Reconceptualizing Positive Feedback Models: Is "Tipping" Inevitable in Standards Contests?

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Published as

Scott Gallagher and Joel West, "Reconceptualizing and expanding the positive feedback network effects model: A case study," *Journal of Engineering and Technology Management* 26, 3 (Sept. 2009): 131-147. DOI: 10.1016/j.jengtecman.2009.06.007

Abstract: During the 1980s, economists developed the concept of positive network effects and switching costs as the key dynamics of *de facto* standards competition. They concluded that a positive feedback loop usually "tips" a market to the standard with the most users and complementary assets. While recent scholars have acknowledged that not all markets tip, and suggested some possible limitations on this phenomena, these limitations have not been integrated systematically into a model for competition in these industries. Using examples drawn from the standards contests of the past 20 years, this paper develops an integrated model for competition in these industries.

Key words: *de facto* standards, network effects, switching costs, strategy, communications standards

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De Facto Standards Competition: Rethinking the Assumptions

1. Introduction

The development, sale, and adoption of important products are enabled by compatibility standards. These standards create value by either allowing interconnectivity directly between products or facilitating the provision of complementary assets (Katz & Shapiro, 1986; Grindley, 1995; Shapiro & Varian, 1999). While the standards in some markets are determined via *de jure* or quasi-governmental mechanisms, e.g. the FCC selecting RCA's color TV broadcast standard, in many industries over the last 25 years the standards that emerged have been *de facto* compatibility standards, sponsored either by individual firms or alliances of multiple firms.[1] These are what have captured the most attention and a model of network effects, termed the "hardware-software paradigm," has become the dominant way of thinking about standards competition (Shapiro & Varian, 1999). This model is usually applied as an "overlay" to traditional strategic and technology models of competition.

This framework has played a powerful role in both industry (where firms try to pre-empt standards contests) and public policy, such as the 1997-2001 *U.S. v. Microsoft* trial (Gomes, 1998). But such theories have been largely shaped by the VCR wars of the 1980s and anecdotal references to Microsoft and Intel, even though many more such standards competitions have taken place in the subsequent two decades (Table 1). In fact, competition in standard based industries is nothing new. Examples from the late 19th and early 20th century have included railroad gauges, electrical transmission systems, and, most famously, typewriter keyboard layouts (Shapiro & Varian, 1999; Utterback, 1994; David, 1985).

<Insert Table 1: Major *De Facto* Standards Battles 1980-1999 about here>

While more recent research has updated the network effects model — as with Sheremata's (2004) framework for challenger entry and Suarez (2005) analysis of the effects upstream of consumer choices — the model still dominates thinking about standards competition. Here we revisit the earlier and more recent models of network effects, and consider both the assumptions and limitations of these model. We offer a compact model of standards competition, discuss the distinctions between network effects based on interconnectivity and software compatibility, and offer ideas for future research.

2. Theoretical Overview

Standards

Product compatibility standards assist technical coordination between various economic actors in two ways. First, it enables a division of labor between the various suppliers (producers) of an overall technological system (Antonelli, 1994). Second, standards facilitate consumer adoption by reducing transaction costs (Kindleberger, 1983; David & Greenstein, 1990). In particular, many products require the provision of key complementary assets or need to be connected to other similar products in order to be useful. In these circumstances, standards become important in an industry for both producers and consumers.

As with other types of innovations, technical coordination needs can include distribution, support, training and documentation. But most of these products also require complementary

[1] A few such as Krechmer (2000) argue that firm-controlled compatibility standards are proprietary specifications, not standards. To distinguish

technologies — such as computer peripherals and software — which must be specialized for the particular standard (Teece, 1986). Compatibility standards define the interface between the standard and its complementary assets. Not only do they allow the independent development of complementary assets, but for multi-vendor standards they also allow complementary assets to be employed on a wide range of implementations of a given standard (Katz & Shapiro 1985; Langlois & Robertson 1992, 1995). For example, power tools from a wide range of manufacturers use common sizes of drill bits from an equally large or larger number of providers.

Given adequate resources, firms may choose to vertically integrate downstream from their innovation and provide their own complementary assets when they have adequate resources. In fact, this can often be an intended strategy for a firm to reap the rewards of setting the standard, e.g. Gillette in safety razors. However, if they lack the capital or capabilities to produce all the complementary assets ("software") necessary to make their products successful, they must rely on third parties to provide this software. Even if they do produce complementary assets on their own, third parties can often provide desirable supplemental products, often unique innovations that the initial firm did not anticipate. For "hardware" such as personal computers and videocassette recorders, this software must be co-specialized by the software producer in order to insure compatibility, and thus hardware producers often provide incentives to the software producer to make these investments (Teece, 1986).[2]

from formal governmental or quasi-governmental compatibility standards, we adopt the "*de facto* standard" terminology common in industry and economics (Yamada, 1993; Shapiro & Varian 1999).

[2] For example, Apple Computer paid Microsoft to write an Apple II version of its spreadsheet program Multiplan (Cringley, 1996).

Theories of "Tipping" in Standards Contests

The concept of positive network externalities in product adoption was introduced by Katz and Shapiro(1985: 424), who wrote "There are many products for which the utility that a user derives from consumption of the good increases with the number of other agents consuming the good." While this theory of positive network externalities has been used to explain the adoption of specific innovations (Saloner & Shepard, 1995), its greatest impact has come from its prediction that greater market share in a standards battle increases product utility.

As developed and extended the traditional model of competition between rival standards is resolved by a positive feedback loop involving adopters and producers of complementary assets. In this model, for a class of product (usually dubbed "hardware"), the most popular standard attracts the largest supply of complementary assets (generically dubbed "software"), which, in turn, further increases the standard's popularity with adopters and thus its attractiveness to software producers. Thus, the leading standard enjoys "demand-side economies of scale," where every new adopter increases its advantage over rivals. Note that considerable debate has occurred regarding the nature of the effect later subsequent users have, ranging from monotonic over the history of the industry to only a certain critical threshold (Katz & Shapiro, 1985; Liebowitz & Margolis, 1994). However, usually based on clear feedback from consumers, producers shift to making products compatible with the dominant standard rather than sticking with an incompatible losing standard (Katz & Shapiro, 1985, 1986, 1994; Farrell & Saloner, 1985, 1986; Besen & Farrell, 1994).

