Aalto University
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Multi-Sided Platforms - How to Attain Critical Mass?

Bachelor's Thesis

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Fall 2020

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Abstract of bachelor's thesis

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Title of thesis	Multi-Sided Platforms - How to Attain Critical Mass?
Degree	Bachelor of Science in Economics and Business Administration
Degree Programme	Economics
Thesis advisors	Miri Stryjan and Jan Knoepfle
Year of approval	2020 **Number of pages** 28 **Language** English

Abstract
Businesses in various industries create value by connecting users in distinct customer groups through a platform, where the value for users stems at least partly from cross-group network effects. Multi-sided platforms may be able to grow rapidly, but only after attaining a critical mass of users that make the platform attractive for more users. In this literature review, I explain the distinctive characteristics of multi-sided platforms, examine what makes reaching critical mass an easy or difficult task, and demonstrate strategy options that platform startups can use to attain a critical mass of users. I present two models by Rochet and Tirole (2003) and Armstrong (2006) to illustrate what separates two-sided platforms from traditional one-sided businesses and to show why platform pricing tends to favor one group and harm the other. I use another theoretical framework by Evans and Schmalensee (2010) to address the critical mass problem of a two-sided platform, showing that the challenge may be easy or difficult depending on customer tastes and behavior, and pricing options. I present multiple concrete launch strategies suggested in earlier literature and discuss them in light of the theoretical findings.

Keywords Multi-sided platforms, network effects, critical mass

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1 Introduction

Multi-sided platforms, and the multi-sided markets where they operate, are very different from traditional markets where firms buy raw materials, produce and sell products to customers. Instead, platform businesses attract different sides of the market to connect, creating value through these interactions. Thus, multi-sided platforms are market intermediaries that help customers get together and create valuable ”matches” that could not be obtained without the coordination provided by the platform (Evans and Schmalensee, 2005). The value for users on one side depends on the number and quality of users on the other side of the platform. Hence, starting a new platform business is particularly difficult without an initial ”critical mass” of users on each side. This literature review examines the economics of multi-sided platforms, the initial critical mass constraint faced by new platform businesses, and strategies for overcoming this problem.

Multi-sided platforms have been around for millennia, but they have become increasingly important with the rise of the internet (Evans and Schmalensee, 2016, Chapter. 3). A village market, for example, connects buyers and sellers, but a similar marketplace is now offered on a larger scale by companies such as Amazon, eBay and Taobao. Multi-sided platforms appear in many industries. Credit card companies connect cardholders and merchants, game consoles connect players and game developers, shopping malls connect shoppers and retailers, and ad-supported media connects advertisers and ”eyeballs”. Many of the most valuable companies as well as the fastest-growing start-ups operate multi-sided platforms. A good example of a platform with multiple sides is Facebook, for which Evans and Schmalensee (2016) identified six sides: friends, businesses, advertisers and app developers (friends and businesses can be both senders and receivers of messages).

The value users assign to a platform depends on who else is using it, proving that network effects (also called network externalities or demand-side economies of scale) are present. In the case of a one-sided platform, or a network, the effect is direct and within a group. For instance, the Finnish national coronavirus tracing app *Koronavilkku* becomes more beneficial for a user when more people start using the app. However, in the case of two-sided platforms, the value for a customer on one side of the market arises from interactions with customers on the other side. Hence, multi-sided markets are characterized by cross-group network effects: the benefit enjoyed by one group of customers depends on how well the platform does in attracting customers from another group (Armstrong, 2006). The cross-group network effects are often positive, for example, travelers using Airbnb benefit from having a large selection of available rental apartments to choose from while hosts prefer to have a large pool of tenants. The effect can also be negative, for example in advertising-supported media, where readers of an online newspaper might be irritated by too many ads.[1]

Early work by Rohlfs (1974) showed that businesses that are strongly affected by network

[1] In this case, the network effect is positive in the other direction since advertisers benefit from being seen by as many ”eyeballs” as possible.

effects can grow rapidly after acquiring a user base that attracts more users. However, most platforms do not reach the stage of explosive growth, because they fail to acquire a critical mass of users that will attract more users (Van Alstyne et al., 2016b). For multi-sided platforms the challenge is multi-dimensional: enough users from all sides must sign up. No one agrees to use the platform if users from other groups have not signed up.

