Network Effects

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1. **Introduction**

For now more than 15 years, the world economy has been transformed by the emergence and growth of firms operating on the Internet. These firms have adopted very diverse business models. Some, like Amazon, are mainly intermediaries between sellers and buyers. Others, as Facebook, connect people together, and use the presence of agents on their sites to advertise products. Firms can also provide a service, say a search engine, and make selective suggestions to the users related to this service. A common feature to all these companies is not only the fact that they operate on the Internet, but also that the quality of their services is enhanced when more people visit their website. There is thus a specific pattern where market shares, or more globally the number of users, are key elements in the value people derive from the good or the service. This pattern is called the network effect and this will be the topic of this report.

To be more precise, we can define a (positive) network effect as a situation where the individual consumption benefit depends positively on the number of people that buy the same product or compatible products. The existence of services providing users with a value that depends not only on the characteristics of the good they buy but also on the number of people who buy the same good was of course known to economists or practitioners before the emergence of the Internet. The communication devices as the telephone or the fax are good examples of that. In these cases, agents directly benefit when others use the same good and the network effect concerns all the agents in the same manner. But there are other types of network effects that Katz and Shapiro (1985) have called indirect. Indeed, in some situations, the number of users does not directly affect the utility derived by users but only affects them via the number of services or complementary products available. In the case of standards, say on the quality of video recording, the more users, the more programs will be available and therefore the higher the benefit of being a user. This second type of network effects is more indirect, but it is not less common. In particular, it comprises the well-studied case of two-sided markets, where an intermediary, quite often a platform, connects two sides and each side benefits from an increased number of users on the other side. A classic example is given by the credit-card market where the two sides are consumers and merchants but many websites on the Internet operate under the same logic, linking consumers and producers of digital or non-digital goods. Note that one side may be exempted from charge, it may even be offered some goodie, in order to increase the number of users and so, for the platform, to extract most of the benefit of the network effect generated on the other side. This is in particular the case when the website is financed through advertising revenues or through taxes levied on realized transactions. The smartphone industry is also subject to indirect network effects because the larger the number of applications on a smartphone platform, the higher the benefit users derive from this platform. And conversely, the number of users influences the number and the quality of applications available.

Markets with network effects display some features that do not appear in more traditional markets. First, as the number of people using the network is a key parameter in the benefit of buying the network good, some coordination issues arise when consumers choose which network good to buy, in particular at the early stage of development. Second, network effects are likely to lead to standardization to a single technology or monopolization by a single network, a phenomenon referred to as tipping. This may induce the firms to adopt very aggressive strategies either to gain rapidly large market shares or to prevent the emergence of new competitors.

This article does not aim at presenting an exhaustive view of the huge economic literature devoted to network effects, but rather at discussing the main issues that have been studied and the key insights that have emerged. We will start the exposition by discussing the demand faced by sellers of network goods. We will then detail the implications for firms' strategies, regarding dynamic pricing and compatibility decisions. We finally explore some implications for competition policy and a few relevant antitrust cases.

2. Consumer behavior with network effects

We first discuss the mere notion of network effect at the consumer level. More precisely, we want to explain what the core patterns of network effects are for consumers. At this stage, we do not discuss the firms' choice – say of price - by assuming either a monopolist structure or by setting aside most of the actions that firms could strategically choose.

To abstract from any discussion about the competition among firms, we first assume that only one network is available. As discussed before, the benefit derived by any user from the network good depends on the number of other users, but in many cases also on the characteristics of the good itself. The first benefit is a network benefit and in most cases is increasing in the number of users. The second benefit is a standalone benefit, and may or may not be user-specific. The complexity and specificity of the analysis comes from the first element. Indeed, when evaluating *ex ante* the benefit from buying a network good or subscribing to a network, a consumer must anticipate the number of other users who made the same choice. The presence of anticipations in the choice to be made by each user is crucial to understand the specificity of network goods. Indeed, most of these goods lose a large share of their value when the number of users is limited. Even a good with potentially huge benefits may fail to emerge because users do not believe that enough people will adopt it, or because there is not enough early adopters. With network goods, the users' expectation and the timing of adoption can make their commercial success or failure. Most of the existing analyses rely on this idea of fulfilled-expectations in a static framework but others rather rely on a dynamic approach where potential users have a myopic view and consider the current network size to make their decision.

