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Survey on Competing in Network Industries: Firm Strategies, Market Outcomes, and Policy Implications*

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Abstract. We review the recent literature on market structure, firm strategies and public policy in network industries. In particular, we focus on the latest applied work, including case studies and empirical work as well as refinements of the established theoretical results. We group each set of results along two dimensions: Static (within-generation) and dynamic (across-generations).

Keywords: network effects, market structure, firm strategies, public policy

1. Introduction

Network effects are commonly defined as the general property that the utility of a product increases with the number of users. They are sometimes called ''demand-side economies of scale'', suggesting that network effects are similar in their outcomes to economies of scale on the supply side. The literature distinguishes between direct (communications) and indirect (systems) network effects. In the first instance, the utility for an individual consumer increases when there are more others to communicate with, while in the second, utility depends on the availability of complementary goods, which in turn depends on the number of potential buyers—again generating a positive effect of other users on an individual's utility.

Network effects have long been a subject of intense study in the Industrial Organization literature. Many aspects of competition in network markets (*i.e.*, market displaying significant network effects) have been studied theoretically, such as pricing (*e.g.*, Laffont et al., 1998), product introduction (*e.g.*, Katz and Shapiro, 1992), R&D (*e.g.*, Kristiansen, 1998) and others. Of particular interest in the literature has been the study of consumers' adoption incentives. Models with strategic (*e.g.*, Farrell and Saloner, 1985, 1986) and myopic (Regibeau and Rockett, 1996) adopters have been developed and

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shown to generate different market outcomes. Both the myopic and strategic adoption assumptions can be justified, while reality—*i.e.*, how adopters decide which (if any) technology to adopt—is likely to be somewhere in between. Similarly, models with competing new technologies also have to specify precisely the strategies available to proponents of the technology—sponsors who can price their technology strategically can overcome a superior, but unsponsored technology that is priced at marginal cost (Katz and Shapiro, 1986).

Since theoretical models with network effects generate very different outcomes dependent on the assumptions about agents' behavior and the strength and functional form of network effects, empirical work is necessary to corroborate and discriminate some of the assumptions and to measure the strength and overall importance of network effects.

The first wave of empirical work has mainly focussed on the question of existence of network effects: They have been found to exist in the PC and software industries (*e.g.*, Gandal, 1994; Koski, 1999; Gandal et al., 1999; Sarnikar, 2002), fax machines (Economides and Himmelberg, 1994), ATMs (Saloner and Shepard, 1995), telephone directories (Rysman, 2004), VCRs (Park, 2003; Ohashi, 2003), consumer electronics (Bayus and Shankar, 2003; Gandal et al., 2000) and others. Most of these papers however mainly set out to show the existence of network effects in these particular industries.[1,2] In particular, the connection between the strength of network effects and the likely market structure is rarely made in empirical work. Also, the relationship between expected market structure and firms' and policymakers' strategies to affect it has not been studied in great detail.

In this survey we summarize the results from earlier literature and stylized facts along three lines: market structure, firm strategies and public policy. We document and discuss the market structures likely to emerge in network industries. Since utilities are interdependent across consumers in network industries, there is a tendency to follow earlier adopters and choose similar (*i.e.*, compatible) products. On the other hand, we give examples and explain why this need not necessarily result in complete

1 There are several ways of documenting the existence of network effects. In the hedonic approach (*e.g.*, Gandal, 1994; Sarnikar, 2002), the installed base is treated as a product characteristic that will have a positive effect on prices if there are network effects. In the adoption approach (*e.g.*, Koski, 1999, Gandal et al., 1999), the installed base at $t-1$ carries a positive expected sign in the adoption or diffusion equation at t. The complementary goods approach (*e.g.*, Gandal et al., 2000) derives a system of equations and uses the number of software available as a variable in hardware adoption regressions and vice versa. Finally, the timing approach (*e.g.*, Saloner and Shepard, 1995) establishes that firms with higher expected network effects will adopt a technology earlier and proxies expected network benefits by the number of potential (internal) users of the technology.

2 Most of the recent papers in this list add one particular angle to the question of existence however. For example, Gandal et al. (1999), Ohashi (2003) and Park (2003) document the dynamics of a standards battle, and Bayus and Shankar (2003) and Ohashi (2003) estimate the strength of network effect on a vendor level or for different time periods, respectively, and find that the strengths may vary by vendor or time period. Most recent empirical structural models with network effects also perform some welfare or counterfactual analysis with the obtained parameters on demand and network effects.

standardization. We also track technological generations over time and find that the pace of technological progress is affected by the presence of network effects. After surveying predicted and actual market structures, we review firm strategies and policymakers' actions in network markets. Profit-maximizing firms will factor in network effects in the formation of their strategies. Further, there are strategic instruments specific to network industries, such as vaporware (or more generally the management of consumer expectations), the strategic choice of compatibility and R&D strategies in network markets, which we will discuss in detail. Policymakers have also played a crucial role in the development of network industries. Since AT&T's breakup—largely based on the notion that combining local and long-distance telephony in one firm may create unhealthy tendencies to abuse monopoly power—competition authorities have kept a keen eye on the dealings of (actually or potentially) dominant owners of network technologies, often having to tread a thin line between preserving innovation incentives and keeping alive healthy competition. Research on public policy in network industries so far has focussed either on specific industries (see, *e.g.*, Laffont and Tirole (2000) for a treatment of issues specific to telecommunications markets) or on the elusive social planner who can implement first-best solutions, but clearly more work is needed here. We summarize and discuss the work done so far and suggest directions for further research.

Any survey on a topic as wide as network markets is necessarily selective. It is appropriate that we make our biases clear at this point. First, we emphasize results from the theoretical literature that have been studied empirically, and try and account for some of the situations we observe in real life but that do not have a corresponding result in the classical formal papers. Second, we feel that previous surveys have been focussing on a set of theoretical results on certain issues in network markets rather than their empirical implications and factors that are likely to affect these results in real life.[3] Our survey therefore attempts to fill a gap in the meta-literature on networks and standards. Third, and possibly most evident in this piece, our choice of topics has been influenced by our own work on the economics of network markets. While these justifications are not an excuse for some of the omissions we undoubtedly make, we want to at least offer an explanation for them.

The structure of this survey is as follows: we discuss actual and predicted market structures in network industries in Section 2, we review firm strategies in Section 3 and turn to public policy issues in Section 4. Section 5 concludes the paper.

3 Some recent surveys that give an excellent overview of the state-of-the-art in theoretical work at the time of their writing are David and Greenstein (1990), Gilbert (1992), Katz and Shapiro (1985), Economides (1996a), Matutes and Regibeau (1996), and Farrell and Klemperer (forthcoming). Gandal (2002) is a recent survey that focusses on policy relevance, and Shapiro and Varian (1999) give an entertaining and comprehensive ''how-to'' guide to decisionmakers to deal with network effects in their spheres of influence.

2. Market structure in network industries: facts and predictions

One of the reasons why network industries often feature prominently in the popular business press is that success and failure seem to be very close together. For every Windows-style success story, there is a failure of Betamax dimensions. New, ostensibly superior technologies fail spectacularly while incumbents hang on to their market share seemingly too long in spite of superior alternatives for consumers. In a nutshell, network effects seem to generate extreme and often unpredictable outcomes on the one hand, but over time market structure and leadership in network industries appear surprisingly stable. This section documents and explains these two features of network industries.