A second stream of standards research examines the effect of asymmetric switching costs upon adopter decisions (David 1985; Klemperer, 1987; Beggs & Klemperer, 1992). Switching costs are costs that consumers incur to move from one product to another. For most products, this is very low. However, for some products it can be significant such as learning a different set of commands for a different software program, e.g. Lotus 1-2-3 versus Excel. If intra-standard adoption of successive generations of products is less expensive than inter-standard adoptions, customers tend to "lock in" to one standard, as Greenstein (1993) demonstrated with U.S. mainframe computer purchases.

New adopters can calculate the net present value of a prospective switching cost, decreasing the attractiveness of a flagging standard that might eventually disappear. This is one reason researchers have concluded that the *combination* of network externalities and switching costs lead to the "tipping" of the standards contest (Farrell & Saloner, 1986; Arthur, 1989; Arthur, 1996; Besen & Farrell, 1994; Shapiro & Varian, 1999). Specifically, the theories make a strong and unambiguous prediction that, *ceteris paribus*, a virtuous cycle will inevitably "tip" a standard contest in favor of the leader, consigning the trailing standard(s) to market pressures that irrevocably force its share to zero. To quote Katz and Shapiro: "In dynamic models, tipping is reflected in equilibria where new placements of the losing standard simply dry up once a rival system is introduced or accepted in the marketplace" (Katz & Shapiro, 1994: 106).

Pervasiveness of "Betamax" Paradigm

The most often cited example of such a "tippy" standards battle is that of VHS vs. Betamax (Cusumano, et al, 1992). It forms the basis of early theories, (e.g. Katz & Shapiro, 1986) and is cited in most subsequent discussions of tipping - a search of business publications during the early 1990s reveals articles with titles like "Betamax versus VHS all over again?", "Betamax Wars All Over Again?" and "Betamax redux." In these cases, the word "Betamax" is synonymous with tipping and failure, (e.g. Brandt & Gross, 1993).

Whether directly through the VCR wars or indirectly through academic theories of positive network effects, there is little doubt that this winner-take-all, positive feedback model has driven standards-related decisions by adopters, producers and regulators. For more than a decade, producers developed aggressive strategies to improve the actual supply of software, by courting software developers and using a penetration pricing strategy to quickly establish a market share lead that would attract developers. Producers have also sought to influence the perception of software availability and market share (truthfully or otherwise) to attract both users and producers of complementary assets. Adopters have sought to reduce their likelihood of adopting a losing standard (and paying the concomitant switching costs) by handicapping standards battles based on the availability of software and perceived market share.

Meanwhile, the role of proprietary standards upon competition policy has not gone unnoticed. Because technology such as software is easily reverse-engineered, intellectual property safeguards such as trade secret, copyright or patent protection is sought by standards producers to shield themselves from competition. At the same time, the tendency of standards battles to tip to a single victor has prompted policy concerns about the anti-competitive nature of such standards monopolies. In response, various governments throughout the world have reduced intellectual property protection, instituted compulsory licensing, or filed anti-trust lawsuits to rein in the power of the standards-holders (Teece, 1986; West, 1995; Sheremata, 1998).

This model has been compactly illustrated by Hill (1997) and is shown in figure 1. In this model, the number of users facilitates the development of complements, which in turn increases the utility of the product, which in turn drives demand, further feeding installed base. This model also serves as the theoretical foundation of this paper.

<Insert Figure 1: Hill's Positive Feedback Model about here>

Reservations

Despite the pervasive impact of the "tippy", positive-feedback model upon theory, practice and policy, a few reservations have been expressed and many acknowledged by their developers. Berg (1989: 365) concluded that "although the network externality formulation sheds light on market performance, the predictive capabilities of these models are limited." Shapiro & Varian (1999) admit "not every market tips," arguing that the likelihood of tipping depends on the combination of economies of scale and the homogeneity of customer tastes. Much more pointed criticism has come from Liebowitz and Margolis (1990) who distinguish between network effects — where differences in network size are incorporated in the price mechanism — and externalities that are not captured by markets or hierarchies. As an example, a certain amount of "excess inertia" for incumbent standards is fully rational, since any new standard must offer potentially benefits exceeding the costs of switching to be considered by established users (Liebowitz & Margolis, 1990). However, even if the network effect – externality dichotomy is accepted, the implications for firms seeking to obtain competitive advantage through the adoption of their standard is unchanged – rationally committed customers are still committed.

Reconciling Opposing Perspectives

It is possible that one or the other perspective is exactly right — either that positive network externalities (mediated by a supply of complementary assets) explain tipping results, or that the outcomes of standards battles are completely explained by other factors. However, a more likely explanation for the conflicting interpretations is that there are contingencies that explain when markets are tippy and when they are not. There are potential moderators of the hypothesized positive feedback loop in standards battles as well as additional main effects. For example, the base model (figure 1) cannot explain the failures of first movers, who by definition have 100%

market share but are then often overtaken by a subsequent rival, e.g. Apple's Newton vs. U.S. Robotic's Palm Pilot vs. Research in Motion's Blackberry in personal digital assistants. Recent work has attempted to refine exactly these types of limitations but has not directly integrated them into the network effects model (Suarez, 2004; Sheremata, 2004). During head-to-head competition, other factors may moderate the impact of the positive feedback loop. Finally, the established model does not offer insight into how existing standards are overturned.

The Chicken and Egg Problem and the Bootstrap Process

As with most new technologies, standardized products will rarely be cash-flow positive from day one. Sponsors must bootstrap a product or process that embodies a standard by providing resources until such time as it is profitable —otherwise no new standard would ever be offered. At the same time, they must create or motivate a supply of complementary products. This is commonly referred to as the chicken and egg problem in the standards literature.

Why do producers supply complementary assets without a proven market, and why would users adopt without complementary assets? Absent an installed base of users, potential suppliers of complementary assets must make predictions both about the absolute size of a future market, and also the size relative to competing technologies for which co-specialized technologies must be developed. There is no shortage of examples of these products that failed to make this hurdle including quadraphonic sound (Postrel, 1990) and the digital audio tape. Similarly, users may make a purchase decision based on software that is promised but not delivered. Therefore, not surprisingly, preannouncing products and/or complementary assets is common in these industries.

Both parties may go beyond the current relative standing of competing standards to incorporate expectations of future success (Katz & Shapiro 1986; Besen & Farrell 1994). The immediate adoption and software supply for the IBM PC — despite an initial lack of either — was due in large part to IBM's reputation and thus the perceived likelihood of IBM's success in this market (Chposky and Leonsis, 1988).[3] Therefore, early on, strategic behavior regarding expectations is especially helpful in trumping installed base. Suarez (2004) makes a much bigger use of this in describing five stages of development in battles for technological dominance.