To understand more clearly the consequences of the presence of the network effects in the satisfaction users derive from network goods, let us assume that potential users only differ in their standalone value for the good, whereas the network benefit is identical across users. Some consumers are more eager to buy the good because their standalone value is higher whereas some other consumers will buy the good only if they believe that enough people will do so. To derive the equilibrium, that is the number of subscribers, in this setting, one must compare how standalone benefits matter compared with the network effects. If the network effects are low, users will mostly make their choice by comparing the standalone value and the price of the good. As it is the case with goods without network effects, the number of final users is uniquely determined as the number of consumers with non-negative value for the good. The most interesting case is instead when the network effect is the dominant element driving the consumers' decision. In this case there may exist several stable demand configurations, with various levels of participation. Indeed a low level of participation reduces the value of the good which makes it rational for a large part of consumers not to buy, while a large level of participation induces more consumers to buy. As an illustration let us suppose that the price is above the highest standalone value but below the maximal value of network effects (obtained when all consumers buy the good). Then it is possible that there is no user but it is also possible that all consumers adopt it. Indeed it is rational for consumers not to buy if all others do not and to buy if all others do. In this case there may be even more equilibrium outcomes. Indeed, the price the marginal user is willing to pay is higher the more people adopt the good, leading to a demand for the good increasing with the number of subscribers expected by consumers. For a given price, we may then have three equilibrium situations. A first one with no user, because the benefit for the first user will be too low; another where all users choose to buy the good, the total benefit exceeding the price; and an intermediate equilibrium, where a subset of the most eager users buy the good. In this particular situation with multiple equilibrium outcomes, some are more stable than others. Indeed, the interior equilibrium may not persist because a change in the decision to buy the good by a small subset of users would lead all the others either to buy the good or not to buy it anymore.

In this simple setting, we assume that users do not coordinate. If they could, they would all buy the good because this is the most efficient outcome. When interactions are local – i.e. between people who are already in the same informal networks – we may think that in presence of multiple and competing networks, coordination is likely to happen. We discuss now the difficulty of coordinating in the case of a market with several network goods.

To do so, let us consider a situation with two network goods, A and B, and two groups of consumers. Some consumers value good A (resp. B) both for the network effects and the standalone benefit whereas they value good B (resp. A) solely for the network effects. The first group of consumers is called the A-fans whereas the second group is called the B-fans. As an example, one may think of the fans of iPhone as A-fans and fans of Samsung Galaxy as B-fans. To understand the dynamics of adoption, we assume that there are as many A-fans as B-fans, and that they arrive in the market sequentially. Absent network effects, the equilibrium situation would be a situation where half of the users adopt one product and half the other. Even if one product takes the lead at one moment, this will have no influence on the final outcome. With network effects, things dramatically change. Indeed, consider the choice of an A-fan to buy either A or B. Even if the standalone value could make him choose his preferred item, an A-fan will nevertheless consider the number of people that have already adopted either good A or good B. If the number of previous B adopters is above the number of A adopters, and the network effects are strong enough, an A-fan will choose to buy B. And from this moment on, all the other users will make the same choice. To state it differently, as long as the market shares between A and B is relatively balanced, each user chooses his preferred good. But when one good becomes prevalent, even the fans of the other good will buy it. Moreover the latter situation must eventually arise if consumers arrive in a random independent way (see Auriol and Benaim, 2000).[1] This simple model predicts that market dominance will prevail in the long run, even if the identity of the surviving firm cannot be predicted. Notice also that the speed with which this dominance will occur depends on the strength of the network effects.

There is thus genuine uncertainty on which network will prevail. By similar arguments, a firm that has conquered the market can be dismissed by a new entrant; at least if this entrant has the chance to build a sufficiently large installed base to reach the "tipping" point where the network effects prevail in its favor.

The existence of network effects can also influence the speed with which new technologies replace old ones (see Farrell and Saloner, 1985). When agents consider using a new technology, they must be confident that enough people make the same choice - in the case of direct network effects - or that enough developers produce services or programs for this new technology - in the case of indirect network effects. The uncertainty on the taste of the other users or on the willingness of developers to propose new applications may delay the adoption of the new technology or even deter its adoption. An example of this phenomenon is the quadraphonic sound which failed to be the standard in the 1970's in spite of being a higher quality standard.

There is still an active debate on whether the existence of network effects, either direct or indirect, leads to inertia. For instance Paul David's classical view that the QWERTY keyboard prevailed over Dvorak keyboard because of network effects was latter challenged by Leibowitz and Margolis (1990). These authors argued that this prevalence was not due to network effects but was rather the result of a better quality.

[1] This is because there will be a point where by chance a large mass of consumers of the same type will arrive in the same sequence, in which case tipping will occur.

With network effects, price and intrinsic quality are not the only parameters users consider to decide whether to buy a good or not. Therefore firms must modify their strategies to conquer a market or protect their market shares, compared to more conventional markets. The next section of this report will focus on these strategies, either in terms of price, choice of standard or connectivity.

3. Firm Strategies with Network Effects

In this part, we discuss firm strategies in the presence of network effects. We first discuss the choice of price by a monopolist. Then, we will introduce competition, first by studying the choice of compatibility, and then the choice of installed base. Finally, in a context where the supply-side is made of competing networks, we analyze the choice of network or technology made by firms providing complementary products.

MONOPOLY PRICING OF A NETWORK GOOD

Let us first consider a situation where there is only one firm, and no prospect of future competition. There is a current standard, or network good, and the firm wants to induce consumers to change, that is to adopt the new standard or network good. In the first section, we looked at this issue taking as given the strategy of the firm. We are now interested in investigating what the firm can do to foster adoption. Taking a broad perspective, the problem of adoption can be seen as a public good problem where each agent, by subscribing to the new network, contributes to the public good. Indeed, for all users, the value of the good depends on the decision of the other consumers to adopt it or not. As is standard in these types of situations, there is quite often insufficient provision of public good, which means here not enough adoption.

