line the *y*-intercept is $v_{2,1}^{N}(t_0) = 22$ and the slope is $k_{2,1}^{N}(t_0) = -0.000001$. A cell phone clearly performs better than a land line along this dimension (a land line is portable only to the extent of the length of the phone cord, or the range of the base station), such that all customers hold a higher part worth for the cell phone. We therefore assume that $u_{2,1}^{B}\left(\theta_1, t_0\right) = 43 - 0.0000012\,\theta_1$.

With regard to the part worth for status (the left side of the bottom frame in Figure A-1), we assume business customers are “all business” and accordingly do not place much value on this attribute, while individuals are more status conscious and teens are highly status conscious. Clearly, this is an oversimplification, but we proceed under this approximation. We assume the part worths are: $u_{3,1}^{N}\left(\theta_1, t_0\right) = 45 + 0.00005\,\theta_1$ and $u_{3,1}^{B}\left(\theta_1, t_0\right) = 66.5 + 0.0000754\,\theta_1$.

The mobile customer segment is illustrated in the right portion of Figure A-1. Without loss of generality, first order customers in terms of willingness-to-pay for the attribute of status. We again (simplistically) assume business customers are “all business” and teens are most swayed by status. We assume $u_{3,2}^{N}\left(\theta_2, t_0\right) = 170 - 0.0001\theta_2$ and $u_{3,2}^{B}\left(\theta_2, t_0\right) = 255 - 0.0001424\,\theta_2$, suggesting all customers attribute higher status to a cell phone. With regard to the attribute of reception, mobile customers were probably not so concerned with reception back in 1985, as shown in the right side of the top frame, but everyone would have rated a land line more favorably along this dimension than a cell phone, with mobile business customers willing to pay more than teens (and individuals in between). Thus we assume $u_{1,2}^{N}\left(\theta_2, t_0\right) = 125 + 0.000008\,\theta_2$ and $u_{1,2}^{B}\left(\theta_2, t_0\right) = 60.4 + 0.000009\,\theta_2$. However, as shown in the right portion of the middle frame, mobile customers highly value portability, and a cell phone’s portability is much superior to that of a land line. Thus the slope of the cell-phone part worth is greater; we assume $u_{2,2}^{N}\left(\theta_2, t_0\right) = 19.5 + 0.000011\theta_2$ and $u_{2,2}^{B}\left(\theta_2, t_0\right) = 40 + 0.0002061\theta_2$.

Note that as is the case with a disruptive innovation, phone customers are assumed to have differed significantly with regard to the value they placed on individual product attributes. Stationary customers highly valued reception, while mobile customers highly valued portability. The new (disruptive) cell phone was weak on the first dimension, but strong on the second.

To obtain the reservation price curves for each customer segment, we sum the part worths within that segment. Define $k_\alpha^j(t) := \sum_{i=1}^n k_{i,\alpha}^j(t)$ and $v_\alpha^j(t) := \sum_{i=1}^n v_{i,\alpha}^j(t)$, such that $u_\alpha^j(\theta_\alpha, t) := \sum_{i=1}^n u_{i,\alpha}^j(\theta_\alpha, t) = v_\alpha^j(t) + \theta_\alpha\ k_\alpha^j(t)$ denotes the customer's reservation price for product *j* within segment α. Thus for our phone example, $u_1^N(\theta_1, t_0) = 517 - 0.000081\theta_1$ and $u_2^N(\theta_2, t_0) = 315 - 0.000081\ \theta_2$, such that $k_1^N(t_0) = k_2^N(t_0) := k_N(t_0) = -0.000081$. Generalizing, our model assumes that for each product, the sums of the slopes of the part-worth curves are equal across all customer segments. (If for any given segment the sum of the slopes $k_\alpha^j(t)$ is of opposite sign as compared to a different segment, reverse the order of customers within that segment.) We denote this sum by $k_j(t)$ for $j \in \{N, B\}$.

We further assume there is an ordering of customer segments such that $u_\alpha^j\left(\sum_1^\alpha s_\alpha(t), t\right) = u_{\alpha+1}^j\left(\sum_1^\alpha s_\alpha(t), t\right)$ for $\alpha \in \{1, ..., w-1\}$. Effectively, we assume the reservation price curves for the individual segments can be pieced together to form a linear reservation price curve for the product. (The segments may need to be reordered to achieve this.) Thus a customer of type θ_α can simply be referred to as being of type θ, where $\theta \in [0, s(t)]$, effectively yielding a uniform distribution of customer types over the interval $[0, s(t)]$. (Technically, uniformity will not hold at $s_1(t)$, $s_1(t) + s_2(t)$, …, $s_1(t) + ... + s_{w-1}(t)$, but we ignore this as the effect is infinitesimal.) The reservation price for a customer of type θ is simply denoted by $u_j(\theta, t)$ and the reservation price curve for product *j* can thus be described by $u_j(\theta, t) = v_j(t) + \theta\ k_j(t)$ where $v_j(t) := u_1^j(0, t) = \sum_{i=1}^n v_{i,1}^j(t)$.