2.1. Within-generation market structure

When taking a snapshot of network markets, it appears that similar products can have very different market shares. VHS and Betamax VCRs had different strengths, but their overall quality appeared roughly equal,[4] yet the ratio of their market shares was 2 : 1 in 1981 and 9 : 1 in 1988. Microsoft's Windows OS was modeled after the Apple graphical user interface, so that the specifications and the ''touch and feel'' were inevitably similar. The ratio of Microsoft's share to Apple's was more than 10 : 1 in the 1990s, less than a decade after Windows' introduction. Network effects are said to be at least partly responsible for these extreme outcomes.

The theoretical literature states that small initial advantages (Arthur, 1989; Arthur et al., 1983), different consumer expectations (Katz and Shapiro, 1985) or differences in firm strategies (Katz and Shapiro, 1986) can all translate into highly asymmetric market structures in the presence of network effects. In these models, entering a network market thus seems a highly risky bet from the outset, as technologies (and their sponsors) end up in one of two buckets: Total success or dismal failure.

This result from the early theoretical literature has been documented in case studies and empirical studies and seems to hold true up to a certain degree: There is a single format of VCRs (Park, 2003; Ohashi, 2003), all CD players and CDs are compatible with each other (Gandal et al., 2000; Gamharter, 2003), and stereo sound remains the standard for all hi-fi sets (Postrel, 1990). There are exceptions to this rule, however. Although the overwhelming majority of desktops run on Microsoft operating systems, there is a stable minority of users that use competing products (Kretschmer, 2003b). There are currently three incompatible game console systems competing for consumers (Genakos, 2001; Bayus and Shankar, 2003), and in Switzerland, a rather small country, four languages have been coexisting for centuries. We discuss three factors limiting the degree of dominance of a single technology: consumer heterogeneity, existence of a critical mass for software and local network effects.

4 Both were, in fact, developed from the same technology, U-Matic.

It seems obvious that if network effects are comparably small, they may not be sufficient to dominate consumer heterogeneity, and multiple standards may coexist to cater for varied tastes (Farrell and Saloner, 1986). This typically does not preclude a single technology from dominating large parts of the market since network effects will still convince *ex-ante* indifferent consumers to adopt the dominant standard, but it allows for niche products to survive. Heterogeneity may originate from inherent consumer preferences,[5] from differences in the willingness and ability to pay,[6] or from differences in demands on the technology. Different demands appeared to contribute chiefly to the usage of alternative operating systems in Kretschmer (2003b), who documents the operating systems usage of firms and shows that establishments with more varied tasks are more likely not to standardize on the Microsoft operating systems family.

If network effects are indirect (*i.e.*, originate from the availability of complementary products), there may be a threshold, or critical mass, beyond which an additional user or variant of a complementary product does not confer any additional value. For example, it is well-known that game console software has a highly skewed sales distribution. In 2003 up to October, the best selling game in the U.S. (Madden NFL 2004 by EA Sports) sold close to half a million copies, while its closest competitor, Tiger Woods PGA 2004, sold 180,000. In revenue terms, the difference is even more stark: Madden NFL outsold Tiger Woods PGA by 3 : 1, and the number 10 game (All-Star Professional Wrestling) by 23 : 1.[7] What's more, these ''blockbuster'' games are rather predictable: Lara Croft's Tomb Raider made the top five in all of its incarnations, and most games charts consist overwhelmingly of sequels, expansion packs and spinoffs from movies (http://www.playcenter.com). What does this imply for market structure? If a large proportion of consumers only want to play a tiny selection of games anyway, any system that can provide a sufficient number of blockbuster games is viable and thus unlikely to be crowded out by a system that offers yet more games and complementary products. The existence of a threshold effect or critical mass of software may therefore generate a relatively even spread between technologies even in the presence of network effects. If relatively indifferent consumers split more or less evenly between technologies passing the threshold, the overall market structure may be equitable, on outcome we do not obtain in pure cases of consumer heterogeneity.

Languages are especially evocative examples of the third factor curbing market-wide standardization, local network externalities. Every holidaymaker having traveled to a remote village in a foreign country had the experience of being unable to communicate with the locals, who seem curiously unwilling to learn languages spoken elsewhere.

5 For example, despite the unanimous adoption of the CD among home users of audio equipment, DJs have persisted in buying vinyl records because it allows them to handle the sound medium more accurately and immediately than CDs. Lately however, even this last stronghold of vinyl seems to be waning (http://www.thedecks.co.za/djwords/cdvinyl.htm).

6 Bental and Spiegel (1995) develop a model in which network effects are a source of vertical differentiation. The firm with the largest network consequently charges the highest price, which drives consumers with lower willingness to pay for quality to the lower-quality option.

7 http://www.the-magicbox.com.

This is in fact rational behavior on the part of the locals provided they do not travel themselves and theirs is not a major tourist destination, since almost everybody they are likely to interact with speaks the local language, there is no need to study any other language. For instance, in Graubünden/Grisons (Switzerland), Romansh, a language closely related to Latin, is still spoken, mostly in small villages that are difficult to access from outside and have therefore been shielded from outside influences for centuries. In Rondonia (Brazil), two languages spoken by four and seven people respectively have recently been identified, stemming from Indian dialects rather than Portuguese (http://www.ogmios.org). These and many other examples suggest that languages are maintained as a function of the people that its speakers are likely to encounter—so-called local network externalities. ''Local'' however is not to be understood only in terms of spatial characteristics, but more generally as a set of agents that interact more frequently or intensively with each other than with other agents, which then allows for a broader interpretation of isolated (standardized) equilibria. In a series of papers, Jonard and Yildizoglu (1998a,b) and Cowan and Miller (1998) show that local externalities are at the heart of technological diversity, *i.e.*, non-standardization.[8] Local (*i.e.*, national) externalities of the most extreme form of course also explain the left versus right-steering problem in different parts of the world. Many technologies are also regionally standardized, but nationally diverse—pest control strategies (Cowan and Gunby, 1996) *e.g.*, display strong network effects for short distances[9]—causing regions to standardize, but as distance grows, network effects vanish, and another standard prevails elsewhere.[10]

The examples show that network effects are not necessarily strong enough to force standardization. Economists have recently started to incorporate this into their work by letting the shape of the network benefit function vary. For example, Jonard and Schenk (1999) study different functional forms of the network benefit function and their effect on compatibility choice, and Bassanini and Dosi (1998) show that standardization need not ensue even with unlimited, but decreasing network benefits. Swann (2002) derives the shape of an aggregate network benefit function from individuals' utility functions. In fact, Swann finds that linear (let alone convex) network benefits are only likely to materialize under very restrictive conditions and argues that most two-way communications networks (*e.g.*, e-mail, telephony language *etc.*) will have decreasing marginal network benefits. There has not been any empirical work to our knowledge that specifically recognizes and

8 Church and King (1993) develop a model with global network externalities to analyze the incentives to be multilingual and find that speakers of the minority language will have an incentive to learn the majority language but not vice versa. A conjecture of their model is that the minority language will die out eventually because adopters starting afresh will learn the majority language and stay monolingual. A standardized outcome therefore is likely to evolve in their model.