This view of adoption externalities has been developed in Dybvig and Spatt (1983) where they study the role of subsidies to the adopters. More precisely, they advocate the use of an insurance system where, if the number of subscribers is low enough, the subscribers can obtain a compensation for the risk they took in buying the good. In a market economy, it seems difficult to consider seriously the implementation of such an insurance policy, not only because it is hard to commit to future conditional compensations, but also because if there is not enough subscribers, the firm may not exist anymore in the future. But some pricing strategies may lead to a similar outcome.

As the objective is to induce potential adopters to hasten the speed of adoption, the most common strategy adopted by some firms is a strategy of penetration pricing. This means that, at the early stage of their development, the firms set a low price, even below cost, to build a large network. This can be done directly, say by setting low price for people entering a night club before 11pm, or indirectly, by offering advertising-free services as Facebook's founders did at the inception of the social network. This will therefore call for having a path of price increasing in the time. Indeed, in this case, one can say that the price is quality-adjusted because it takes into account the network externality. If a price should be paid at every period, it is as if subscribers were protected from the impact of the other consumers' decision to subscribe or not. The relevance of these quality-adjusted prices is less clear in the case of durable network goods where users have to pay only once, when they subscribe for the first time, but they benefit from the network good for all the periods. More precisely, when there is learning-by-doing, the second generation benefits from the size of the first generation, and not the reverse. In this case, consumers will be tempted to wait to benefit from a higher quality good, except those attaching a very high standalone value to the good. This tends to depress price overtime to target the remaining demand and monopoly prices increase overtime only if network effects are strong enough (Bensaid and Lesne, 1996).

But when the network effects result from the use of complementary goods (say applications) or are simply direct, then even the first generation of users anticipates a benefit from the participation of the second generation. In this case, the consumers' willingness to pay depends on the number of subscribers at the first period but also at the second period. If users believe that the future price will be high, some may think that this will deter future potential users to subscribe and then may not be willing to pay even a low price at the first period. Others may advance their purchase. If firms cannot recover their first-period losses by setting high prices at the second period, then they may choose to set higher prices at the initial period and commit to low prices later on. If such commitment is possible, then this calls for having a path of price decreasing in the time. But this type of commitment is not easy. Therefore, even if the firms can use complex strategies to foster early adoption and solve coordination problems, their potential opportunistic behavior may prevent them from succeeding.

Introductory prices are one instrument that producers of network goods may use to foster the development of the network. This corresponds to some form of intertemporal price discrimination as earlier adopters are subsidized while late adopters finance the network. Different strategies involving some other forms of price discrimination may be used by the firm. For instance Jullien (2011) shows that in a static framework a firm can foster demand by offering selective discounts to some consumers while charging others. The subsidized consumers will typically be the most valuable in terms of induced network effects. In a different vein, Weyl (2010) and Weyl and White (2015) point that networks often use complex contingent tariffs, for instance by combining fixed fees with transaction fees or usage fees. Restoring the idea of Dybvig and Spatt (1983), they argue that the firm will try to design tariffs neutralizing the effect of consumers' expectations on their demand, referred to as "insulating" tariffs. Whenever feasible, such tariffs ensure the firm against unanticipated events that may affect consumers' beliefs. However full insulation may require complex tariffs that are difficult to implement.

COMPETITION WITH NETWORK GOODS

We now consider situations where there is more than one network good, and take the simple case with only two competing firms, each one selling one network good. From past periods, both firms have captive consumers, and the installed bases can be different from one firm to another. In the work of Katz and Shapiro (1985), at the period under study, firms are competing *à la* Cournot for new consumers. More precisely, the two firms invest in new capacity and, given these capacities, the prices clear the market. Because of the different initial installed bases, the perceived quality of the network goods differs across firms so the prices must reflect these differences. At the equilibrium, the consumers are indifferent between both networks because any difference in network sizes must be offset by a difference in prices. Typically, the network with a larger installed base will sell more and at a higher price than the other network. One important element to keep in mind is that the difference in network sizes has only an impact if the two networks are not fully compatible. Otherwise, it is as if there was only one network.

A first simple question that has been addressed is the choice made by the two firms to make their products/networks compatible or not, with the immediate consequence of creating *de facto* a unique network. To simplify the exposition, we assume that one firm (say firm A) is large with a positive installed base while the other firm (firm B) has no installed base. If there are initially two standards, standard 1 being the standard of firm A and standard 2 being the standard of firm B, each firm can either keep its own standard or, at a cost, choose the standard of the other one. There are two main effects of standardization, defined as the fact that both firms choose the same standard. First, as the network for every consumer is larger, the network effect benefit is increased and total demand increases. Second, the initial differences between the networks, in particular with respect to the installed bases, are not relevant any more. Third, in case of standardization, one of the two firms must pay the cost of standardization, which means that one of the firms must change its technology. When the cost of changing technology is high, standardization is unlikely and instead standard wars will occur. However, standardization is likely when the parties are relatively symmetric because, in this case, both firms benefit from the increased demand.