The thesis proceeds as follows: First, I discuss network effects and multi-sided platforms in general, defining relevant concepts. I also review the effect of data and information technology on platform businesses. In 2.3 I survey the relevant literature on multi-sided platforms and explain two pioneering models by Rochet and Tirole (2003) and Armstrong (2006). Section 3 provides a framework by Evans and Schmalensee (2016) for analyzing the critical mass problem of a platform startup. In Section 4 I present multiple concrete strategies that have been suggested for overcoming the critical mass problem and discuss them in light of the theoretical findings. Section 5 concludes.

2 Multi-Sided Platforms

2.1 Defining Multi-Sided Platforms

In this section, I examine what defines a multi-sided platform and what are their most important attributes. Earlier literature uses the terms *two-sided market* and *two-sided platform* somewhat interchangeably.[2] However, businesses in many markets may opt for a platform business model (connecting distinct customer groups) and, therefore, "multi-sidedness" is an endogenous business choice rather than a market feature (Evans and Schmalensee, 2016). Thus, I favor the term *multi-sided platform* which also allows an arbitrary number of sides instead of just two.

Literature suggests that multi-sided platforms are closely related to network effects. Most markets with network effects are indeed characterized by two or more sides, who benefit from interacting through a platform (Rochet and Tirole, 2003). Formal analysis of network effects was started by Rohlfs (1974) who considered a communications service as an example of a one-sided network with *direct network effects*. Direct network effects arise when a person's utility from a good depends on the number of other users of that good. *Indirect network effects*, on the other hand, arise when the demand for a certain good depends on the provision of a complementary good, which in turn depends on the demand for the initial good (Rysman, 2009). The pioneering work by Katz and Shapiro (1985)[3] considered indirect network effects in the context of hardware and software. They noticed that hardware is more valuable to users when compatible software is widely available. On the other hand, when more hardware is purchased, there will be more incentives to develop compatible software.

Technically, the literature on multi-sided platforms combines the research of network effects with the research of multi-product pricing (Rochet and Tirole, 2003). The former branch

[2] *Economic catalyst* is also used by some authors, for example Evans (2009).

[3] Concurrent influential contributions were made by Farrell and Saloner (1985, 1986).

of research, from the initial paper by Rohlfs (1974) through the pioneering work by Katz and Shapiro (1985, 1994) and Farrell and Saloner (1985, 1986), emphasized non-internalized network externalities and ignored multi-sidedness. Multi-product pricing literature, on the other hand, stressed cross-elasticities and did not pay attention to externalities. As an example of this approach, a buyer of razors internalizes the surplus from later buying razor blades. The end-user of a multi-sided platform, on the contrary, does not internalize the welfare effect on other sides. For instance, a potential reader of a newspaper does not take into account that advertisers would benefit if she decided to read the newspaper.

The division of direct and indirect network effects does not fully reflect the understanding of network effects experienced with multi-sided platforms. The value for a customer on one side of the market arises from the interactions with customers on the other side. Therefore, multi-sided platforms are characterized by *cross-group network effects*: the benefit enjoyed by one group of customers depends on how well the platform does in attracting customers from another group (Armstrong, 2006). The network effect might arise from usage and/or membership on the other side. That is, a user on one side of the market might appreciate a large number of users on the other side, or that they are particularly active. For instance, a credit card holder hopes that most merchants accept the credit card (membership), while a merchant chooses to accept those payment methods that are used most often by customers (usage). In addition to cross-group network effects, there may be *intra-group network effects* that could arise, for example, due to congestion or competition within a group. For instance, an AirbnB host prefers as little competition from other hosts as possible, indicating negative intra-group network effects.