9 Network effects here are true externalities in the sense that pesticides travel through the air and affect neighboring crops, which may or may not be beneficial for neighboring farmers depending on their own pest control strategy.

10 Mukand and Rodrick (2002) develop and test a model in which ''national social policies'' diffuse in the order of geographical distance from a pioneer, suggesting local network effects or knowledge transmission.

estimates this, although Ohashi (2003) distinguishes three regimes in the history of the VCR with different strengths of network benefits.

2.2. Across-generation market structure

Many network industries are subject to rapid innovation, significant technological progress and intense technological rivalry among firms. Lucent and Cisco's fight for the future standard of data transmission, Oracle and Microsoft's struggle for dominance in the database applications market, or the battle for the standard of third-generation (3G) mobile communications are among the best known and documented rivalries in business. Is this a good thing? It is often argued that rivalry is good for technological progress, but systematic studies are rare for several reasons, not least because studying the pace of technological progress relative to some benchmark is difficult because it is hard to specify the ''optimal'' speed of generation changes. There are a number of theoretical results however that can guide the way we think about the likelihood and speed of generation changes in network markets as a function of market characteristics.

An important element of most theoretical models is the uncertainty surrounding a new network technology: Not only is the quality of the new product unknown (as is also the case with many non-network products), but also the expected (but unknown) number of other adopters will affect the utility and therefore the eventual success of network technologies. The first papers to address this problem in a formal setting were Farrell and Saloner (1985, 1986) and Katz and Shapiro (1985, 1986). Generally speaking, generation changes in network markets are affected by network effects because adopters take into account switching decisions of other adopters in their own decision. An adopter preferring a switch ceteris paribus[11] may delay a decision until others have switched, which of course may delay a new technology emerging or, in the extreme, even shut it out completely. This socially undesirable persistence of the incumbent technology is often referred to as excess inertia (Farrell and Saloner, 1985). Excess inertia typically requires a degree of consumer uncertainty and/or heterogeneity. If all consumers knew each other's preferences or if they were all the same, the problem would be less dramatic. Given that heterogeneity and uncertainty seem plausible assumptions, are all network technologies stuck at the technological level of the first successful generation, following the intuition given for excess inertia? Not necessarily. Excess inertia can be alleviated and even overturned under certain conditions.

The need for compatibility is likely to be especially big for technologies that currently enjoy a large market share. If everyone uses the same technology, switching is costly as it entails losses from incompatibility, which is the essence of excess inertia. This may also manifest itself in an inefficiently fast transition to the new standard if there are important adopters that switch early. Smaller adopters that need to ensure compatibility with the

11 That is, given equal network sizes, the new technology would be preferred.

dominant one will have to follow suit. This is evident in the computer industry. When Microsoft introduces a new version of Windows, it is fair to say that users are typically not constrained by their current version of Windows and therefore are not clamouring for an upgrade, albeit priced lower than a full version. Yet, Microsoft succeeds in convincing over 70% of users to upgrade for every major release and about one-quarter to upgrade even on ''dot'' releases, *i.e.*, from Windows 3.1 to 3.2 and so on (Kretschmer, 2001). Two factors may be at work here. First, Microsoft has been very successful in getting large institutions to upgrade their PC operating systems, which corresponds to the ''lead adopter'' concept—private customers subsequently want to upgrade to be able to exchange files between home and their workplace. On the other hand, Microsoft's dominant position in complementary markets is crucial. By tailoring applications software to the most recent release of Windows and gradually reducing support and ''patches'',[12] Microsoft encourages users to upgrade their operating system as well in order to take advantage of the full network of applications, even if the added functionality of the operating system itself would not have been worth the upgrade cost. The opposite of excess inertia therefore occurs—excess momentum, the inefficiently frequent replacement of the incumbent technology (Katz and Shapiro, 1986).

Another way of reconciling the intuition of excess inertia with the fact that technological progress does occur in the real world is that technology develops to some extent exogenously, *i.e.*, changes occurring outside the product's immediate technological domain make the development of better new technologies easier and/or cheaper, so that ''the time is up'' for the incumbent technology simply because the quality of the replacement is sufficiently high to overcome even the installed base advantage of the incumbent. The CD for instance was an important improvement over analogue vinyl records and was facilitated by advances in optics and its (failed) applications in visual media, as well as compression and error correction techniques. When the CD came on the market therefore, its advantages were apparent to a large subset of adopters who then subsequently started a bandwagon. Thus, while several incremental improvements over the vinyl record may have failed (inefficiently) it was finally overcome by a vastly superior alternative. A similar pattern is evident in removable data storage on personal computers. When consumers were faced with the Zip drive as a superior alternative to floppy disks in 1995, it was known that commercially affordable versions of CD writers (CD-RW) would be available soon. As a consequence, many buyers delayed their purchase of Zip drives and eventually made the CD-RW a major success at the expense of the Zip technology suffering from insufficient network effects.[13] While it has to be said that Iomega—the manufacturers of Zip drives—did make a profit from the technology (mainly through aftermarket sales of Zip disks), the penetration of Zip drives now is minimal compared to the almost ubiquitous CD-RW. Here again, the improvement in

12 These are small files available to download for free that iron out small hitches in applications software.

13 The following quote illustrates this: ''[Rewritable CD technology] has done the most to decrease the Zip disk's hold on the removable media market. Not only do you get 650 MB of storage, but the cost per media is extremely low'' (http://www.macobserver.com/editorial/2001/02/27.1.shtml).

capacity and ease-of-use of Zip drives over floppy disks was not enough to replace them and the advent of the CD-RW finally did the job—admittedly at the expense of numerous users suffering from the problem of fitting ever growing files onto floppy disks for a few years. In these cases, while there may still be an element of excess inertia since better technologies failed, technological progress eventually took place in the form of a discrete technological jump to a new standard.[14]

Considering that the purchasing or upgrading decision is a combination of the relative importance of standalone and the expected (and uncertain) network benefits, it is also important to discuss factors that increase or decrease this uncertainty. In particular, we expect adoption incentives to be lower when the degree of uncertainty about future network size is high, keeping the maximum network size[15] constant. A decisive factor for uncertainty is the number of active technologies in the market. Kretschmer (2003a) shows that individual adoption incentives are strictly lower with two technologies rather than one and that excess inertia may be exacerbated if multiple (incompatible) versions of the new technologies exist. The effect of lower adoption incentives however can be offset by the increased variety in the market, increasing the likelihood of early adopters for any new technology. Kretschmer's (2003a) result formalizes the intuition put forward by Postrel (1990), who argues that uncertainty about the future standard was what caused Quadraphonic sound, a technology developed in the mid-1970s to replace stereo sound, to fail.