It is important to note that the large firm has fewer incentives to coordinate on a common standard than the small firm because this removes its initial advantage. We can elaborate on this idea by adding some flexibility on the standardization process. Indeed, in some cases, the degree of standardization can be imperfect. This occurs for example when compatibility can only be achieved by consumers at a cost and some choose to remain incompatible. As another example, the gap between on-net and off-net prices charged by mobile networks creates a difference between calls in the network or to another network, sometime referred as price-mediated network effects. The higher is this gap, the lower is the probability that an agent subscribing to a network will contact someone from the other network. The difference between on-net and off-net prices tends to create two separate groups of users that can hardly communicate. Choosing the on-net/off-net price structure is then tantamount to choosing the level of compatibility between networks.[2]

Crémer, Rey and Tirole (2000) have analyzed the impact of increased compatibility on the price and quantities in an oligopoly market for a network good. Assuming again that each firm has an installed base, the issue is to characterize the capacity for market expansion chosen by the two firms. Because of imperfect compatibility, size matters and buying one network good yields different network benefits than buying the other network good. What are

[2] Rey and Lopez (2016) show that a dominant mobile operator may achieve de facto incompatibility by imposing high access charges and a large off-net/on-net price differential.

the effects of increasing the compatibility in this context? As discussed above, there are two main effects. First, the two network goods generate more satisfaction for customers, because under competition the price increase will offset the increase in network benefits. As a consequence of this augmented satisfaction, there is a market expansion effect. But increased compatibility also reduces the differentiation between the networks. So the impact of the differences between networks, for example the size of the installed base, is reduced. As a consequence, in a competitive setting a large firm is more likely to oppose increased compatibility than a small firm. This work has been used to study the likely effect of allowing the merger proposal in 1999 between MCI-WorldCom and Sprint. These two firms were among the four major telecom operators able to provide universal connectivity. Even if excess capacity was driving the prices down and the market for connectivity had low barriers to entry, the work of Crémer, Rey and Tirole (2000) suggested that such a dominant player had strong incentives to lower the connectivity with the other networks. This reasoning has been followed by the European Commission that decided to block the merger.

Another interesting question raised by the role of installed bases in the competition between networks is the determination of these installed bases in the context of dynamic competition. So let us take a step back and study how installed bases are chosen. This question is essential to understand the role of the installed base in shaping *ex post* competition and deterring entry. There is an old debate (see for example Dixit, 1980, or Milgrom and Roberts,1982) on whether firms can use investment or predatory pricing to deter entry in markets. There exists however few fully articulated dynamic models of network competition to address this question. Fudenberg and Tirole (2000) deal with this topic, considering that the investment is the size of the installed base, and that this size depends on the price set at the first period. To make the strategic role of the installed base as clear as possible, let us assume that only one firm, say firm A, is active in period 1 whereas two firms, A and B, may be active in period 2. Firm A's choice of installed base depends on the strength of the network effect and on the degree of compatibility between the two goods. For a given size of installed base of firm A in period 2, one can look at the choices of capacity expansion by the firms. As the competition is biased, it may well be that firm B has to lower its price so drastically that it prefers not to produce at all. In other words, when the goods are incompatible enough, the incumbent can deter entry by choosing a large enough installed base. But investing in the initial base is also worthwhile when there is no risk of entry because it allows charging higher monopoly prices in period 2. When the compatibility is low enough and network effects are strong enough, the monopoly level is sufficient to deter entry and will thus prevail. But in general, in the case of incompatible networks there is an incentive to aggressively build market shares to gain a strategic advantage in the future competition and we expect tough competition at the infant stages of network industries. When the compatibility is high, the competitor benefits from any increase in the installed base of the incumbent. As part of the benefit goes to the entrant, the incentives of the incumbent are reduced. Therefore, the incumbent firm's incentive to increase or decrease the number of first-period users depends on how its competitor will benefit from this installed base.

The general conclusion is thus that, due to bandwagon effects, firms supplying network goods gain from fast building of clientele. The dynamics of competition is shaped by the intensity of network effects and the degree of compatibility between groups, with incentives to preempt and intense competition when goods are incompatible.

COMPETITION WITH INDIRECT NETWORK EFFECTS

In this section we discuss in more details the special case of indirect network effects. In the case of direct network effects, the number of people buying the good is a primary element of satisfaction for users. But in many cases, what really matters is the number of people (or producers) either buying a complementary good or providing a complementary service. To put it differently, instead of considering only direct effects, one could also look at indirect network effects. These indirect network effects are prevalent in the context of two-sided markets, where each side cares about the number of people on the other side. From dating websites to credit-card markets, examples abound of these situations. In the standard model of two-sided market (see for example Rochet and Tirole, 2003, or Armstrong, 2006), a platform intermediates the relationship between two classes of users, say A and B. What makes this situation different from the standard model of network goods is the fact that the utility derived by one side depends on the number of people on the other side. The two sides may be similar but complementary users as men and women in the case of night clubs. They may also be of different kinds, when one side consists of consumers and the other consists of merchants as in the case of e-commerce platforms such as Amazon. In this situation, as for a standard network good, the value derived from consumption depends on the number of subscribers. But there is a natural heterogeneity between users because the utility gained from