Rysman (2009) distinguishes the literature on multi-sided platforms from that of network effects by the presence of a market intermediary who facilitates the interaction between groups. However, if the platform offers the same service and price for all groups, it is best viewed as a one-sided network (Weyl, 2010). Multi-sided platforms offer distinct services, which can be priced separately, to distinct customer groups. This feature is evident in models that consider platform pricing: optimal pricing tends to favor one customer group and hamper the other.[4] A necessary condition for multi-sidedness of a platform is that end-users cannot negotiate their way into an efficient outcome (Rochet and Tirole, 2006). That is, the platform can, *de facto*, determine the allocation of prices between sides, not only the total price level. For this condition to hold, the Coase theorem must not apply, which can happen due to imperfect information between the sides or some other reasons (Rochet and Tirole, 2006). For example, if a merchant experiences a hike in interchange fees on one payment card operator, she can not move this cost to customers because ”no surcharge laws” prohibit charging buyers higher prices when they use a payment card.

[4]I discuss models by Rochet and Tirole (2003) and Armstrong (2006) in Section 2.3.

2.2 Platforms in the Internet Era

A two-sided platform as a phenomenon is ancient. For example, marketplaces that connect buyers and sellers, such as village markets, are two-sided platforms. The owner of a marketplace operates a two-sided platform, facilitating valuable trades between buyers and sellers. Another ancient example is matchmaking. In ancient Greece, for example, the *promnestria* made a profession of matching suitable marriage partners and handling the communication between families.

Both of these ancient examples of two-sided platforms (connecting buyers and sellers, or men and women) have become more substantial in the last few decades. The development of information technologies that have reduced the cost, increased the speed, and expanded the scope of possible interactions between platform sides has made it possible for these two-sided markets to set off multiple billion-dollar businesses, such as Amazon and Tinder. According to Evans and Schmalensee (2016, Chapter 3) the most important technologies behind the surge of multi-sided platforms are computer chips, the Internet, broadband communications, programming languages, and the Cloud, all of which have seen rapid development in the last few decades, especially.

The fact that firms outside the technology sector are finding success with a platform business model is indicative of a wider shift in the economy. A driving force for platform businesses is the availability of data, which can offer a competitive advantage over traditional business models. Platforms are essentially designed to extract data: they provide the infrastructure and intermediation between customer groups, allowing the platform to monitor and analyze interactions between the groups (Srnicek, 2017).

The effort towards more data can help companies learn about their customers and improve their products and services. For example, data has helped online marketplaces such as Amazon better understand their customers, allowing them to facilitate more buyer-seller matches and more valuable advertiser-eyeball matches. The fact that data has become a central resource raises privacy concerns that need to be factored in by platform businesses and addressed by policymakers. On one hand, data can be seen as a positive externality whose value depends on how well the information is used (Bergemann et al., 2019). This implies that a social planner would increase the number of such platform interactions that create valuable data. On the other hand, consumers might not fully understand how their data is used and, if well-informed, they would actually want to decrease the amount of data. Bergemann et al. also point out that data extracted from one user conveys information about other users. An online marketplace, for example, learns about the willingness to pay of users who have a similar purchase history. Acemoglu et al. (2019) show that the price of data is depressed because individuals have less reason to protect their data after it has been partially leaked by others, indicating that data will be shared excessively.

2.3 Theoretical Framework for Multi-Sided Platforms

The concept of multi-sided markets was introduced by Rochet and Tirole (2003) who noticed that businesses in many industries share certain features that set them apart from businesses traditionally studied in economics. Following their breakthrough, and the understanding that such businesses are widespread and growing in importance, the research on multi-sided platforms has flourished. Along with the seminal paper by Rochet and Tirole, the most influential paper on multi-sided platforms is arguably Armstrong (2006).