3. Reconceptualizing the Positive Feedback Model

The established model of "tippy" network effects industries focuses strictly on the positive feedback of market share and software supply. As was shown in figure 1, the model has three major components — the provision of software, the increased utility provided by such software, and then the concomitant increase in adoption resulting from such utility improvements. In order to describe our model, we adopt the basic building blocks of the extant model and add addition potential main effects and moderators. This offers a more robust model that combines this base model with other factors to explain the success of a given *de facto* standard. This model is shown in Figure 2. This model includes both the moderators of positive feedback effects and also other more directly actionable steps available to the standard's sponsor to increase the adoption of standardized products. Therefore, we organize our discussion of this revised model around the factors that impact the three major constructs: supply of software (complements), product utility, and number of users. We review both the existing main effects, possible moderators of these effects, and additional factors that might fuel the positive feedback model.

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[3] Ironically, IBM approached Microsoft initially because of its need for the BASIC programming language to be available on its PC. Essentially, users were expected to use BASIC to create their own complementary assets.

<Insert Figure 2: Model Incorporating Mediators and Moderators of Standards Based Competition and
Table 2: Summary of Robust Model's Paths about here>

1) Increasing Software Supply

The path from installed base to "software" supply is tied to cases where software suppliers must make a strategic choice between standards. The main effect (path 1) network effects model postulates that an increase in software supply (or quality) for a given standard depends on the number of adopters of that standard. Such software is a specific category of what Teece (1986) categorizes as "co-specialized assets." For many class of goods, co-specialization has been quite expensive. For example, in application software, the co-specialization cost is the engineering cost of adapting the software to each computer platform's application programming interface (API), plus a similar cost of producing and inventorying titles for platforms beyond the most popular one. It may also be applicable in cases as outlined by Arthur (1996) with high up front costs and low marginal production costs — as with R&D-intensive application software. Therefore, network effects theory has assumed that if two systems are mutually incompatible that the co-specialization cost will be great and, thus, the decision of third party software vendors will help cause the markets to "tip" to the more popular standard. Thus, before market share trends become clear, hardware producers must provide incentives to the software producer to invest in such co-specialization (Teece, 1986). However, these costs can be reduced by additional direct effects, labeled 1A in figure 2, such as vertical integration as well as moderating effects, such as converters and variances in the cost of co-specialized assets, labeled 1B.

Vertical Integration (or Diversification into Complements) (1A). Discussions of vertical integration and diversification are typically driven by cost issues — can a firm more profitability buy a given capability in the market or must they build it in house (Chandler, 1997; Williamson, 1985). This "market failure" framework has been extended to look specifically at vertical integration to supply complementary assets for a firm's standard, concluding that it rarely is appropriate to do so (Teece, 1986). The relatively recent success of two firms in one particular industry — Microsoft and Intel — has spawned normative claims consistent with network effects models that vertical integration is obsolete and now a path to failure (Grove, 1996).

As a result, extant theory also assumes that the sponsors of a standard lack the either the capital or the capabilities to produce all the complementary assets necessary, and thus motivate outside suppliers through actual or prospective market share. But if a firm vertically integrates to provide its own complementary assets, then market share may not directly affect software supply.

Not surprisingly, firms choosing to internally provide complementary assets has a long history and continues unabated. IBM thrived for more than two decades based on its role as a vertically integrated supplier of components, software, systems and services (Chandler, 1997). Even before the IBM 360, vertical integration was used to supply complementary assets (content) to supported vinyl record and broadcast TV standards (Langlois & Robertson, 1995; Besen & Farrell, 1994). One of the reasons General Electric is such a diversified firm is that it made investments not only in electrical generation and distribution but downstream in appliances that were powered by electricity. Vertical integration for content was not a factor during the VCR wars, but rather its aftermath: Sony's failure to get enough pre-recorded movies for its VCRs prompted it to buy CBS Records (1987) and Columbia Pictures (1988), while Philips —

which also failed to establish a VCR standard (V2000) — increased its control over its Polygram recording subsidiary (Grindley, 1995: 129). Since the 1985 launch of the Nintendo Entertainment System, publishing videogames has been central to the success of videogame consoles, to the point that consoles are sold at a break-even price to create users for profitable game titles (Gallagher & Park, 2002). Borrowing from this, platform vendors such as Microsoft, Sun and Apple have developed applications to help the success of their respective platforms.

<Insert Table 3: Examples of Vertical Integration about here>

One motivation for vertical integration is clearly related to the chicken and egg problem, when outside suppliers may not see an economic incentive for supporting a new platform and yet platform sponsors need a supply of assets to be successful. Such vertical integration is also effective when the need for complementary assets is limited, such as in personal digital assistants where most people limit their applications to address book and calendar functions. Another is when sponsors of competing standards provide crucial assets — which are thus unavailable to the sponsor of a new standard. A final historical (though not necessarily rational) motivation has been a desire to control all the profits of a market-leading innovation and to facilitate strategic pricing of that innovation, e.g. penetration pricing early.

Variable Co-specialization Costs (1M). The main effect of increasing supply is moderated (1M) by the cost of creating the specialized or co-specialized assets. Since software suppliers want to reach the largest possible market, they will tend to support a wider range of standards if the specialization cost is low for both production and distribution. High specialization cost was applicable in the VCR wars — where inventory costs for each format limited distribution of Beta tapes. It may also be applicable in cases as outlined by Arthur (1996) with high up front costs and low marginal production costs, as with R&D-intensive application software.

But there may be other cases where the cost of specializing is fairly low compared to overall product development costs, and thus suppliers can hedge their bets by supporting multiple standards. For example, the cost of online video streaming is driven by content creation, and by overall network infrastructure to deliver it. Since it is often a automated process handled by a computer program, the cost for a high-volume site to convert content into multiple formats, e.g. Quicktime, Windows Media Player, is low compared to content creation and delivery. If firms can buy licenses on a per-server (or per transaction) basis, firm can easily offer all formats -- not losing any customers -- and letting the market determine the relative importance.

However, we have also observed cases where the cost of specializing may be high but firms still supply product in multiple competing standards. The VCR case (as with LP records before) was driven by exclusive agreements committing software suppliers to particular platforms. But for many types of software, third party developers support any format that has a large enough market share to be attractive, despite duplicative R&D cost. Similarly, during the 1990s, most leading vendors of cellular telephone equipment development support for the major mutually incompatible standards, even offering support for multiple standards in those markets (US, China, Japan) were such standards competed. In addition, a special set of firms will emerge that specialize in converting software from one platform to another, such as with computer game software.