The existence and extent of excess inertia is difficult to assess empirically in a strict product-introduction context. However the diffusion of new products is also governed by consumers' aggregate incentives to adopt a new technology,[16] so that increased uncertainty about future adoptions should translate into slower diffusion speed through the lower willingness to pay for the technology. Uncertainty about future adoptions is arguably biggest when several technologies compete for the future standard. Koski (1999) studies a panel of eight European countries and their PC diffusion rates and finds that diffusion is indeed slower where Apple and IBM/Intel/Microsoft have relatively similar market shares. Similarly, Gruber and Verboven (2001) and Koski and Kretschmer (2002) study the diffusion for 1G and 2G mobile telephony, respectively, and find that standardization (*i.e.*, reduction of uncertainty as to the future technological standard) accelerates diffusion.[17]

14 Shy (2001), Chapter 4, develops a model to illustrate this tendency to ''skip'' generations if there is a deterministic drift in product quality. In his model the likelihood of generational jumps depends on the growth rate of the installed base and the quality improvement between each generation.

15 Typically the entire population of users of the technology it attempts to replace.

16 See Geroski (2000) and Stoneman (2002) for derivations of diffusion curves from individual adoption incentives.

17 Koski and Kretschmer (2002) show that this holds even after controlling for price, suggesting that this effect is indeed due to uncertainty reduction rather than well-known economies of scale from standardization.

3. Firm strategies in network industries

Following our discussion of likely equilibrium market structures in network markets, what do firms do to manipulate them in their favor? Clearly, pricing and capacity decisions will be affected by anticipated or actual network effects, but the presence of network effects may also cause firms to use additional competitive instruments. Building on our observations from the previous section, we ask the question of what firms do to ensure that they get some of the payoffs that come with being part of (or becoming) the industry standard and subsequently maintaining it.

3.1. Achieving a standard: pre-market standardization versus standards battles

On a broad level, firms have two options: to engage in a standards battle with other competing technologies or to agree on a common standard beforehand and compete within the same standard. Clearly, both strategies involve a tradeoff: Engaging in a standards battle would yield a large share of a new technology's profits if it wins the standards battle, but there is a distinct chance that one's own technology might not turn out to be the standard at all. On the other hand, teaming up with other technology providers to create a new technology will increase the likelihood of succeeding, but the prospective gains from being part of a large group of firms with access to the same technology are clearly limited.

3.1.1. Pre-market standardization

Agreeing on a common standard prior to the introduction of a new technology is one way of avoiding a risky and costly standards war. Industry bodies like the GSM consortium for 2G mobile telecommunications are platforms for negotiations among industry players on technological specifications and ensuring the compatibility of products by different vendors. For instance, when developing the compact disc, Sony and Philips forged an alliance that respected their complementary strengths while avoiding bringing two incompatible products to the market. Matsushita had been developing a parallel digital audio technology on their own and was looking for partners to join their alliance. However, in the run-up to a standard-setting conference in 1981, organized by MITI and attended by all the major consumer electronics manufacturers, Matsushita recognized that it would not be sensible to go to loggerheads with the CD alliance of Sony and Philips and decided to stop developing their own technology and submit to the standard. The end result was a better product than any of the suppliers could have developed without a competing digital audio format to confound consumer expectations.[18]

18 Of course the CD format still faced the formidable task of dislodging a technology with a large installed base and sizeable software libraries, but agreeing on a single standard certainly helped to concentrate efforts on this battle rather than standards battle among several suppliers.

An alternative way of avoiding a fierce standards battle is to ensure some degree of compatibility between different products. Compatibility choice is a double-edged sword in that it is often time-inconsistent. Firms typically prefer compatibility at the outset of a technology, while they would prefer to be incompatible once they have gained a dominant position.[19] Further, once an installed base of consumers has been established, decreasing compatibility has the same effect as increasing product differentiation and therefore softening competition. It would be wrong however to view compatibility with other products simply as another product characteristic.[20] Compatibility is typically achieved by fixing a number of product characteristics such that products are interoperable or can use the same software, which makes products less differentiated. What's more, the network effect, another component of the products' utility, is equalized across technologies since users of compatible technologies can make use of the other technologies' networks and vice versa.

Finally, licensing is another way of pre-market standardization. Licensing commits the standard sponsor to low prices in the future, which makes consumers less anxious about locking-in to a dominant technology—which in turn increases the chances of the new technology succeeding in the first place. This is of course in addition to the common effect of ensuring competitive prices from the outset. Licensing has certain advantages for sponsors of a new technology over standardization by committees or negotiation. The sponsor can specify the technical details of the technology, thus maintaining control over the product and ensuring that incremental improvements will be incorporated into the technology. At the same time, securing a number of suppliers for the new technology is an effective way of setting an industry standard (Farrell, 1996). Shepard (1987) shows that, even without network effects, licensing may serve to increase industry demand for a new technology, which may be especially important in network markets with the danger of ''excess inertia''. Finally, Economides (1996b) shows that in network markets, licensing may be an optimal strategy if expected network benefits are large enough. The rationale for licensing is similar to the ''open standard'' idea, where the sponsors of a new technology make it publicly available to encourage adoption by suppliers. Suppliers who make their standards publicly available however often keep control of a part of the technology, which is then supplied above cost and enjoys the benefits from high demand and being part of an industry standard.

19 This is what Besen and Farrell (1994) refer to as the ''pesky little brother'' phenomenon: The larger firm prefers to be incompatible in order to preserve its network advantage, while the smaller firm wants exactly the opposite.

20 Gandal (1994), Brynjolfsson and Kemerer (1996) and Sarnikar (2002) use hedonic price regressions to capture network effects through compatibility in the spreadsheet and graphics applications market, respectively. Implicit in their technique is the assumption that the other product characteristics included in the estimations are not necessary for compatibility choice. In other words, a product characteristic that needs to be sacrificed in order to achieve compatibility cannot appear independently in their regressions. In addition, these papers do not account for possible negative effects of other products' compatibility. In other words, if many products are compatible with the market leader, the leader's prices should decrease.

3.1.2. Strategies in standards battles

If pre-introduction standardization has not been achieved, multiple technologies will compete in a standards battle. The race to gain an installed base early is similar to competition with learning curves (Cabral and Riordan, 1991, Benkard, 2000), where aggressive pricing (even below marginal cost) is an optimal strategy. While learning curve models often do not consider consumer expectations, these are crucial for markets with network effects. The time horizon and expectations of consumers of future adoptions play an important role—if consumers' utilities are intertemporally linked, the degree of their foresight will be important for determining firm strategy. In most cases, at least some degree of foresight can be assumed, which implies that raising consumer expectations without actually selling the product be can profitable since it raises future consumers' willingness to pay. Portraying one's own technology as the inevitable winner can be self-fulfilling; if consumers expect others to buy it, their expected network benefit will increase and their incentive to buy the same product is higher. For instance, Oracle regularly runs advertisements mentioning that 98 out of the Fortune 100 companies use Oracle technology. Kazaa, the filesharing service, stresses the fact that ''Kazaa Media Desktop has become the most downloaded software'' (http://www.kazaa.com)—implying that the larger community of users will provide higher network benefits than their competitors.[21]

A particularly salient variant of expectations management is the announcement of future products in order to deter consumers from buying others—vaporware (Levy, 1996; Haan, 2003). Dranove and Gandal (2003) show that the mere announcement of DiVX, a rival technology to the emerging DVD, was sufficient to reduce adoption incentives of potential buyers and to slow down overall adoption. Software producers are also well-known to announce their products in advance, often allegedly with the aim to slow down adoption of a competing, existing technology. In particular dominant firms will often respond to potential threats of competitors with the pre-announcement of a new, improved version of the currently leading product. In fact, the preannounced version of the dominant product often has specifications similar to the entering technology, typically with the pre-announcement by the dominant firm following shortly after the release of the entrant's specifications.[22] It should be noted however that software vendors can legitimately claim to be responding to their customers' needs by pre-announcing their products; as a survey by Computerworld[23] in 1995 shows, 80% of respondents (information systems professionals) found pre-announcements useful for planning purposes and 91% welcomed the release of the planned product specifications of products due for release within the next year. While this could be interpreted as a ''hands-off'' warning to antitrust authorities by the industry, it is also clear that firms announcing

21 In the case of Kazaa, adoption of the basic version is free, so that profits come from advertising revenues. Recently however, Sharman Networks launched a premium version of Kazaa (Kazaa Plus), which sells at $29.95 and comes without pop-up advertisements and offers access to additional content.