These two papers, both of which consider pricing decisions and competition of two-sided platforms, provide a set of basic models that much of the newer literature has built on. The models help us understand, among other insights, why some multi-sided markets are competitive while others shift towards a natural monopoly, and why platforms tend to subsidize one side of the market while making money on the other side. I explain the monopoly versions of their models in 2.3.1 and 2.3.2, after which I discuss how the literature has evolved since.

2.3.1 Rochet and Tirole Model

In the basic model Rochet and Tirole (2003) assume a two-sided monopoly platform that adds value through interactions between end users on different sides denoted with superscripts B (buyers) and S (sellers). The paper considers, without the loss of generality, an example of payment cards with consumers and merchants as the two sides. Buyers can make purchases with a payment card or some other method. If they choose to pay with the card, the model considers a *transaction* to have happened. The seller charges the same price regardless of payment method. Therefore, the buyers' (sellers') demand depends only on the price imposed by the platform, P^B (P^S). The difference in utility for buyers (sellers) from using a payment card rather than another instrument – *gross per-transaction surplus* – is denoted by b^B (b^S). Due to network effects *total buyer surplus* depends on the number of sellers, and is denoted by $(b^B - P^B)N^S$. However, the buyers' "quasi-demand function" is independent of the number of sellers:

$$N^B = Pr(b^B \geq P^B) = D^B(P^B), \tag{1}$$

The quasi-demand function for sellers is identical by changing the superscripts. The term *quasi-demand function* is used by Rochet and Tirole to illustrate that the actual demand depends on the decisions of users in both sides of the market (Schmalensee et al., 2014). In their model, the demand (proportion of transactions) is given as the product of the two quasi-demand functions:

$$T(P^B, P^S) = D^B(P^B)D^S(P^S) \tag{2}$$

Given a constant marginal cost c, a private monopoly's profit is given by

$$\pi = (P^B + P^S - c)D^B(P^B)D^S(P^S) \tag{3}$$

The monopoly chooses P^B and P^S to maximise profit. Assuming that $D^B(P^B)$ and $D^S(P^S)$ are log concave, it follows that π is log concave jointly in (P^B, P^S). In order to maximise profit we can now maximise $log(\pi) = log(P^B + P^S - c) + log(D^B) + log(D^S)$ from which we get the first order conditions:

$$\begin{aligned} \frac{\partial(log(\pi))}{\partial P^B} &= \frac{1}{P^B + P^S - c} + \frac{(D^B)'}{D^B} = 0 \\ \frac{\partial(log(\pi))}{\partial P^S} &= \frac{1}{P^B + P^S - c} + \frac{(D^S)'}{D^S} = 0 \end{aligned} \tag{4}$$

Combining the equations, $(D^B)'D^S = D^B(D^S)'$ gives the volume-maximising prices per side given a total price $P = P^B + P^S$. This implies that a small change in prices has to produce the same volume impact in both groups. We can now introduce the elasticities of the quasi-demand functions:

$$\eta^B = -\frac{P^B(D^B)'}{D^B} \quad and \quad \eta^S = -\frac{P^S(D^S)'}{D^S} \tag{5}$$

Combining (4) and (5), the profit-maximising prices must satisfy

$$P^B + P^S - c = \frac{P^B}{\eta^B} = \frac{P^S}{\eta^S} \tag{6}$$

The monopoly platform chooses a total price according to the classical Lerner (1934) rule

$$\frac{P-c}{P} = \frac{1}{\eta} \tag{7}$$

where, in this case, the elasticity η is the sum of the two elasticities η^B and η^S, assumed to exceed one. The monopoly platform chooses a price structure given by the ratio of elasticities:

$$\frac{P^B}{P^S} = \frac{\eta^B}{\eta^S}. \tag{8}$$

Hence, platform prices on each side depend on demand elasticities and marginal costs on both sides. The prices are *directly* proportional to the quasi-demand elasticities, contrary to a one-sided two-product monopoly who would choose prices *inversely* proportional to elasticities. Rochet and Tirole emphasize that two-sided platforms should often treat one side as a "subsidy side" or "loss leader", while the profits are made on the "money side". The platform might even want to charge a negative price from one side – i.e. offer a subsidy – in order to make the platform more attractive to the other side. For instance, credit card companies offer rewards for active users, shopping malls offer free parking, and advertising-supported media offers free content. Microsoft arguably charges third-party developers below the marginal cost of serving them, while consumers who value the developers' contributions have to pay a mark-up over marginal costs (Rysman, 2009).