Finally, costs can be reduced by converters — such as when a computer platform (e.g. Mac) has an emulator to run software designed for another platform (in this case, Windows). In addition, efforts to build common platforms across multiple vendors — as with the “open systems” movement (Grindley, 1995) — allows a software developer to supply software for multiple types of systems with little or no-cospecialization cost.

So what are the net effects of variable co-specialization costs? The lower the costs the less likely the market is to tip to one standard and the less impact that will have on consumers and producers if it does.

2. Increasing Product Capabilities

The positive feedback model (main effect 2) is based on the assumption that an increase in the supply of software increases the desirability of the corresponding hardware platform. This part of the model is clearly a stylized version of the VCR example, but may not be applicable for other classes of goods. It rests on two basic premises, each of which can serve as a moderator of this effect (2M).

Variability in the Relationship Between Software and Utility (2M). The first premise is that an increasing supply of software increases the utility of the product. The VCR wars centered on variety-seeking buyers who usually rented pre-recorded videos once and then sought to watch something else. Such a usage pattern places a high premium on variety of complementary assets. A similar usage pattern can be observed in videogames, where variety-seeking teenagers use a game for weeks before discarding and not returning to it.

But is such variety seeking consumption of complementary assets the norm? Or are there a wider range of patterns observed across the complete range of standards contest (see Figure 3)? Three basic patterns seem possible. The first is a monotonic increasing returns pattern, that each new complement increases consumers' utility. While highly stylized, this would basically be the pattern for VCR tapes and DVDs – each new item of pre-recorded content increases customer's utility. However, other patterns are possible. A declining returns to software supply is probably much more likely – are more complements are available the value of each additional one is slightly less. For example, consumer electronics products driven by self-recorded rather than pre-recorded content — such as camcorders — require only distribution of a handful of unrecorded tapes rather than a room full of prerecorded ones. New tapes of different length, say 90 minutes versus 60, add only marginally to the utility of the product. Finally, and this has been the position of network effects harshest critics (Liebowitz & Margolis, 1999), there may simply be some critical value of complements, and it may be fairly low, that results in no additional utility for consumers from complement supply. For example, the adoption of home computers since 1995 has been driven by the Internet. While some also play videogames or pursue esoteric hobbies — which would drive them towards systems with a large software library — others use their computers primarily for e-mail and web surfing, and thus satisfice rather than optimize their search for software (West, 2000).

<Insert Figure 3: Utility Created from Software Variety about here>

Consumer Discernment of Standards Variation (2M). This second premise is how easily can buyers detect differences between the standards? It was particularly easy for VCR or PC owners visiting their local videotape or software store to see the differences in the availability of complements between standards, but is this applicable to all classes of goods? Does it even apply today in the case of online vendors whose physical inventory is hidden from customers (Kotha and Dooley, 1998)? Another example is mobile telephone users, where a greater number of adopters helps support a greater number of radio towers, but differences between network operators, e.g. signal strength, are hard discern prior to purchase? In his analysis of upstream network effects Suarez (2005) points out that this invisibility of network effects at the customer level moved the standards competition up to the supplier level for the competing technologies.

Direct Effects (2A). Of course, as acknowledged by the earliest scholars the utility of a standardized product is driven by both it's intrinsic utility as well as that created from network effects. The question then becomes what is the ratio between a product's intrinsic utility and that which derives from its supply of complements. In their ongoing efforts to dispute the importance of network effects, Liebowitz and Margolis (1994) have argued that the VCR battle was decided by tape capacity (recording longer shows) and not software supply. Similarly, each winning standard in the videogame industry has been displaced by the next generation of game console featuring faster and more vivid graphics, despite a huge initial advantage held by the incumbent in software variety (Gallagher & Park, 2002).

Low Platform Cost Relative to Complements (2 A). Some authors have argued that the buyer of a standardized good tries to anticipate the outcome of a standards contest, and are thus reluctant to invest in a standardized platform that is losing and thus likely to become extinct due to "tipping." This is based on the assumption of switching costs that it is expensive to acquire multiple versions of a platform in order to use multiple versions of software. But in some cases, if the end price of the standardized platform is low compared to the typical complementary asset price, a distinct possibility when one considers that penetration pricing of a core product is a key tactic in a standards battle, a consumer's commitment to any one platform is low. Consumers may switch platforms without great consideration, or simultaneously use multiple standards. A low-tech standards example would be someone who owned two or more razor blade handles (supplied at a low price), and bought whichever type of razor blades were on sale. This is exactly the situation of various web clients given away free, such as streaming media players (RealPlayer, Windows Media, QuickTime) or web browsers. If one particular site requires (or works better with) one given client, and each client is given away free, then the user can install all available clients and use whichever one is appropriate for a given site.

A more moderate example of this phenomena is video games. Currently the price of the platforms is three to four times the cost of individual software programs. Consider the potential for the emergence of a piece of software that justifies not only its purchase but the purchase of the platform as well, so called "killer-applications", e.g. Lotus 1-2-3 for the IBM PC. It is not hard to imagine the emergence of a "killer-application" videogame that is viewed by consumers as being four times more valuable than their next marginal choice on their extant platform.

3) Increasing User Adoption:

The positive feedback model rests on a utilitarian view of product adoption, in which increased product utility drives increased adoption (path 3). Clearly this is an important factor, and no one would argue with this as a general principle, *ceteris paribus,* but then things rarely are exactly equal. Two important distinctions apply to the relationship between increasing installed base further driving product adoption, marketing and variances in the strength of network effects.

Marketing (3A). Marketing often has more to do with the success of a given product than the actual product attributes, including consumer utility derived from its existing installed base. One of the oldest concepts in marketing is the "4 Ps": product, price, place (distribution), and promotion (Kotler, 1980). Labeled 3A on figure 2, non-product characteristics include:

- *Price*. Capable lower-priced products are more likely to become mass market items, and mass-market solutions have generally trumped specialized solutions in standards wars (Morris & Ferguson, 1993). So in handheld computers, the Apple Newton had far more capabilities and a three year head start with complementary assets, but the 1996 introduction of the Palm Pilot at half the price quickly dominated the category and eliminated the Newton within two years.Toshiba's HD DVD also fought against Blu-Ray on the basis of a lower price before finally succumbing to a coordinated series of strategic decisions by complement providers.