22 The list of alleged and actual vaporware products is endless. The computer magazine byte.com offers their list of the most famous vaporware products (http://www.byte.com/art/9509/sec7/art26.htm).

23 http://www.computerworld.com/news/1995/story/0,11280,4336,00.html

vaporware may have less leeway than typically assumed. Announcements further than 1 year into the future are likely to be disregarded, which often means that product development must be well underway at this stage, since software development cycles are often longer than that.

3.2. Replacing an existing standard: R&D, timing and backward compatibility

As discussed previously, technological progress in network markets is often rapid, but the pace of technological change can be distorted by an incumbent technology with an installed base. Firm strategies related to the introduction of a new technology will also be consequently affected by network effects, in particular R&D, the timing of product introduction and the choice of backward compatibility.

3.2.1. R&D incentives

There has been some limited theoretical (*e.g.*, Kristiansen, 1996, 1998) and empirical work (Koski, 2000) on the incentives for R&D strategies. As in markets with switching costs or economies of scale, we expect a tendency for firms to go to one of two extremes: Either a firm will concentrate simply on product development within the industry standard (*i.e.*, incremental innovation) and accept the lower rents associated with a less differentiated and therefore more competitive market, or it will spend large amounts of money to try and replace the current standard, which is likely to require more money than in conventional markets. To illustrate this, consider a simple case of vertical differentiation: A slight improvement over the existing technology is sufficient to replace the existing technology without network effects, while a better technology without an installed base may still offer less value to consumers than the incumbent technology if network effects are substantial.

When examining R&D strategies in network industries, we have to consider two dimensions; first, the intensity of R&D efforts, *i.e.*, how much should be spent on the development of new products in a network market, and second, the riskiness of R&D efforts, *i.e.*, for a given R&D intensity, should money and effort be spent on risky or safe projects? The question of R&D intensity has not been examined in detail in the literature, which is surprising given that high-technology industries (many of which display network effects) lead the tables in new product introductions and research efforts.[24] Kristiansen and Thum (1996) show in a model of R&D investment that quality-improving technologies are often undersupplied (compared to the social optimum) by firms because network effects essentially work in the same way as spillovers in that part of the benefits go to producers of complementary products—*e.g.*, investments in better CD player

24 In 2000 *e.g.*, U.S. firms in high-technology industries (information and electronics manufacture and services) had an average R&D/sales ratio of almost 8%, compared to all other firms' average ratio of just over 3% (Source: Standard and Poor's, Compustat, and corporate financial statements submitted to the U.S. Securities and Exchange Commission).

technology is likely to result in higher demand for CDs as well, an externality that may not be appropriated by the innovator unless the firm is vertically integrated, *i.e.*, produces both hardware and software. R&D competition in network markets also displays the characteristics of a ''race'' of the type analyzed by Budd et al. (1993). They predict a tendency for increasing dominance, *i.e.*, the leader will work harder to maintain its lead than the follower to catch up. If this holds true in network markets as well, we would expect considerable asymmetry in R&D efforts in network markets and consequently more successful product introductions by currently dominant firms. There has not been any detailed empirical work on this to our knowledge, but it seems that there is a relatively small number of persistent innovators in many network industries, which would confirm the ''increasing dominance'' hypothesis. Clearly however more systematic work is needed in this area. The choice of R&D riskiness in network markets has been studied in more detail in papers by Choi (1994) and Kristiansen (1996). Both find that, somewhat surprisingly, the incumbent will typically choose more risky research projects than the potential entrant or follower, the intuition being that an entrant will only be concerned with overtaking the incumbent by a minimal amount, while the incumbent internalizes the effect of fending off competition in its choice of R&D riskiness, leading to more risky R&D than socially desirable.[25] This effect may be what counteracts the asymmetry of R&D efforts between leaders and followers—*i.e.*, even though leaders in network markets may spend more on R&D, they may invest in risky projects and as a consequence may lose their technological leadership.

Ownership of a physical network that has to be opened up to competitors by law (such as local telecommunications networks in the EU countries) will also affect the R&D strategy of a market leader, since some fraction of the benefits arising from upgrading the network spills over to the owner's rivals using the same network, which may reduce the incumbent's incentives to undertake R&D. On the other hand, an increase in the demand for a rival's services arising from improved quality also benefits the incumbent via the usage (or access) charge typically levied on the use of the physical network.[26] The incentives of an incumbent to invest in R&D then depend greatly on its ability to get compensated in the form of access charges. Access price regulation plays an important role here (see also the following section for a discussion of this topic). Existing work does not give much empirical guidance on the relationship between investments or R&D incentives and access prices (regulation).

In addition to R&D efforts with the goal of developing new products, research is also undertaken with the aim of building up a licensing portfolio. Licensing has become an important source of revenues for innovators in network markets. In particular, technological interdependencies combined with network effects can create lucrative

25 Theirs are, however, models of vertical differentiation where only the better technology is adopted by a discrete number of adopters. Cabral (2003) develops a model in which the follower chooses a more risky research strategy than the leader in an ''all-or-nothing'' bid to catch up with the leader.

26 In theory, the incumbent might then try to accommodate rivals' entry to its network. Empirical evidence however suggests that at least in telecom markets the incumbents deter rather than accommodate entry (Koski, 2002).

markets for intellectual property. For instance, the patent portfolio of IBM generated about $10 billion in intellectual property royalties over the 10 years prior to 2003.[27] Consequently, the underlying reason for the upsurge in the number of patent applications may not only be rapid advancements in R&D but firms' use of technological inventions as trade instruments in the IPR markets. This may result in ''patent portfolio races'' as firms aim at increasing their portfolios of patents with which to trade in order to be able to negotiate access to external technologies (*i.e.*, licensing or cross-licensing) at favorable terms. Another explanation for the strong licensing activity of firms in network markets is given by Choi and Thum (1998), who find that licensing is a commitment device by sponsors by new technologies to low prices in the future, which reduces adopters' incentives to delay adoption.

Empirical evidence on the use of IPR strategies on network markets is sparse. The study of Hall and Ziedonis (2001) finds that firms[28] responded strategically to a shift toward stronger patent rights by patenting more frequently. The findings in Koski (2000)[29] suggest that increased competitive pressures have facilitated large telecommunication operators' investments in R&D and further increased their propensity to file patent applications. Given that global telecommunication markets were, by and large, not particularly competitive in the sample period (1991–1996), this may have also been a strategic move (*i.e.*, entry deterrence) by large incumbents to the threat of entrants.