In later chapters Rochet and Tirole consider equilibrium behaviour of two competing platforms. Proposition 3 (p. 1004) states that increased frequency of single-homing – more customers using only one of competing platforms[5] – increases price competition on the side with single-homing customers and results in lower prices for that side. Single-homing customers are

[5] In the case of mobile operating systems, for example, most people tend to single-home (use only one phone at a time), while developers multi-home (write apps for many operating systems)

"more valuable": if they don't participate on the competing platform, the competing platform will become less attractive to others. This could explain why payment card pricing has often favoured card holders – who typically use only one or two cards – rather than merchants who accept multiple methods.

They also study the effect of *marquee buyers* who have a particularly large impact on the demand on the other side. Securing marquee customers is a commonly used launch strategy, for example, nightclubs invite celebrities, and shopping malls offer low rent for the most popular retailers. Since the presence of a marquee customer makes the platform more attractive for the other side, Rochet and Tirole show that the platform decreases its price for the side with a marquee customer and raises the price on the other side.

2.3.2 Armstrong Model

Now I describe the monopoly platform model by Armstrong (2006). Contrary to Rochet and Tirole who assume that prices and costs incur on a transactional basis, the basic model by Armstrong involves a monopoly platform that charges for participation – not usage. Costs are also dependent on participation by both sides. For instance, a shopping mall charges rent from retailers but does not take a provision from transactions between shoppers and retailers. A mall might even be far enough from other shopping centers to behave as a regional monopoly.

Suppose there are two groups, denoted by $i = 1,2$, whose agents may participate on the platform. The platform attracts n_1 and n_2 users, respectively. Utility for an agent in group i is

$$u_1 = \alpha_1 n_2 - p_1; \quad u_2 = \alpha_2 n_1 - p_2 \tag{9}$$

where the participation fees charged by the platform are p_1 and p_2. A measure of the benefit for an agent in group i from interacting with an agent from group j is given by α_i. The number of users n_i joining the platform is an increasing function $\phi(\cdot)$ of utility:

$$n_1 = \phi_1(u_1); \quad n_2 = \phi_2(u_2) \tag{10}$$

Suppose now that the platform incurs a cost f_i from serving an agent from group i. Then, the firm's profit is given as a sum of profits from each side: $\pi = n_1(p_1 - f_1) + n_2(p_2 - f_2)$. With expressions (9) and (10), the profit can be written as

$$\pi(u_1,u_2) = \phi_1(u_1)[\alpha_1\phi_2(u_2) - u_1 - f_1] + \phi_2(u_2)[\alpha_2\phi_1(u_1) - u_2 - f_2] \tag{11}$$

where the firm is thought to offer utilities rather than prices. Profit-maximizing utilities satisfy the first order conditions

$$\begin{aligned} u_1 &= \alpha_1\phi_2(u_2) - \phi_1(u_1)/\phi_1'(u_1) - f + \phi_2(u_2)\alpha \\ u_2 &= \alpha_2\phi_1(u_1) - \phi_2(u_2)/\phi_2'(u_2) - f + \phi_1(u_1)\alpha. \end{aligned} \tag{12}$$

Now, from (9) and (12), the profit-maximising prices are

$$p_1 = f_1 - \alpha_2 n_2 + \frac{\phi_1(u_1)}{\phi_1'(u_1)}; \quad p_2 = f_2 - \alpha_1 n_1 + \frac{\phi_2(u_2)}{\phi_2'(u_2)}; \tag{13}$$