an additional person on the other side may not be the same for the two sides. The multi-sided nature of the network calls for differentiated tariffs across sides.
Even in the context of two-sided markets, it is not easy to boost demand so that, according to the same logic motivating introductory pricing or price discrimination for direct network effects, the platform that intermediates the relationship between the two sides may decide to subsidize one side without overcharging the other side at the very early stage of development. Some users may even pay a zero price when they subscribe to the platform. As an example, Amazon and Uber offered highly subsidized services until they built up large enough user bases. The flexibility in the tariffs that two-sidedness allows is interesting for at least two reasons. First, it takes into account the heterogeneity between the different classes of users, here between the two sides. Second, if the tariff is set for every transaction, one can again "insulate" the consumers from the variation in the strength of the network effect, by adjusting the total payment of each client to the number of users on one side or the other (see Caillaud and Jullien 2003). In a different way, Uber exploits this flexibility by making the price depend on supply and demand, which improves the supply at peak hours.

More generally, the flexibility offered by the two-sidedness of the market opens possibilities for the firm that would not be available to a non-discriminating seller of a good with direct network effects. For instance, the firm may vertically integrate on one side and propose its own services, as Amazon or gaming consoles producers did for instance. Vertical integration allows securing some participation on one side and avoids the "chicken & egg" problem that arises when each side fails to buy the network good because it anticipates low participation of the other side. The firm may also bundle some goods for free on one side to boost its participation and raise the value on the other side (see Amelio and Jullien, 2012). An example is the expansion of free services proposed by Google.

An interesting particular case is when two technologies compete to attract users on one side and softwares on the other side. While the concept of two-sided market was coined in the years 2000, indirect network effects had been the object of attention before, for instance for operating systems or gaming consoles. A nice example is the investigation by Church and Gandal (1992) of the competition between two differentiated hardware technologies. They assume that software producers must choose one hardware technology and consumers choose also only one hardware technology, often referred to as singlehoming. It is also assumed that consumers value software variety, but at a rate decreasing with the number of software products offered via a technology. In this situation, the software firms decide first to enter the industry and which platform to patronize. Then consumers decide to purchase both a hardware and software products. The consumers' decision depends on the number of software products available for each network, the prices of hardware and software products, and the degree of hardware differentiation. In this setting, the profitability of a technology depends on these different elements, in particular on the number of software firms choosing to provide this technology. For example, with horizontally differentiated[3] hardware technologies, and high prices but low benefits from software products, the two technologies are viable except when all software firms standardize on one technology. Conversely, with relatively homogenous hardware technologies, and low prices but large benefits from software products, a technology needs a large share of the software firms to be adopted by consumers, so full coordination on a unique technology is much more likely. In the case of competition between computer standards, it was therefore crucial for Apple (Mac) to be very differentiated from standard PCs so that the lower number of softwares available on Apple does not fully deter consumers from buying Apple computers.

The choice of a technology by software producers depends on their ability to influence the consumer demand for hardware. If the software is of little importance for consumers, this choice depends only on expected equilibrium market shares of the technologies. By contrast, firms producing leading softwares internalize the effect of their decision on the size of each network and on which technology is active. The profitability of providing a software product to a platform depends on two effects. On the one hand, there is a standard network effect, as the more software products are available on a platform, the more users choose this platform and the higher the demand for this software. On the other hand, due to increased competition, an increase in the number of software products on the same technology decreases the number of sales and the profit for each software product. Depending on which effect dominates, the equilibrium outcome will be with only one technology – the case of standardization – or with two technologies – the case of standard wars. When the technologies are strongly differentiated and consumers display a small preference for software variety, then the two technologies will coexist at the equilibrium. Conversely, when the technologies are not differentiated and consumers display strong preference for software variety, there will be only one technology prevailing.

[3] Horizontal differentiation means that consumers don't agree on which hardware they like the most.

The hardware-software paradigm allows to illustrate also two interesting features of situations involving multi-sided network effects. First the price structure may be shaped by issues of firms' commitment. Given that current demand depends on agents' expectations about other agents' participation, the firm would benefit from being committed to boost participation. For instance, in the case of durable network goods, committing to lower future prices may boost current demand. As we mentioned earlier, relying on transaction fees such as royalties provides a form of insurance against low participation levels. In the context of hardware and software such as a gaming console and games, another issue arises. When software developers are charged fixed fees, the hardware firm may have little incentive to expand the market once it has collected the fees, in particular if the margin on the hardware is small. A tariff structure based on transaction fees preserves the firm's incentive - because demand expansion remains very profitable - and thus helps convincing developers that the firm will be proactive (Hagiu, 2006). For instance, producers of gaming consoles derive revenues from royalties from game sales which has led them to subsidize consoles.