- *Place*. Distribution is important in the success of any product, both in terms of the product and also its associated complementary assets. If users don't see the product (either tangibly or in catalogs or web sites), then they cannot purchase it. During the VCR wars, Phillips' V2000 format was technically comparable, if not superior, to both Matsushita's VHS and Sony's Beta. However, with distribution only in Europe — not on three continents as with the Japanese formats — it was unable to match even Sony's volumes and was quickly supplanted.
- *Promotion*. Advertising, co-marketing and other promotional efforts increase the name recognition and credibility of any product. Even relatively uncontested standards can bring heavy promotional efforts, as when Microsoft spent $200 million to launch Windows 95. The stakes will be higher in a contested standards battle: for example, for 2001 launches of the Xbox and GameCube video game consoles each side budgeted nearly $500 million for initial promotion (Guth & Tran, 2001).

Sponsoring Firm Resources (3A). Closely tied to marketing, many of the other factors in the success of a product standard tie back to firm resources. Increasing product capabilities via R&D, better distribution and larger advertising budgets all require both capabilities and capital. Price wars either require economies of scale or the capital or diverse product lines to subsidize low-margin introductory prices until rivals exit. Especially during the early periods of competition, a firm with greater resources can afford short-term losses in hopes of long-term profitability. In addition, large incumbents may have other resources not available to startups, such as distribution, brand name, R&D labs and patents.

The mythology of Silicon Valley emphasizes the success of new entrepreneurial start-up firms in fast-moving high technology industries (Levering, Katz & Moskowitz, 1984). In this theory, the new entrants are first to new technological opportunities that are underestimated by incumbents (Foster, 1986). This early stage of a new technology is precisely when most *de facto* standards competition occurs, and thus firms that overlook at opportunity too long will be unable to successfully promulgate a new standard.

At the same time, other researchers have noted the advantages of well-capitalized Fortune 500 sized incumbents, particularly for R&D intensive industries (Ferguson, 1988). This is particularly acute during times when new firms are unable to raise new capital, as in the period 2000-2001 after the .com stock crash and declining I.T. spending eliminated most internal and external sources of capital for young firms. During this period, Microsoft was able to advance its standards by increasing R&D and marketing expenses at a time when single-product line technology rivals were cutting back (Buckman, Tam & Mangalindan, 2001). This further reiterates the power of firm resources, cross product subsidies, and other corporate strategy issues in resolving a standards battle.

First Mover Advantage (3A). Another direct relationship is the timing of market entry. The earlier a product is on the market, the more time it has to gain adopters. Of course, this is only really an issue if there are switching costs, assets that can be preempted, or large reputational advantages to be reaped (Lieberman & Montgomery, 1988). This basically reverts to an issue of the strength of network effects and if there is a critical hurdle rate of complements or a more linear relationship between market share and utility. This gives rise to examples of niches, such as different cell phone standards in different countries, or clusters of users around different applications, such as the Apple Macintosh's continued dominance of the graphic arts.

Segmentation: Profits vs. Units (3A). The positive feedback model is based on relative success in unit sales of the product incorporating a standard. For hardware such as a VCR, PC, videogame console, the suppliers of complementary assets care about the unit sales of the hardware because each represents a potential customer.

However, the sponsoring firm's long-term interest lies in profits not market share. Firms that blindly pursue market share can both disrupt operational efficiency and unexpectedly incur substantial losses (Anterasian, Graham & Money, 1996). This was touched on earlier when we discussed the boot strap process. Price is an important tool for engendering adoption of a core product, this puts a lot of emphasis on market share. However, the firm must survive. Only in the most unusual of cross subsidy situations, e.g. Microsoft's multi-billion dollar support for its video game unit, can firms pursue market share alone for extended periods.

Nonetheless, it may be possible for a standard sponsor to segment the market and pick a profitable niche, just as with other types of products. This will disappoint suppliers of complementary assets but could still prove a successful standard strategy as long as it provides for minimum efficient scale. Such as a niche strategy depends on differentiation that keeps the larger market distinct, as Apple was able to do with its Macintosh standard (West, 2000). Otherwise, the general purpose solution with its flexibility and economies of scale will vanquish its niche rival every time (Morris & Ferguson 1993).

Variable Network Effects (3M). In addition to these marketing variables, all network effects are not the same in every market. This has the effect of moderating (3M) the feedback on future customers from a product's installed base. Products that must be interconnected to be of use to the consumer have higher network effects than those that simply require the provision of complementary products. For example, the number of extant telephone users is more important for a potential consumer in that industry than the number of LP record players would be for a similar consumer. The strength of network effects can also varies in an industry. Consider the personal computer industry. During the 1980s the network effect of selecting a PC was primarily driven by software availability (Cottrell & Koput, 1998). However, later in the 80s and 90s, PCs were increasingly networked together providing a larger incentive for standardizing on a single platform (Bakes, Kim and Ramos, 2003). Large firms also developed specialized information technology departments that further institutionalized this standardization, increasing the positive feedback to select a specific platform, (i.e. Windows).

Network effects are clearly important but their role can easily be overstated. In addition to marketing, traditional strategic considerations such as minimum efficient scale, learning effects, and market timing need to be considered. In the absence of network effects consumers will choose products on the basis of their relative location on the price/performance frontier. Price and certainly profits are often driven by costs so issues of when economies of scale start to be realized as well as other drivers of cost reduction can be significant. Firms that seek market share due to their worries over tipping may be tempted to go prematurely to the market. This appears to have happened to several PDA makers in the early 1990s.

Finally, another explanation for when markets tip and when they do not is the idea of variable network effects. Network effects, the degree to which one user's utility of a product is determined by how many other users of that product there are, could vary across both products and over time. For example, the importance of a common standard for telephone communication is more important for the success of the product than for say a new recording medium. The early users of the a new telephone network would reap no utility unless the people whom they wanted to communicate with had also joined their network. Conversely, the purchaser of a new recording medium, say a 8mm format Cam-corder, could still enjoy their product, even if few others purchased one. Furthermore, network effects are not static, they can evolve in markets over time. For example early on network effects were relatively low in the personal computer industry as the computers themselves were not very powerful and it was not expensive to develop software for multiple platforms. However, over time, production values became more sophisticated, software became more expensive and network effects grew. Furthermore, the desire to network computers together begin to emerge further increasing network effects. This can also work in the opposite direction, network effects may become less important over time. As Liebowitz and Margolis (1994:140) point out, "Many activites require a critical mass but are not much helped by participation beyond that level. … [T]he marginal benefits of increasing the number of households that own our kind of VCR are likely exhausted now."

4. Structuring the Tipping Phenomena: Market Evolution and Network Effects

Both the fear and reality of Betamax-style extinction have had a powerful influence on the practice of sponsors, suppliers and adopters, who seek to predict whether, when, and to whom a standards contest will "tip." But few standards have the same relationship to complementary assets as do VCRs, so it is important to re-examine the fundamental feedback mechanisms behind the "tipping" model and assess their applicability. So in order to further understand the tipping mechanism, we propose integrating two environmental variables that are consistently important across all standards battles – the nature of the network effects (see figure 2 and figure 3) and the industry's stage of adoption. We will then tie this into the four types of resulting standards battles (see p. 26).