3.2.2. Timing of product introduction

Assuming that a new product is potentially marketable, the timing of introduction now takes center stage. New products are often rushed out on the market because as well as generating revenues immediately, they may also serve to shut out other technologies by building up an installed base. The theoretical literature on technology introduction and adoption of technologies with network effects is extensive (De Bijl and Goyal, 1995; Kristiansen, 1998; Regibeau and Rockett, 1996). Pre-emption has also been studied by Fudenberg and Tirole (1985), who show that the race to obtain first-mover advantages (which we would expect to exist in network industries, where first-movers benefit from building up an installed base early) may lead to such an erosion of these advantages that there is no benefit in being the first to enter. The tendency of firms in network markets to introduce their product early can be witnessed especially in software markets where initial ''bugs'' can easily be rectified through free updates. However, it is important to note that if incremental improvements cannot be offered after the technology's introduction (*e.g.*, if the technology is ''hard-coded'' and cannot be modified), firms are more likely to increase R&D efforts prior to introduction rather than rushing a flawed product on a market. Therefore, while the two are linked, the applicability of either the

27 http://www.ibm.com/news/us/2003/01/131.html.

28 Their sample comprises 95 U.S. semiconductor firms during 1979–1995.

29 The data comprise 61 of the world's major telecommunication operators between the years 1991 and 1996.

arguments relevant for product introduction or R&D strategies is likely to depend on the potential for post-introduction improvement.

3.2.3. Backward compatibility

The effect of additional (or improved) product characteristics on the likelihood of technological progress is clear: A better product will have higher demand. Backward compatibility is more interesting because its effects on the desirability of switching are less clear-cut. The downside is that backward compatibility, like intragenerational compatibility, fixes some product characteristics, thereby restricting the potential for departure from the old technology. Especially in high-technology industries, the currently available supporting technology often is the bottleneck, so if technology has developed significantly, ensuring backward compatibility may impose significant sacrifices in terms of technological advancement. It is often argued for instance that new versions of Windows operating systems represent only marginal improvements over the last version in part because they need to be backward compatible. On the other hand, the CD represented a novel way of storing and reproducing music (digitally) and thus could not be made backward compatible with cassettes and vinyl records.[30] The benefits of backward compatibility however can be significant too: Backward compatibility allows the new generation technology to ''carry over'' some of the network effects from the old technology to the new. That is, owners of a Sony Playstation 2 can still play games designed for the original Playstation, which lessens the problem of a small games library (and consequently lower network benefits) in the early stages of the PS/2 rollout. Here again however the tradeoff becomes clear: If most of the software I use is on the old system anyway, what incentive does do I have to switch to the new generation? Anticipated future consumer demand plays an important role here. If novel complementary goods appear frequently (*e.g.*, releases of new games or CDs), switching to the new technology is attractive just to enjoy these new product, and backward compatibility is beneficial since it offers higher immediate benefits. If new complementary goods are not as frequent, backward compatibility may result in ''equalizing'' the old and new technologies' qualities and therefore slow down adoption.

3.2.4. Entry deterrence

The market power of dominant firms, technological interdependence and switching costs give incumbent firms incentives to manipulate market entry to their own advantage. Farrell and Klemperer (forthcoming) suggest that entry into network industries may differ from entry into non-network industries in several respects. On the one hand, incumbents will try to extract profits from their existing consumer base and charge higher prices than entrants—as long as they can keep a sufficiently profitable installed base of old customers—making a small scale market entry feasible. On the other hand, economies of scale or network effects may make small scale entry unprofitable and/or the incumbents may strategically prevent entry, for instance, by innovation strategies (*e.g.*, investments in

30 This is the compatibility-performance tradeoff outlined in detail in Chapter 7 of Shapiro and Varian (1999).

patent portfolios) or by increasing switching costs. In some markets, it may also be possible to simply deny would-be entrants access to the physical network of incumbents (such as the local wire-line network in telecommunications), or at least making access prohibitively expensive. Such a policy however is likely to be observed very closely by regulators and their responses will be discussed in Section 4.

There exist relatively few published empirical studies investigating the responses of incumbents to threats of market entry in network markets. What empirical evidence there is suggests that the incumbents have indeed employed some of the strategies discussed above. The empirical study of Koski and Majumdar (2002) using data from the major U.S. local exchange carriers for the years 1994–1998 finds evidence on strategic entry deterrence behavior of large incumbent companies in network markets. Their findings suggest that entry deterrence has not generally taken the form of aggressive pricing—which is hardly surprising given the heavily regulated prices in the U.S. local telecom markets—but that incumbents have used non-price strategies such as advertising in the face of entry threats. Their study also suggests however that some large ILECs have been able to enjoy relatively high access prices despite the price regulation.[31] There is also some anecdotal evidence from European telecoms markets suggesting that the local incumbent telecommunications operators have used high access prices to deter market entry.[32]

4. Public policy in network industries

Public policy should have the goal of rectifying market inefficiencies. Network effects can indeed generate inefficiencies non-existent (or only to a lesser extent) in conventional markets. In particular, dominant firms are often said to have a higher likelihood of holding on to their market position, and relatively small differences in efficiencies are often translated into large differences in market shares.[33] This exaggerated and continued dominance is often traced to consumer uncertainty and the importance of small initial differences translating into large asymmetries as markets develop. This of course raises

31 The U.S. regulatory system allows for this as, in practice, it is impossible to distinguish incoming interstate calls, regulated by the FCC, from incoming intrastate calls, regulated by the state public commissions. This gives some of the ILECs the required degrees of freedom to use the regulatory system to their advantage.

32 For instance, the Finnish incumbent local telecommunication service provider, Elisa Communication, was found guilty of abusing its dominant position; Elisa offered certain Internet services at lower than competitive prices to prevent entry and covered losses by high interconnection fees collected from its competitors in the provision of local telecommunication services (Finnish Competition Authority, 26 June, 2001, see http://www.kilpailuvirasto.fi/english/index.html). Similar complaints have been lodged in other European countries (see European Commission, 2000).

33 Liebowitz and Margolis (2001) argue that market inefficiencies due to network effects are less prevalent than frequently claimed. In particular, they say that the inefficient ''lock-in'' of consumers to an inefficient technology is an unlikely occurrence. We are less concerned here with showing that certain were or were not instances of inefficient lock-in but rather than discussing what a policymaker should do in order to minimize the dangers of an inefficient lock-in occurring.

the question whether public policy in network industries should differ from that practiced in conventional markets since the reasons for inefficiencies are also specific to network markets. The fundamental economic importance of various network technologies (*e.g.*, telecommunications and railroad networks, personal computers, *etc.*) and their diffusion from the point of view of social welfare—*i.e.*, the (assumed) positive relationship between welfare and the adoption and use of information and communications technologies—emphasizes the importance of appropriate public policy in network markets (see, *e.g.*, Stoneman and David, 1986). Only a few decades ago, typical network industries such as telecommunications and railways used to be run by government-owned monopolies. Now, network industries in industrialized (and in a growing number of developing) countries are, by and large, partially or totally privatized and various firms compete in the market.