Using the most recently defined ordering of *w* customer segments and ordering of customers within each segment, the part worths for the other product *J* are plotted, $J \in \{N, B\}$ and $J \neq j$. Again it is assumed that the sums of the slopes are equal, $k_J(t) := \sum_{i=1}^n k_{i,1}^J(t) = \dots = \sum_{i=1}^n k_{i,w}^J(t)$, but $k_J(t)$ need not equal $k_j(t)$, and that the linear reservation price curves for the various segments can be pieced together to form a linear reservation price curve for the product. Recall that without loss of generality $k_j(t)$ is negative; in the current paper we provide analytical results for the case where $k_J(t)$ is positive.

Given the above setup, product *J*'s reservation price curve can be described by $u_J(\theta, t) = v_J(t) + \theta\ k_J(t)$ where $v_J(t) := u_1^J(0, t) = \sum_{i=1}^n v_{i,1}^J(t)$. For phones, the stationary and mobile segments meet at $2s(t_0)/3$, where they are joined. The resulting reservation price curve for land lines is $u_N(\theta,t_0)=517-0.000081\theta$, while for cell phones it is $u_B(\theta,t_0)=162.5+0.0000727\,\theta$.

For ease of exposition we normalize the curves such that $v_N(t_0)=1$, $k_N(t_0)=-1$, and $s(t_0)=0.5$. This results in the reservation price curves in the text, $u_N(\theta,t_0)=1-\theta$ and $u_B(\theta,t_0)=0.314+0.9\ \theta$.

APPENDIX B: Theorems Delineating Market Outcomes

Prices determine the ordering of θ_N, θ_B, and θ^*, and establish the quantities sold, per Lemma 1 below. Theorem 1 gives the Nash equilibrium prices, quantities, and profits in the case where different firms sell the two products. Theorem 2 gives the profit maximizing results in the case where the same firm offers both products. Note that $\theta_j=\theta_j(p_N,p_B)$ but for simplicity we do not explicitly show the price dependencies. Also, we do not show time dependencies in the Theorems. Proofs are available from the authors.

The ratio of unit sales of new product *j* to unit sales of old product *J*, j and $J\in\{N,\ B\}$ and $j\neq J$, is denoted by $S_j^M(t)$ in the region of detached monopolies, by $S_j^B(t)$ in the benign duopoly, and by $S_j^D(t)$ in the differentiated duopoly. Since the new product is B, from Theorem 1 we find:

$$S_B^M(t)=\frac{q_B(t)}{q_N(t)}=\frac{m(t)}{k(t)} \tag{1}$$

$$S_B^D(t)=\frac{q_B(t)}{q_N(t)}=\frac{s(t)\big(2+k(t)\big)+m_N(t)\big(m(t)-1\big)}{s(t)\big(1+2\ k(t)\big)-m_N(t)\big(m(t)-1\big)} \tag{2}$$

To identify the ratio of market shares in the benign duopoly region, recall that in this region there is a continuum of price equilibria. We assume a product is priced at the midpoint of its continuum (since each reaction function is linear in the other product's price, if one product is priced at its midpoint, so is the other). This yields $p_B(t)$ = $r_B(t)$ – $\big(k(t)\,s(t)/2\big)$ – $\big(m_B(t)-k(t)\,m_N(t)\big)/4$ and $p_N(t)$ = $1-s(t)/2$ + $\big(m_B(t)-k(t)\,m_N(t)\big)/\big(4\,k(t)\big)$ and $q_B(t)=s(t)/2+$ $\big(m_B(t)-k(t)\,m_N(t)\big)/\big(4\,k(t)\big)$ and $q_N(t)$ = $s(t)-q_B(t)$. The ratio of market shares is:

$$S_B^B(t)=\frac{q_B(t)}{q_N(t)}=\frac{2\,k(t)\,s(t)+m_N(t)\big(m(t)-k(t)\big)}{2\,k(t)\,s(t)-m_N(t)\big(m(t)-k(t)\big)}. \tag{3}$$

Lemma 1. *Given p_N and p_B, sales quantities q_N and q_B are as follows:*

a) If $\theta_N\le\theta^*\le\theta_B$, then $q_N=\theta_N=1-p_N\ge 0$, and $q_B=s-\theta_B=(r_B-p_B)/k\ge 0$.

b) If $\theta_B \le \theta^* \le \theta_N$ *, then* $q_N = \theta^* \ge 0$, *and* $q_B = s - \theta^* \ge 0$.