There have been many models of market evolution over time. Perhaps an especially useful one is Rogers' (1995) typology of adoption motivations. The most daring adopters he labels "innovators," those who are willing to try something without a proven market and the possibility that an innovation will fail. For most innovations, the bootstrapping process must continue to the early adopters, who are opinion leaders in their community. Many innovations fail to go beyond these two categories, failing due to the "chasm" between early and mass market adoption motivations (Moore, 1991). The provision of complementary products becomes increasingly important as the product moves towards mass market adoption. This is the classic chicken and egg problem - while innovators may not care too much, those in the mass market definitely will. There is no shortage of examples of these products that failed to make this hurdle including quadraphonic sound (Postrel, 1990) and the digital audio tape.

Any standards contest will have a first entrant and one or more followers. By definition, the pioneer starts with 100% share, but the reality is many of such pioneers fail (Schnaars, 1994). For example, Sony's Beta format had the market to itself for over a year in the both the US and Japanese market (Cusumano, et al, 1992). Other early winners were also vanquished: Among 16-bit PCs in Japan, NEC's PC-98 platform dominated the market for 7 years, holding a 60% market share, yet 5 years later had a 33% share (West & Dedrick, 2000). A similar fate befell the Apple Newton. So obviously, early market leadership is no guarantee that the contest will tip to such an early leader.

The key question is when does such an "early" phase end, i.e. how long is a contest "up for grabs?" Roger's typology for innovation diffusion offers some insights. Rogers (1983) identifies potential break points as after a market's innovators (first 2.5%) or its innovators and early adopters (first 16%) have chosen one standard or the other. Of course, these groups have different demand profiles than later adopters, this makes identifying a cut off point much more difficult (Moore, 1991).

When the market will tip between any one of these three break points – innovators, early adopters, or mass market – we think will be driven by the nature of the network effects in the industry. Not surprisingly, the stronger the network effects, the faster the market will tip. As shown in figure 3, if the network effects indicate monotonic increasing returns, then we expect a clear winner, probably identified even before the product is introduced to the market, as firms attempt to make an agreement anticipating the strong network effects they will face. A more interesting case is when there are decreasing returns to the availability of complements. In this situation a standards battle may only tip later in the market's life, or not at all. If the complements are only a small part of the cost of the product, or if converters can be provided to get users to the point where the returns flatten out, then tipping is much less likely to occur. Finally, as championed by some network effect critics, in circumstances where their effects mirror the critical value pattern, markets may not tip at all. This latter pattern may have become more the case in the PC industry where we see Apple's Macintosh mounting a serious comeback in market share driven by internet access and Microsoft Office being the compelling complements.

5. Nature of Standards Battles

The basic model describes any one standards battle. However, many standards battles take place against different backdrops, especially prior standards battles. Therefore, a final challenge is once a standard established, when does the next battle begin? The tendency has been to gloss over this issue leaving technological discontinuities as endogenous. However, this may not be the case, perhaps the nature and strength of lock-in determines how great a technological advance must be in order to be significant enough to result in a technological discontinuity. CDs supplanted records and cassettes, despite the ability of the latter to also record. How much better did CDs have to be in audio fidelity, durability, and compactness in order to prevail? Did the fact that network effects were not very pronounced in these markets aid the rise of CDs? How high must the frog leap to use one author's metaphor (Schilling, 2004). What about something like the QWERTY keyboard that relies on tacit user knowledge as its foundation of being a standard? How much better must the next keyboard be? It is interesting to note that other areas where specialized operators were used for functions similar to typing, such as linotype machines in newspapers and court reporter's stenotype machines, did not quickly move to QWERTY (Tripsas, 1997).

Four basic types of standard battles have been observed. The first are one time or static contests where the winning standard prevails for many product cycles, e.g. RCA's NTSC color broadcasting standards. The sheer volume involved often results in standards being frozen and helps explain the failure of Sony's MiniDisk, Philip's DAT and other similar efforts. A second type consists of clear episodic contests that repeat with every new product generation, such as with home video game consoles. These successive battles are not linked by reuse of complements or installed base. In the videogame industry, there is episodic competition as the major players introduce new consoles every five years. However, there are few if any linkages between generations: each battle begins anew because (with rare exceptions) the new consoles are not compatible with the previous installed base of software. The new consoles have been sold based on exciting new games that take advantage of the new technology, and thus compatibility with older games is not highly valued. Third, there are linked series of contests, similar to episodic contests, but when complements from one generation carry over to another. In 1989, the Macintosh had a dominant market share (and variety of complementary software) compared to

Windows and other GUI-based personal computers, but over the next eight years the Macintosh market share fell to less than 10% as the installed base of MS-DOS users switched to Windows 3.x and then Windows 95. Sony changed the nature of the home video game industry's competition from episodic to linked series when it made the PlayStation 2 backwards compatible with the earlier PlayStation. Finally, standards battles can be effectively continuous in nature, such as with software. Internet-based client software such as web browsers or streaming audio players can be and often is upgraded on a monthly or even daily basis (Cusumano & Yoffie, 1998).[4] More expensive hardware sold to industrial customers in small numbers — such as mainframe computers or Internet routers — is also more practical to field upgrade than a consumer video console or VCR.

6. Conclusions

The actual practice of standards competition over the last 20 years has often diverged from the stylized model adapted from the 1980's VCR wars. There are some key opportunities to extend our knowledge of *de facto* standards competition, to determine how often the VCR model is applicable, and to identify conditions under which new model(s) are most appropriate. At the same time, managers making decisions in environments where the VCR assumptions are no longer applicable should be most wary of making product strategies assuming that the VCR predictions are also applicable.

This paper has expanded and refined the current dominant logic of competition in standard based industries. The traditional "triangle" model (figure 1) is subject to numerous moderating

[4] Technically speaking, the so-called "browser wars" of 1995-1998 did not involve proprietary *de facto* standards, but instead proprietary extensions to open, public good standards. This meant that web page content co-specialized to one browser would be partially compatible

effects that are often significant. The most common is the idea that network effects are variable, but each issue discussed here, supply, capability, and user adoption, as well as a number of other minor factors, are important in fully understanding competition in these complex industries.