The role of the government has therefore shifted from direct market participation to indirect control of the markets as a regulator. The problems arising in network markets are increasingly dealt with by national competition authorities whose key roles—to reward innovation and to preserve fair competition—are stressed in today's network markets. The legal battle between Microsoft and the Antitrust Division of the U.S. Department of Justice is probably the most prominent recent example of the importance of competition and innovation in the network markets.[34]

As discussed previously, notable features of network markets include the frequent emergence of a single dominant technology within a single generation and the persistence of an incumbent technology over extended periods of time despite the existence of superior alternatives. Public policy especially geared toward network industries should therefore pay special attention to the following likely inefficiencies:

a. *Abuse of dominant position*. First, the emergence of a single dominant supplier of a technology carries with it the potential for abuse of market power in the main and related markets, which is the most obvious domain of public policy intervention.
b. *Securing sufficient entry*. The dominance of a single firm may also imply that entry is not possible (even on a small scale) in such a market since sizable network effects may serve as an entry barrier for new products. Therefore, policymakers have to ensure that sufficient entry can take place in standardized network markets.
c. *Promoting generation changes*. Third, the degree and speed of technological progress has been shown to be affected by network effects. While this is somewhat connected to the difficulty of entering a standardized market, the probability and speed of replacing the existing industry standard, *i.e.*, entry across generations, is affected by network effects as well. In this context, policymakers have an incentive to maintain innovation incentives for potential entrants while avoiding the serial orphaning of cohorts of users of the incumbent technology.

34 See also the debate in an earlier issue of this journal (JICT, 2001).

d. *Intervention in standards battles*. Finally, if policymakers decide to let the market decide at least to some extent and allow for a standards battle to ensue, the policymaker still has a role in ensuring that most efficient standard is chosen by the market, at least in expected terms. While it is sensible to assume that, on average, the most efficient standard will win, the policymaker's aim should be to minimize the probability that it is not.

4.1. Curbing abuse of dominant position

Dominant firms in network markets have as strong an incentive as any to abuse their market power. Abuse of market power in the form of elevated prices has been documented in the airline industry (Kim and Singal, 1993) and electricity (Borenstein et al., 2002), to name a few.[35] Famously, the question of whether Microsoft charges excessive prices for their operating system has not been answered conclusively (see Werden 2001; Reddy et al., 2001 and their responses), but it appears that market power in network markets, especially with indirect network effects, may give rise to another type of anticompetitive behavior, namely entry deterrence in complementary markets. The notion that Microsoft has been using its market power in the PC operating systems market to improve and cement its market position in software applications markets and server operating systems is well-known and hotly disputed in courts. The boundaries of such accusations however became clear when Intergraph—previously a multibillion computer hardware provider, now a software producer—sued its computer chip provider, Intel, for withholding critically important product information from Intergraph, thus harming Intergraph's ability to function in the hardware market. While the behavior as such was not disputed, the court (The Court of Appeals for the Federal Circuit) found Intel not guilty of anticompetitive behavior since they were not in direct competition in the hardware market. As such, the behavior was classified as fiercely competitive rather than anticompetitive in the sense of carrying market dominance in one market into related ones. Antitrust policy in network markets therefore has to take into account the linkages between markets through (often indirect) network effects.

4.2. Securing sufficient entry

The possibility for efficient firms to enter a market is another crucial point in policymaking in network markets. In the words of Baumol et al. (1982), markets need to be contestable to function efficiently. In the event, Koski and Sierimo (2003) find that in a

35 See the homepage of Frank Wolak (http://www.stanford.edu/~wolak) for a further discussion and empirical studies on competition policies and market power in electricity markets. Also, this journal has published a special issue on the California electricity crisis (JICT, 2002).

sample of Finnish industries, network markets seem to witness less entry than others, after controlling for extraneous factors.[36] Allowing for entry is therefore particularly important in markets such as local (wire-line) telecoms markets where potential competitors need access to and use of the incumbent's network at reasonable prices. (Access) price regulation plays a key role here; access prices need to be cost-based to enable entrants to compete in the incumbent's network. However, and especially when prices are highly regulated, incumbents may use non-price strategies to deter entry. In markets that rely strongly on sequential and complementary innovation and technological interdependencies are high, intellectual property strategies as the ones discussed in Section 3 provide effective means for deterring entry. For instance, an incumbent may invest in forming a patent portfolio that makes entry impossible or at least very difficult. The initial investment costs of entering the market may then be too high due to substantial licensing fees or, alternatively, due to high costs of innovation or R&D required for new firms. Intellectual property law clearly needs to take this into account and has to recognize the tradeoff between securing entry and maintaining sufficient incentives to innovate. For instance, U.S. antitrust policy has placed constraints on AT&T's activities outside of telecommunications markets and has promoted AT&T's licensing of its information technology innovations (*e.g.*, UNIX) and their extensive diffusion (Mowery and Simcoe, 2002).

Another situation emerges when the physical capacity of a network is limited such as in the case of mobile telephony (*i.e.*, spectrum available); market entry is necessarily highly regulated and the viable number of firms on the market is relatively small. In 2G wireless markets, competition was promoted by allocating spectrum licenses to various firms. In 3G markets, auctioning resulted in bidders being prevented, or at least postponing, to launch their 3G services as their incentive to shut out competition in future stages of mobile telecoms meant that the prices paid for 3G licenses were higher than the short-term revenue situation permitted.[37]

Finally, the incumbents or market leaders may hold their dominant market position due to substantial switching costs. This has been the case for instance in telecoms, where switching to another service provider was (and still is in various countries) made difficult by the lack of number portability. There has been a tendency by policymakers to promote number portability, particularly for mobile telephones—with some success. For instance in Finland, a change to the Communications Act that enforced mobile number portability has produced substantial switching of customers between operators. In the 2 months after the introduction of this new regulation in July 2003, almost 3.5% or about 155,000

36 Note that other reasons may also contribute to this phenomenon—*e.g.*, entry barriers other than installed base advantages and/or technological requirements—but the result highlights that entry patterns do seem to differ in network markets, which implies that there may be a role for policymakers to play in securing entry in these markets.

37 Klemperer (2002a,b) gives an overview of the recent auctions for 3G spectrum in Europe and outlines some of the pre-emption motives that may have prompted firms to overbid for their licenses in some countries. He shows that some of the auctions failed (in a sense that they did not generate the anticipated revenues per potential customer) if pre-emption motives were not ''built into'' the auction.

customers had switched to another wireless operator. The old incumbent wire-line telecom monopolist was the biggest loser, whereas the newer entrants gained new customers.[38] This and other similar cases show that policies aimed at reducing switching costs may indeed facilitate entry and equalize the competitive positions of incumbents and entrants by reducing the incumbent's market power.