The profit-maximizing price for either group is the cost of providing the service, subtracted with the strength of the cross-group network effect $\alpha_i n_i$, and adding a factor related to the elasticity of the group's participation. Armstrong also computes the welfare-maximizing prices that take into account aggregate consumer surplus:

$$p_1 = f_1 - \alpha_2 n_2; \quad p_2 = f_2 - \alpha_1 n_1. \tag{14}$$

Hence, if participation of the group raises positive cross-group network effects, the welfare-maximising prices for that group should be set *under* the cost of providing the service. Large cross-group network effects together with a large elasticity of participation could even make the profit-maximizing price for one group negative, as was also shown by Rochet and Tirole.

In later sections Armstrong considers optimal price levels and structures, and how different pricing formats affect equilibria in a competitive setting. Section 4 addresses platform competition with single-homing and shows, similarly to Rochet and Tirole (2003), that platforms receive a lower margin on the side that is more competitive. Section 5 provides a model with two platforms where agents on one side may multi-home.

2.3.3 Recent Progress

The main difference between Rochet and Tirole (2003) and Armstrong (2006) lies on the assumptions on how the platform charges its customers. The former assumes a per-transaction pricing scheme while the latter assumes a membership fee. Subsequent research on two-sided platforms has mostly followed either of these approaches. For example, Bolt and Tieman (2008) and Weyl (2009) analyse a monopoly that charges customers based on usage, while Hagiu and Hałaburda (2014) study a monopoly with membership fees. Weyl (2010) provides a detailed model where end users value both participation and usage, and the platform may charge both participation and usage. In his model, contrary to earlier contributions, not all agents on one side give the same value for additional users on the other side.

While the majority of research on multi-sided platforms has focused on pricing decisions, another branch of literature focuses on design and investment choices. Bakos and Katsamakas (2008) show that a profit-maximising two-sided platform focuses its investments on one side to ensure maximal participation, while profit is made from the side with limited participation. Thus, not only the prices but also the design of platforms tend to be skewed. The question of openness has also been a focus of research, either from the perspective of how to relate to other platforms, or how many sides to pursue.[6] I consider these questions from a launch strategy perspective in Section 4.

The notion of critical mass in network businesses was addressed in literature already in the 1970's, however, the concept was extended to two-sided platforms by Caillaud and Jullien (2003), who noticed that cross-group network effects give rise to a "chicken and egg" problem

[6] The amount of sides is addressed by Eisenmann and Hagiu (2007) and Hagiu and Wright (2015), and compatibility with other platforms by Knittel and Stango (2008), Jullien (2011) and Lee (2013).

– the platform must have enough users from one side to attract the other side, and no one is willing to sign up first, unless they coordinate. Their model requires that customers make their decisions in a single period, failing to fully address the dynamic process of platform launch. The static models by Rochet and Tirole (2003) and Armstrong (2006) are similarly limited. Hagiu (2006) models a two-period start-up game applicable to platforms where one side can make a commitment to participate. Evans and Schmalensee (2010) study how critical mass depends on network effects, customer tastes and dynamics of customer behaviour. Weyl (2010) shows that a platform may avoid the coordination failure and achieve any desired allocation with an "insulating tariff" where the price on one side is a function of participation on the other side. However, this policy can rarely (or never) be implemented in reality.

3 Critical Mass in Platform Businesses

In this section, I go through two models by Evans and Schmalensee (2010) which address the fundamental nature and sources of the critical mass constraint faced by new platform businesses. Whereas the models discussed in 2.3 provide valuable insights into platform behavior, they give fail to address the dynamic process of early-stage platforms and the critical mass dilemma that they face. Evans and Schmalensee provide a theoretical framework for thinking about that early stage process and the factors that affect the critical mass boundary.