Theorem 1. *When reservation price curves are opposite sloping and the two products are sold by different firms, the Nash equilibrium prices, quantities, and profits are as follows:*

	Detached Monopolies	***Benign Duopoly***
Conditions	$m_N \le 2s - m_B/k$.	$m_N \ge 2s - m_B/k$ *and* $m_N \le s(2+k) - m_B(2+k)/(1+2k)$.
Prices	$p_B = \dfrac{r_B + c_B}{2}$ *and* $p_N = \dfrac{1+c_N}{2}$.	*There is a continuum of equilibria for which prices are:* $p_B = r_B - k\ s + k(1-p_N)$ *and* $p_N = 1 - s + (r_B - p_B)/k$, *extending over the range:* $p_B \in \left[\dfrac{r_B + c_B}{2},\ r_B - ks + k\dfrac{m_N}{2}\right]$ *and* $p_N \in \left[\dfrac{1+c_N}{2},\ 1 - s + \dfrac{m_B}{2k}\right]$.
Quantities	$q_B = \dfrac{m_B}{2k}$ *and* $q_N = \dfrac{m_N}{2}$.	$q_B = s - \dfrac{1 - p_N + p_B - r_B + k\ s}{1+k}$ *and* $q_N = \dfrac{1 - p_N + p_B - r_B + k\ s}{1+k}$.
Profits	$\pi_B = m_B{}^2/(4k)$ *and* $\pi_N = m_N{}^2/4$.	$\pi_B = (p_B - c_B)q_B$ *and* $\pi_N = (p_N - c_N)q_N$.

	Differentiated Duopoly	***Constrained Monopoly for B***	***Constrained Monopoly for N***
Conditions	$m_N \ge m_B - s(1+2k)$ *and* $m_N \le m_B + s(2+k)$ *and* $m_N \ge s(2+k) - m_B\dfrac{(2+k)}{(1+2k)}$.	$m_N \ge 2s - m_B/k$ *and* $m_N \le m_B - s(1+2k)$.	$m_N \ge 2s - m_B/k$ *and* $m_N \ge m_B + s(2+k)$.
Prices	$p_B = \dfrac{s(2+k) + r_B + 2c_B - m_N}{3}$ *and* $p_N = \dfrac{s(1+2k) + 1 + 2c_N - m_B}{3}$.	$p_B = r_B - ks - m_N$ *and* $p_N = c_N$.	$p_B = c_B$ *and* $p_N = 1 - s - m_B$.
Quantities	$q_B = \dfrac{s(2+k) - m_N + m_B}{3(1+k)}$ *and* $q_N = \dfrac{s(1+2k) + m_N - m_B}{3(1+k)}$.	$q_B = s$ *and* $q_N = 0$.	$q_B = 0$ *and* $q_N = s$.
Profits	$\pi_B = \dfrac{\left[m_B + s(2+k) - m_N\right]^2}{9(1+k)}$ *and* $\pi_N = \dfrac{\left[m_N - m_B + s(1+2k)\right]^2}{9(1+k)}$.	$\pi_B = (m_B - m_N - ks)s$ *and* $\pi_N = 0$.	$\pi_B = 0$ *and* $\pi_N = (m_N - m_B - s)s$.

Theorem 2. *When the reservation price curves are opposite sloping and the two products are sold by the same firm, the monopolist's profit maximizing prices, quantities, and profits are as follows:*

	Monopoly for N	***Monopoly for B***
Conditions	$m_N \geq 2s - m_B / k$ *and* $m_N \geq m_B + 2s$.	$m_N \geq 2s - m_B / k$ *and* $m_N \leq m_B - 2ks$.
Prices	$p_B \geq r_B$ *and* $p_N = 1 - s$.	$p_B = r_B - k\ s$ *and* $p_N \geq 1$.
Quantities	$q_B = 0$ *and* $q_N = s$.	$q_B = s$ *and* $q_N = 0$.
Profits	$\pi = \pi_B + \pi_N = \left(m_N - s\right)s$.	$\pi = \pi_B + \pi_N = \left(m_B - k\ s\right)s$.

	Joint Detached Monopoly	***Joint Covered Monopoly***
Conditions	$m_N \leq 2s - m_B / k$.	$m_N \geq 2s - m_B / k$ *and* $m_N \geq m_B - 2ks$ *and* $m_N \leq m_B + 2s$.
Prices	$p_B = \frac{r_B + c_B}{2}$ *and* $p_N = \frac{1 + c_N}{2}$.	$p_N = \frac{2k(1-s) + 1 + c_N + m_B}{2\left(1+k\right)}$ *and* $p_B = \frac{k\ m_N + \left(2+k\right)r_B + k\ c_B - 2ks}{2\left(1+k\right)}$.
Quantities	$q_B = \frac{m_B}{2k}$ *and* $q_N = \frac{m_N}{2}$.	$q_N = \frac{m_N - m_B + 2ks}{2(1+k)}$ *and* $q_B = s - \frac{m_N - m_B + 2ks}{2(1+k)}$.
Profits	$\pi = \pi_B + \pi_N = \frac{m_B^2}{4k} + \frac{m_N^2}{4}$.	$\pi = \pi_B + \pi_N = \frac{\left(m_B - m_N\right)^2 + 4\left(k\ m_N + m_B\right) - 4\ k\ s^2}{4\left(1+k\right)}$.