The second feature is that the ability and willingness to buy several goods or to adopt several standards shape competition in a non-trivial manner. While the assumption of singlehoming made before may fit some markets, there are many instances where at least on one side of the market, agents can participate to several networks – they multihome. For instance, in the case of smartphones, almost all applications are working both on iPhone and Android devices. Multihoming changes the nature of competition as it is much easier to attract users, given that they need not to abandon the other technology (see Caillaud and Jullien, 2003). Moreover attracting a new multihoming user does not confer a competitive edge to the firm because other users have already an access to this user with the competing technology. Competition is thus shifted from multihoming sides to singlehoming sides. For instance in the hardware-software case, when software developers multihome but not consumers, hardware firms can charge the full value of the interaction with their consumers to the marginal software developer. But they lose market power on the consumer side because they are not providing exclusive access to softwares. In such a "competitive bottleneck" prices are low on the singlehoming side and high on the multihoming side. Market power is exerted on the non-exclusive side while competition for exclusive relationship dissipates the profit extracted from multihomers.

The above discussion suggests that multihoming can substitute for compatibility as it allows consumers to access all softwares developed. But this is true only to a limited extent because compatibility is chosen by network firms before price competition occurs and doesn't affect competition in the same manner. Once compatibility is achieved, software producers can reach all consumers by singlehoming on any hardware, which reduces the intensity of competition for consumers. Compatibility is thus attractive for differentiated firms because it allows them to escape from intense competition to attract exclusive users. By contrast, multihoming is a users' decision that shifts competition from multihomers toward exclusive users. The importance of installed bases is lower when all users can multihome at low cost.[4]

4. **Competition Policy with Network Effects**

In presence of network effects, the standard criteria to assess the optimality of market outcomes are blurred. First, it is not clear that competition should prevail, because *ceteris paribus*, consumers are better off when they belong to a large network. Second, network effects may lead to inefficient choices of network or standard, or to some delay in the adoption of the best technology. As a consequence, the way the State should intervene and the timing for this intervention are not easy to determine. Sometimes, public policy should target consumers and try to influence their choice; but it can also be optimal to intervene into markets, either to promote one particular technology or to help the development of new ones. This section intends to look at these issues, and to provide some analysis about recent competition policy cases involving network effects.

EX ANTE VERSUS EX POST INTERVENTIONS

Most of the time, public authorities intervene to correct market imperfections. For industries producing network goods, these interventions can take two forms. At the early stage of development of a market or technology, the authorities can influence the identity of the

[4] Doganoglu and Wright (2006) show that the willingness of firms to achieve compatibility is reduced in this case.

winner. This first type of intervention, called *ex ante*, consists in influencing the competitive process at an early stage, for example by appointing the winning technology. But public authorities can also wait and only influence, if necessary, the competitive process *ex post*. With this second form of intervention, authorities do not influence directly the competitive process but make sure that the winners do not block the entry of new and more efficient competitors. This is the domain of antitrust policy.

Standardization is a classic example of public intervention. Standards can emerge either as a result of standard wars or when different firms using different standards at the early stage of market development agree on a common one. In the former case, there will be standardization *de facto* whereas in the latter case, this standardization is said to be *de jure*. When the authorities aim at encouraging the emergence of the best standard *de facto*, they should proceed carefully. Indeed, at the early stage, there are many uncertainties about the true value of the competing technologies. By intervening too early, the authorities risk picking the wrong technology; conversely, by intervening too late, the market has already appointed the winner and it is extremely costly to change the outcome. An example of standard chosen by the authorities is the GSM Standard in Europe. The *ex ante* intervention has the benefit of reducing the cost and time of coordination. Conversely, by refraining from any early intervention, it is more likely that firms will finally coordinate on the most efficient standard. One common form of intervention is to ensure the compatibility of the new standards with the old ones. In this situation, the authorities do not choose the standard but put some constraints on standards that can be adopted by imposing backward compatibility. This requirement hastens the adoption of the new technology and also enables the users of the current technology to benefit from the new one at a reasonable cost. But it raises the development cost for the firm, potentially slowing down the speed of emergence of new technologies.

The most interesting and difficult issue lies in the way authorities should intervene (or not) *ex post* in the market with network effects. This intervention usually takes the form of competition policy, implemented either by antitrust authorities or a sectoral regulator. But as discussed previously, the application of competition policy should be done with high care, because the emergence of dominant firms may result from competition on the merit and be in line with the maximization of total welfare. Even more than for other products, a sound economic reasoning should not consider the dominance of network good producers as an offense, only abuse of this position should be banned.[5] Moreover, some practices that would be considered otherwise anti-competitive may reflect normal competition when there are network effects. Therefore, the right benchmark to use when evaluating whether a situation requires public intervention cannot be the same as the one used for goods with no network effect.

To take an example already discussed, below-cost pricing may be the natural strategy for a firm trying to foster the development of its network. Of course, this may also be a credible predation strategy because with network effects, it is difficult for a firm that has been almost excluded from a market to recover. This does not mean that new firms cannot enter, when they offer a new good that is superior to the existing ones. But depending on the particular circumstances, dominance may be more likely to persist, or may vanish more quickly when the entrant reached a critical market share. It is therefore very complex to know if any intervention is necessary and, when it is necessary, how it should be done.