The models consider platforms whose customers can *reverse their participation decisions with negligible costs*[7]. Users of social media sites such as Facebook, Snapchat, and LinkedIn, for instance, can effortlessly reverse their participation status. A good example is MySpace, which quickly became the largest social networking site in the US and Europe during 2006 and 2007, only to be overtaken by Facebook in the number of worldwide visitors in 2008. Many relevant two-sided platforms, such as auction sites (e.g. eBay), dating apps (e.g. Tinder), marketplaces (e.g. Amazon), newspapers, payment cards, and video-sharing platforms (e.g. Youtube) allow users to easily reverse their participation status.

If reversing participation incurs no costs for the participant, myopic customer behavior (optimizing period-per-period) becomes rational. Rohlfs (1974) showed, under this assumption, that a one-sided network faces a critical mass constraint. The first model discussed in this section builds directly on Rohlfs (1974). Interestingly, most of the theoretical research on direct network effects has considered the case where participation decisions *cannot* be reversed.[8] This literature has focused on competition between networks for winning the whole market, rather than the initial strive for a user base. The models discussed here allow for multiple firms to exist in equilibrium, and for users to multi-home, which seem to be plausible assumptions for many internet-based platform start-ups.

[7]Customers can join and leave the platform without significant costs.

[8]Survey on this literature is offered by Farrell and Klemperer (2007).

3.1 Platform with Intra-Group Network Effects

The first model (Evans and Schmalensee, 2016) addresses the start-up phase of a one-sided platform, or a network, with positive intra-group network effects. This could include social networking sites[9] such as Facebook, Snapchat, and LinkedIn, or the national coronavirus tracing app Koronavilkku. Early-stage social networking sites put lots of resources into acquiring a large enough user base that will generate large enough network effects and drive future growth. After reaching critical mass, they might open up to advertisers and third-party developers.

The number of agents that participate on the platform (users) at time t is denoted by $N(t)$, which is treated as continuous. At most $\overline{N}$ users can participate. The model assumes, to simplify the analysis, that users are indifferent with respect to the identities of other users. This does not hold in general but it might in some cases. For instance, users of a virus tracing app can not identify other users. A *well-informed* agent is willing to participate at time t if

$$V_i[N(t)|\alpha_i] - \theta_i - P \geq 0. \tag{15}$$

The V_i is an increasing function, with parameters α_i and $V_i(0) = 0$, and represents the benefit to an agent i from being connected to other users through the platform. Therefore, the platform's attributes as well as attributes of the specific agent are reflected in the function. The price P is taken as constant. The non-monetary cost θ_i is affected by how the user reacts to the platform's attributes such as advertising intrusiveness, content provided by the platform, design, and ease of use. The above inequality (15) can be written as

$$\Omega_i \equiv V_i^{-1}(\theta_i + P|\alpha_i) \leq N(t) \tag{16}$$

Here, Ω measures the *net resistance to participation*, and is assumed to be non-negative. Raising the price will increase Ω_i for all i. The distribution of Ω among agents is affected by non-price attributes reflected in θ_i. The model assumes that Ω is distributed according to some density function $f(\Omega|P)$ which corresponds to a non-decreasing distribution function $F(\Omega|P)$. With these assumptions, we can write the number of agents who are *willing to participate* on the platform at time t as $F[N(t)|P]\overline{N}$. When this amount equals the *actual number of users*, $N(t)$, *a fulfilled expectations equilibrium* is reached. That is, the number of actual users must, in equilibrium, be equal to the number of individuals willing to participate. As per (16), the net resistance to participate, Ω, is increasing in P and, thus, $F[N|P]$ is decreasing in P.

In reality, agents are not completely well-informed. In the case of digital platforms, people can visit the platform's website to learn about its attributes and price. They can also make a rough estimate of the number of users currently on the platform. To factor in the imperfect information and inertia, the model assumes that the number of users $N(t)$ tends smoothly to the equilibrium. If there are fewer actual users than agents willing to participate at time t, the number of users will increase over time, and vice versa.

$$sgn\{\frac{dN}{dt}\} = sgn\{F[N(t)|P]\overline{N} - N(t)\} \tag{17}$$

[9]This is a simplification since most social networking sites have more than one side.