For managers, it is no surprise that the model is complex. However, we hope that by integrating a lot of the complexity they encounter onto an extant parsimonious model, that greater insights can be gained in practice. Furthermore, all authors who have written about standards note that they are an additional layer of complexity, and we hope this paper is viewed as a successful effort to integrate that overlay with the large number of other factors that can influence success in a competitive market.

For scholars, the challenge of understanding standard based industries is that each battle is simply one observation that can be used to test a model. By developing a more fully specified model that builds on common practice, we hope to facilitate the extensive cross case analysis that needs to occur to really untangle what happens in these markets. To attribute a firm's success to only building installed base that then results in the dominance of a single standard, i.e. tipping, is a tremendous oversimplification.

This re-examination and broader view of how and why tipping occurs is important for firm R&D policy for many reasons. First, to the extent that standards competitions remain de-facto, the current trend, it is frequently the product/service attributes of the products themselves and their marketing that determines who prevails in the market. Second, decisions made at an early stage in product design and development can have important marketing consequences. The VHS/Betamax duel was not decided just by tape length or image quality but also by how much easier it was for Matsushita to build its VCRs than it was for Sony. Second, product designs for

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with the other(s), or that for a small incremental effort, suppliers could choose to publish content in a format compatible with all major browsers.

competition in standard based industries should consider the dynamic nature of network effects. When network effects are seen to be dynamic rather than static product configuration becomes much more important. For example, Sony's tremendous success with its Play Station 2 may be partially based on the fact that it is the only video game player to be backwards compatible with its successful prior generation sibling.

There are a large number of areas available for future research. The first would be efforts to accurately capture the different shapes of network effects that have occurred. A lot of speculation, including that done in this paper, is contingent on what they look like in any one market, but this area seems under developed. Second, there are opportunities in examining platforms, especially fixed versus upgradable platforms in standards battles. We expect more standards battles to become more dynamic, i.e. moving away from the static battle, due to the increasing digitalization of consumer products that allows them to be upgraded much more easily. But little research has been done on the relationship of such upgradeability to the practice of *de facto* standards competition. Is there a fundamental difference between one-time and ongoing standardization? As field upgradeability becomes the norm in consumer devices, will all standards contests converge to a common continuous or linked series pattern?

Questions also remain as to buyer decisions regarding simultaneously evolving standards. Is a rapidly evolving standard considered a positive (high innovation) or a negative (high uncertainty)? When comparing two evolving standards, do buyers use the current or some leading (or lagging) measure of standards capabilities? What level of forward- and backward-compatibility do they expect? To what degree is this contingent on usage patterns, such as satisficing vs. consuming software, and the periodicity of hardware replacement. Another potential area is the role of network effects and the potential for tipping in e-commerce. While we tend to associate tipping with physical products, there are several possibilities for tipping in information businesses where interconnectivity is important. For example, consider eBay. As more and more people use eBay it attracts more sellers as well as more buyers. This is a classic example of a network effect. Not surprisingly, no other significant rival, not even Amazon, has managed to threaten eBay's market leading position.

Finally, probably the most important area for future research centers around the price and benefits of winning or losing a standards battle. What challenges trip up firms who do see their standard adopted - yet are unable to capture any positive returns from doing so. The extant models tend to assume that once the standards battle is won the firm will be able to extract rents, however numerous examples suggest that this is not so. Palm Pilot dominated the PDA market but never showed considerable profits. Hayes' AT command system was the standard of dial up modems but did not save it from bankruptcy…twice. Clearly, additional research on how firms can exploit their success and limits on it are warranted. It may be that additional firm specific resources are necessary to fully exploit the tipping of a market to a firm's standard. For example, Matsushita enjoyed tremendous economies of scale in its VHS production compared to Sony's Betamax. Recent work has shown firms can obtain higher revenues by establishing the dominant design (Cylmer & Asaba, 2008). Similarly, in CAT scanners, GE had no problems overtaking the standard setting firm EMI because the "standard" was published in academic journals. Conversely, even when a market tips it is still possible for firms to generate considerable profits servicing their now legacy products. The Federal Aviation Administration still purchases vacuum tubes for the U.S. Air Traffic Control system. Microsoft's Windows dominates the personal computer operating system yet Apple continues to report profits from its Macintosh computer line. In an empirical study of the personal computer industry it was shown that many companies were able to perform quite well by adopting the dominant design (Tegarden, Hatfield, and Echols, 1999). This further suggests that even when markets "tip" it may be possible for firms to remain competitive if they are able to license or copy the relevant standard.

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Tables and Figures

Table 1: Major contested *de facto* standards batt*les, ca. 1980-1999*

Consumer Electronics

Quadraphonic audio
Video cassette recorders: VHS vs. Beta
Camcorders: VHS-C vs. Hi-8
Digital Camcorders: Digital 8 vs. MiniDV
Digital Memory Cards: SmartMedia vs. CompactFlash vs. MemoryStick vs. Secure Digital (MMC)
Digital audio: MD disk vs. DAT
DVD (read only): DVD vs. DIVX
DVD (writable): DVD vs. DVD-ROM vs. DVD-RAM
HDTV (?): In U.S. government mandated compromise.

Video Game Consoles

8-bit: Nintendo Entertainment System vs. Atari 7800
16-bit video games: Sega Genesis vs. Super NES
32-bit video games: Sony PlayStation vs. Sega Saturn vs. 3DO
64-bit video games: Nintendo64 vs. Atari Jaguar
128-bit video games: Sega Dreamcast vs. Sony PlayStation 2 vs. Nintendo GameCube vs. Microsoft Xbox

Networking and Communications

Networking protocols: TCP/IP vs. OSI
LAN: 100Base-T vs. 100VG
Wireless LAN: Wi-Fi (802.11) vs. HomeRF vs. OpenAir
56K modems: x2 vs. 56flex
Digital cellular telephones (U.S.): GSM vs. cdmaOne vs. NADC

Computers & Operating Systems

PC operating systems: Windows vs. OS/2 vs. Mac vs. Linux
PC architectures (Japan): PC-98 vs. DOS/V
Unix variations: OSF vs. Unix International
Programming languages: Java vs. C#

Application Software

Word processors: Word vs. WordPerfect
Spreadsheets: Excel vs. Lotus 1-2-3
Databases: Oracle vs. Access vs. Sybase
Object frameworks: ActiveX vs. Corba