Another example is whether compatibility or agreements in the standard setting process should be promoted. Suppose that some firms are competing, at first using incompatible technologies/standards or networks with low degree of interoperability. Because of the network effects, it would be optimal to have standardization or full interoperability. This outcome can be reached in two ways. Either there is no agreement between these firms, they compete and, at the best, only one will survive. It means that there is a strong competition *ex ante* but no competition *ex post*. Or the firms competing on a market sign an agreement through which they decide to use a common or compatible technology. As we have seen, with such an agreement, competition is softened because having a large installed base is less crucial to survive; but there will be some form of competition *ex post* because more than one firm will use the winning technology. In general, public authorities are reluctant to allow cooperation between firms, because this may foster collusion and can prevent the entry of new firms. But with strong network effects, compatibility agreements also allow preserving

[5] The formal concept of abuse is specific to the European Union (and similar legislations). In the USA, the concept is "attempt to monopolize". But the two concepts stem from the same philosophy. When applied to a dominant firm, in particular attempting to maintain or expand its position by unfair practices, they lead to similar analysis.

some form of *ex post* competition, so they cannot be dismissed all the time. [6] An example is the adoption of the GSM standard for mobile telephony in the European Union.

To conclude this part, we now discuss how network effects were taken into consideration in some cases by public authorities to regulate markets, focusing on *ex post* interventions in the context of competition policy.

THE MICROSOFT CASE

There are many parts to the Microsoft case, but most of them are linked to networks effects. We will first talk about the American part of the Microsoft case, focusing on the tying of Internet Explorer to Windows. Then, we will discuss the European Microsoft case centered on the interoperability. In both cases, Microsoft was put on trial not for being a monopolist, but for using its position to prevent other firms from being a threat to its dominant position. Let us first review briefly the American Microsoft case, at least the part related to the browser competition. By 1996, Windows was already the dominant operating system but the market for browsers was dominated by another firm, Netscape. At first glance, one may think that browsers and operating systems are not really competing, being more complements than substitute products. But the fact that a substitute product becomes dominant makes this product the standard *de facto* to get an access to the Internet. It creates the potential threat that this substitute supports software products written in protocols incompatible with the ones used by Microsoft. It was also alleged that some top executives at Microsoft feared that the Internet could become a platform on which software products competing with the ones offered by Microsoft could be run. At stake were not so much direct network effects but rather indirect network effects. Indeed, most of the applications for PC were running on Windows, and the more applications were developed for Windows, the greater the utility of using Windows. The existence of Netscape could pose a threat to this eco-system. It was then alleged that by tying Internet Explorer to Windows OS, Microsoft had lowered the incentives

[6] The EC Guidelines on the application of Article 101 to technology transfer agreements (2014/C 89/03) mention the possibility that competition between firms agreeing on a technology pool is sufficient to overcome competitive concerns that some other technology be evicted due to network effects induced (§180).

for consumers to adopt other browsers and thus for developers to optimize their application for other browsers.[7] So the presence of network effects is probably what drove Microsoft to use this tying strategy.

Let us now discuss the European part of the Microsoft case. The European Commission raised a point about an abuse of dominant position on the market of operating systems. The case started with the complaints of Sun Microsystems that Microsoft had refused to provide information necessary for Sun to develop work server products compatible with Windows PCs. As Windows was the dominant player in the market for PC operating systems, all the applications were developed using the Windows language. By refusing to release the information pertaining to the interoperability server-PC, Microsoft prevented full interoperability between non-PC servers and PCs, and thus the development of potential competition in the server market. Here again, the core of the argument lied in the presence of indirect network effects. When the major applications can only be run on a Windows machine, users are prevented from using another operating system. Microsoft was also put under investigation for tying Windows Media Player in the same way as it had tied Internet Explorer, foreclosing competition. In its 2004 decision, the European Commission insisted several times on the role played by network effects to explain why Microsoft practices should be considered as an abuse of dominant position.[8] For instance in the case of Media Player, tying induced more content developers to focus on Windows technology which in turn would convince more consumers to use the Windows technology. Thus, in the Microsoft case, network effects were important for the motivation and the evaluation of the firm’s practices, aiming at preventing the development of content and the application for non-Windows products.

THE AOL/TIME WARNER CASE

[7] Note that, even if this strategy may appear as a barrier to entry, as considered by Judge Thomas P. Jackson, it also benefited consumers by providing freely a browser and therefore enhancing the overall quality of the product sold by Microsoft.

[8] “The nature of the barriers to entry in the client PC operating system market serves to reinforce the conclusion that Microsoft holds a dominant position in this market. These barriers to entry derive from the network effects in the market.” Decision of European Commission, 24.03.2004

One interesting lesson to be drawn from the Microsoft case is that markets of complementary goods cannot be considered as independent. Indeed, because of the network effects - indirect in this case - the dominance over one product could create dominance over another complementary product. And conversely, to preserve its dominant position in one market, a firm has some incentives to acquire or preserve its dominant position in complementary markets. As a consequence, the competition authorities have started to examine with care the proposal of vertical mergers in presence of network effects.