4.3. Promoting generation changes

The problem of excessively persistent industry standards has been studied theoretically in detail by, *e.g.*, Katz and Shapiro (1985, 1986), Farrell and Saloner (1985, 1986), and others. The general consensus seems to be that whenever network effects are present, early adopters have a disproportionate impact on the emergence of a network technology.[39] New technologies typically have uncertain quality, and this uncertainty gets amplified in benefit terms because network effects will lead to (near-) standardization and the associated potential for orphaned users of the failed technology. A common example is the QWERTY keyboard that is claimed to be technologically inferior to its orphaned competitor, the Dvorak keyboard (see, *e.g.*, Arthur, 1989; David, 1985). Liebowitz and Margolis (1990) however challenge the inferiority of QWERTY and present opposing evidence. Similarly, they challenge another popular lock-in example telling that the superseded Beta video recorder technology was actually better than the market winner, VHS. These few examples cannot, however, be used as generalizing evidence whether or not lock-in to inferior technology is a serious problem in network industries, especially given the lack of counterfactual evidence, *i.e.*, ''how would the world look if the failed technology had succeeded?'' We have virtually no way of knowing how many technological improvements or substitutes to successful but inferior technologies already on the market were never introduced or quickly vanished after they were launched. Even if we did, it would be difficult to establish the fact that the failure is due to network effects. It thus remains an open empirical question how serious the problem of inefficient lock-in (or excess inertia) actually is and consequently if this is a problem that policymakers can alleviate. Preventing lock-in to an inferior technology would require not only very detailed information on the state of technological progress but also knowledge about consumer preferences. These are rather difficult requirements to fulfil given that preferences are likely to emerge and change anyway, in particular concerning new technologies. Forecasting their demand may fail badly. For instance, the success of short message service was a big surprise in wireless telecommunications markets; no one predicted ''texting'' to become a substantial source of income for mobile

38 One of the ''entrants'', Saunalahti, reported that it had gained about 60,000 new customers in 2 months, whereas the old incumbent (Telia-Sonera) had lost about 30,000 of its mobile customers.

39 This of course is also the case for other new technologies and trends. Bikchandani et al. (1992) develop a model of herding and information cascades where the first adopter's decision may decide the evolution of the entire market.

operators. On the other hand, wireless application protocol (WAP), or ''mobile internet'' failed despite widespread support by mobile operators. Had policymakers pushed WAP, it might have generated an inefficiency in itself by ''forcing'' a new technology on the market that had only limited potential. Government intervention therefore seems reasonable only when there is a clearly superior new technology of which widespread adoption would benefit the society as a whole—which are of course the cases when intervention is least likely to be necessary. What can policymakers do when there is a consensus that it would be a welfare-maximizing choice from the point of view of a society to adopt a new standard (*e.g.*, digital television)? When compatibility is of crucial importance and possible between the generations of technologies, standardization authorities may dictate backward compatibility or support the production of converters. For instance, the existence of multiple incompatible television standards among different countries created a need to convert programs such that they could be exchanged internationally. The International Radio Consultative Committee (currently International Telecommunications Union) was an important body helping to establish a European television network that overcame the problems of incompatibility in foreign program exchange. The role of policymakers here therefore has to get around the chicken-and-egg problem of a lack of software, but not to dictate a new standard as such; the execution of a successful launch strategy was still left to the market.

Another strategy to facilitate the adoption of a new standard is to provide subsidies for early adopters (Stoneman and David, 1986) or the government acting as lead adopters for a new technology. The success of Minitel, an electronic directory and rudimentary e-commerce service based on a closed system[40] introduced in 1983 in France, was by and large based on this kind of strategy: the French government sponsored millions of consumers giving them the Minitel terminal equipment free of charge. Apart from the subsidy, this did also come at a different kind of cost: it has been suggested that the diffusion and use of the Internet has been slower in France than in other European countries because of the popularity of Minitel.

Standardization policy supporting a single technological standard such as GSM in Europe is one potential means to maximize network benefits of a new technology. Standardization also reduces uncertainty about the new technology. If governments make a strong statement or decision concerning a new technology, it gains credibility not only because it may be a signal of quality (assuming that the government knows what it is doing), but also serves as a device for coordinating other adopters' expectations about future network sizes.

4.4. Intervention in standards battles

The empirical literature on standards battles has so far not examined the role of policymakers in detail. A first step at modelling this problem however has been taken by

40 The closed nature of the Minitel system also implied that it was not compatible with the upcoming Internet, which operates as an open system with a different standard.

Cabral and Kretschmer (forthcoming), who derive conditions for the timing and direction (*i.e.*, to support the leader or the laggard) of a policy intervention in a standards battle with myopic adopters. They show that the discount factor, *i.e.*, the time horizon of the emerging technology has a crucial role to play: if the new technology is likely to persist for a long time, it is more important to get it right (by supporting the laggard and thereby delaying standardization) than to get it over with (by supporting the leader and favoring standardization). Similarly, Mitchell and Skrzypacz (2003) model a dynamic duopoly model and show that the degree and nature of the divergence between planners' and the market's choice is crucially affected by the discount factor.[41] This line of inquiry presents an interesting departure from the usual dichotomy between standards chosen ''by the market'' or ''by the policymaker''. By incorporating the divergence between private and public objectives but not giving policymakers perfect knowledge and thus guaranteeing the first-best solution, a more realistic model of public policy in standards battles can be developed.

5. Conclusions

This survey has attempted to gather and discuss some of the recent literature on competition in network industries along several lines. First, we discussed the literature on likely market structures in network markets and found that several factors can serve to weaken the two main results on within- and across-generation market structure. We then turned to the two sets of players that contribute to eventual market outcomes in network industries—firms and policymakers. The examples we use throughout this review are illustrations of how the established results in the literature can guide us in our way of looking at industries, but also to give an indication of where these stylized results fall short of describing reality. To be sure, stylized models never intend to give a complete picture of a real-life situation. Actors in such markets therefore require some additional information or intuition as to what to look for and where to look in order to obtain reliable methods of analyzing network markets.

Other than highlighting some of the main principles at work in network markets, we also want to make a number of suggestions for future research. Applied work has now progressed beyond the mere task of establishing network effects in many markets and has started looking more closely at the dynamics of competition (see, *e.g.*, Ohashi, 2003) and different functional assumptions about the (individual and aggregate) network benefit function (Swann, 2002). More work is needed however. Also, the role of consumer expectations has only been touched upon by Dranove and Gandal (2003), but a systematic attempt at discriminating between the strategic (or forward-looking) and the myopic assumption would be beneficial. Examining the use of vaporware or product pre-announcements as a function of the planning horizon of potential adopters may be a first step in this direction. The final area that still remains somewhat underresearched

41 In their model however, the planner selects the welfare-maximizing standard with probability one.

empirically is the decisions of policymakers and antitrust authorities. If market power is regarded as self-reinforcing in network markets, intervention by policymakers has to be balanced delicately—small mistakes by a policymaker may have large consequences. This gets complicated even further by the general result that R&D competition in network markets tends to gravitate toward a more asymmetric distribution of research efforts—the leader invests more and more while the followers give up, which reinforces the leader's position. To study whether policy measures taken in the past indeed follow these principles is another interesting area of research. Clearly, there is an abundance of theoretical results that make broad intuitive sense, but have to be modified to explain concrete cases. Refining and testing these presents a formidable research program in applied economics and applied industrial organization in particular. We hope that this survey has offered a structured look at the state-of-the-art in research on network industries and provides a template for future applied work.

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