Internet Client Software

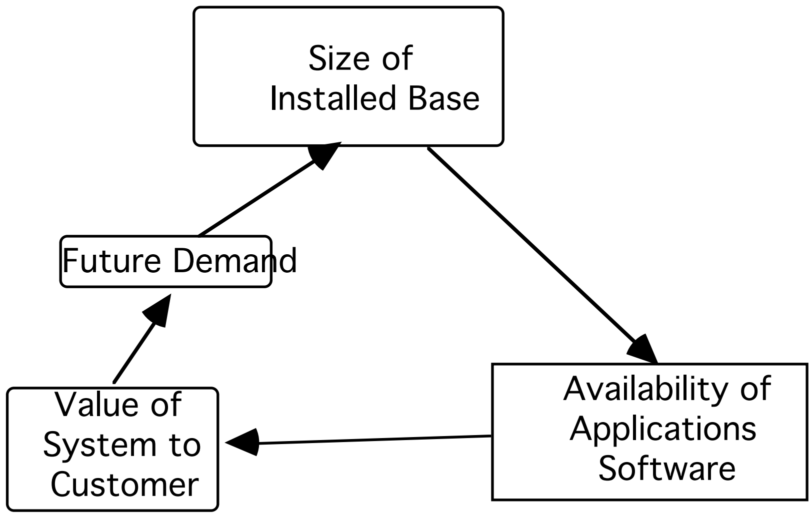
Web browsers: Netscape vs. Internet Explorer
Streaming media: RealMedia vs. Windows Media (NetShow) vs. QuickTime
Teleconferencing: H.320 vs. ProShare
Instant Messaging: America Online Instant Messenger vs. ICQ vs. MSN vs. Yahoo (all based on IRC?)

Table 2: Summary of paths in robust positive feedback model

Path	From	To	Hypothesized Main Effect	Possible Moderators
1	Number of users	Software supply	Larger markets attract 3rd party software suppliers	If cost of co-specialization is low, 3rd parties may support multiple standards
1A	*internal software development*	Software supply	Sponsors vertically integrate to provide their own software	*limited by sponsor resources*
2	Software supply	Product utility	Users value standards with wider variety of software	a. Observability b. Declining marginal returns c. Satisficing
2A	*other product attributes*	Product utility	Sponsors improve product quality, innovation, performance	*limited by sponsor resources*
3	Product utility	Number of users	More capable products are more popular	Complexity of products dissuade users
3A	*3Ps*	Number of users	Sponsors work on price, place (distribution), promotion	*limited by sponsor resources*

Table 3: Examples of vertical integration

Sponsor	Segment	Standard	Integration
Microsoft	PC operating systems	Windows	developed application software to fuel adoption
Sony	pre-recorded audio and video	*various*	purchased CBS Records and Columbia Pictures
Sun	operating systesm	Solaris	Purchased StarOffice office suite
Microsoft	handheld operating systems	Windows CE	ported popular Windows 95 applications and utilities, bundled with OS to PDA manufacturers
Nintendo, Sega, Sony, Microsoft,	videogame consoles	*various*	published popular game titles with proprietary characters to spur initial console sales



Source: Hill (1997: 9)

Figure 1: Positive feedback network effects model for PC industry

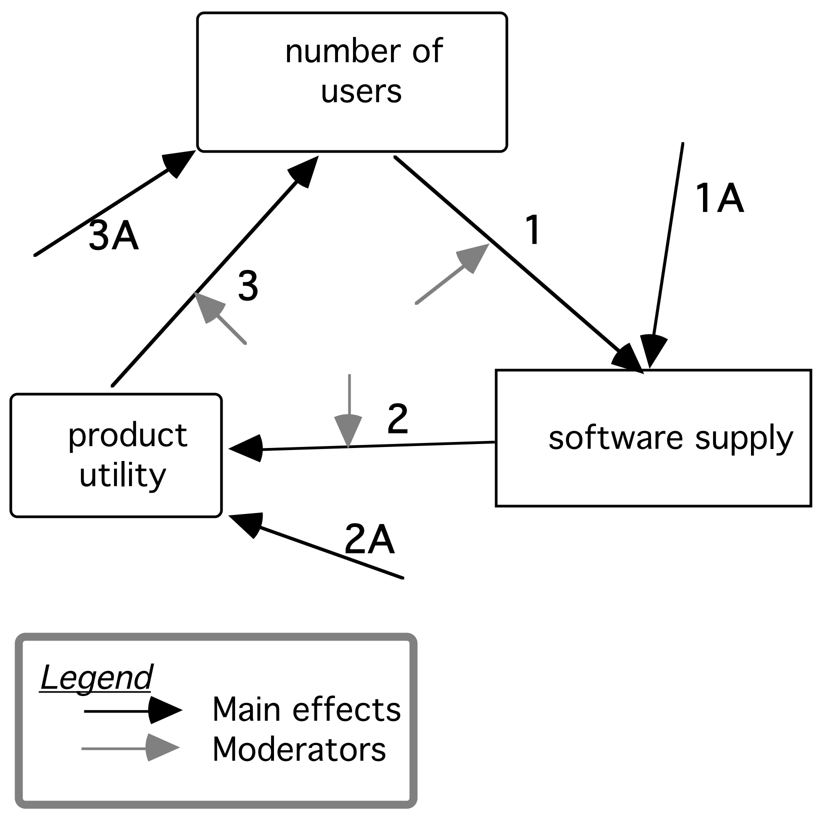


Figure 2: Robust adoption model incorporating positive feedback

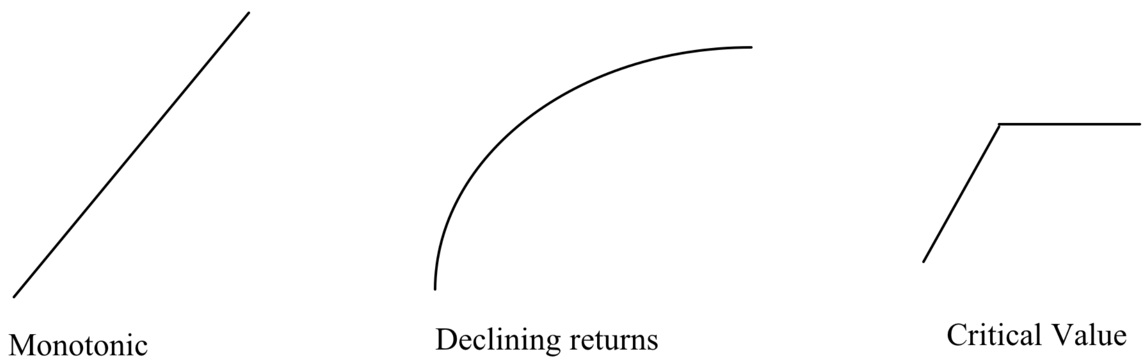


Figure 3: Utility creation from software variety