The merger proposal in 2000 between AOL and Time Warner is a good example of a merger involving firms producing complementary products in the presence of network effects. By then, AOL was the world leader in Internet services, being a provider of Internet online services and offering messaging services. Time Warner was mainly a media and entertainment company. The proposed merger would have impacted several markets: online music (downloading and streaming), music player (DRM, compression, encryption), internet access, and paid-for content other than music. One important element was that AOL had a pre-existing agreement with another large music publisher, Bertelsmann. The merger had the first effect to give AOL control over a large share of publishing rights. But more importantly, the combination of a market power on the network (the Internet access and music player) and on contents (the music catalogue) was raising the possibility to exercise market power on both markets. A key argument developed by the European Commission was that, following the merger, "the combined entity would be in a position to dictate the technical standard for delivering music over the Internet" (EC, 2000). This could also "allow the new entity, by threatening not to license its technology, [to] force developers of music players not to support competing technologies" (EC, 2000). In the mind of the Commission, the main threat was caused by the ability of the new entity to become the dominant platform, excluding *de facto* all other competitors. In its decision, the Commission insisted on the strength of AOL as a "one-stop shop" where standard users can find whatever they want. This position, already prevailing before the merger, would have been reinforced by the merger precisely because of the network effects. Indeed, "the more content AOL acquires and the bigger its community of users, the less reason for a subscriber to abandon AOL's walled garden, and the more reason for potential Internet users to joint AOL" (EC decision, 2000). This merger was finally accepted by the European Commission, under the condition that the new entity severs its links with Bertelsmann and "be not anymore the leading source of publishing rights".

<u>THE FACEBOOK-WHATSAPP CASE</u>

In 2014, the European Commission approved the acquisition of WhatsApp by Facebook for a purchase price of USD 19 billion (most of it via stock shares). This amount was impressive by any standard. Indeed, the acquisition of Instagram by Facebook by Instagram in 2012 was done for USD 1 billion whereas Rakuten’s acquisition of Viber in 2014 only cost USD 905 million. In the case of WhatsApp, the number of users – about 600 million worldwide – could explain this purchase price, but the total revenue generated by WhatsApp in 2014 – less than USD 20 million – can hardly do so.

Considering the huge difference between the purchase price and the revenue generated by the acquired firm, it seems natural to look whether, through this purchase, Facebook could improve significantly its position on its markets. Facebook was (and still is) a firm that mostly provided social networking services and consumers communication services, while WhatsApp was a communication application for smartphones. So the acquisition of WhatsApp could potentially increase the quality of the network on which Facebook offered premium services. It could, at least in theory, improve the data collection process and thereby the monetization of the information Facebook had on its consumers.

The European Commission investigated this merger, taking into account explicitly the presence of network effects and the possibility that these effects could raise competitive concerns. Issues of data collection being viewed as non-problematic, the main problem was the concentration of two communication applications in the same entity, Facebook Messenger and WhatsApp. In the present case, the commission considered that the network effects did not create a threat to competition for different reasons. First, the sector was constantly changing, with a continuous movement of entry and exit. Second, there was no exclusivity in the market for consumer communication services, with multihoming on the consumers’ side. Multihoming, as well as differentiation, reduced pre-merger effective competition between the two communication applications. Moreover this and the small level of switching costs facilitate the entry of new applications. These elements, and the difficulty to fully integrate the services proposed by the two firms, convinced the Europan Commission that this merger was unlikely to put competition at risk by strengthening pre-existing network effects.

Considering the amount paid by Facebook for the acquisition, one is nevertheless left with the impression that some elements may have been overlooked by the Commission. The merged entity must be more than a simple addition of previous market shares and strengths of two complementary non-integrated services to explain the acquisition price.

5. **Conclusion**

Network effects play a major role in the development of many businesses on the Internet and more globally in communication and information services. But their peculiar patterns require a specific analysis and lead to some conclusions different from the one reached in the case of more standard goods.

A first conclusion in presence of network effects is the fact that society could benefit from market concentration. Whereas without network effects, this concentration is quite often harmful for society, at least in the short run, it may be beneficial in the case of a network good because concentration increases the utility derived from consumption when users choose the same good. This concentration can be either defined in terms of market shares or in terms of process standardization. It means that for industries with network effects, the role of competition policy should probably be reduced, in particular at the *ex ante* stage.

A second conclusion when network effects prevail is probably that there will be an increase in the intensity of competition for some strategic users. In a competitive context with two technologies, say the old and the new, when network effects are very strong, firms are likely to compete very fiercely for high value consumers (early adopters, pivotal users, users on one side attracting many others users).

At last, the presence of network effects makes the market dynamics very difficult to predict. This structural uncertainty comes both from the role of anticipations and the sensibility of final outcomes to any perturbation in the economic environment. This calls therefore for careful and probably light-handed public interventions in these very specific markets.

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