Therefore, the demand gradually approaches the equilibrium. The process can be illustrated graphically:

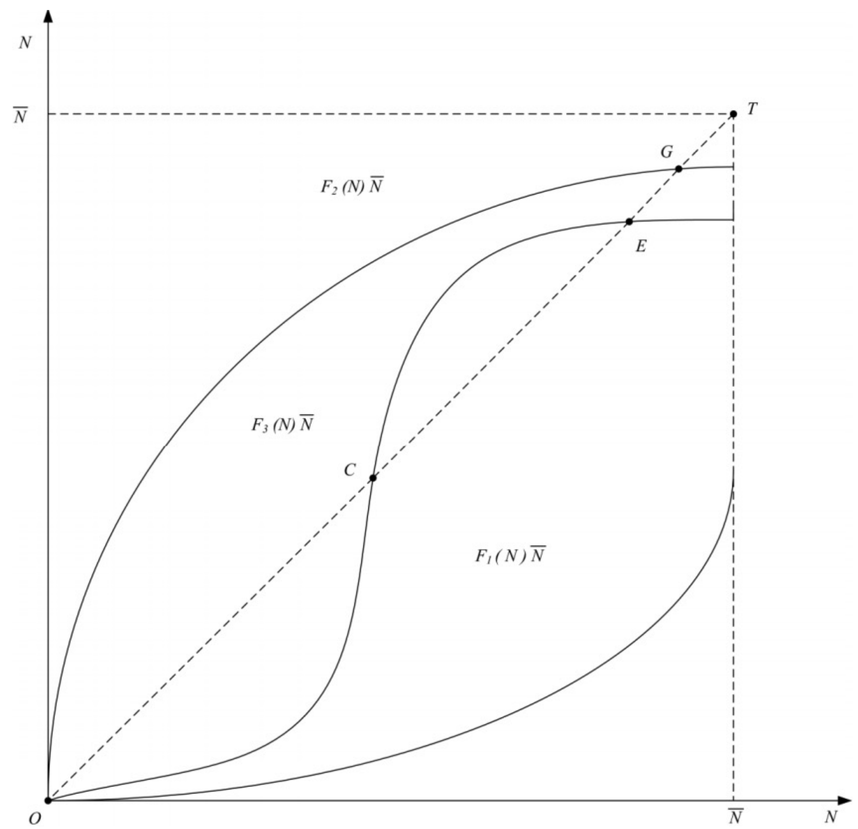

Figure 1: Critical Mass and Equilibria with Intra-Group Network Effects, from Evans and Schmalensee (2016, p. 10).

With price fixed at some level, Figure 1 (Evans and Schmalensee, 2016) shows three alternative curves that correspond to different distributions of Ω. These curves represent the number of agents willing to participate on the platform given the number of actual users. From (17), if $F(N|P)\overline{N}$ is higher than the 45-degree OT-line, then the number of users is increasing. Similarly, if $F(N|P)\overline{N}$ is below the 45-degree line, the amount of users is decreasing.

For example, F_1 represents a situation where most agents have a relatively high Ω and, thus a relatively high resistance to participation. Even if the platform had a large initial user base, users would be leaving gradually as F_1 is always below the 45-degree line. Hence, given the price associated with F_1, the only equilibrium is the origin with no users.

If we assume a distribution of Ω that corresponds to F_2, there are two equilibria, point G and the origin. However, as we can see from the graph, the origin is not a stable equilibrium, because even a very small number of initial users will be enough to attract more and more users to join the platform.[10] Thus, a small launch effort that makes N slightly positive is enough to take the participation (gradually) to the stable equilibrium G.

[10]The conditions for an equilibrium to be stable are shown by Evans and Schmalensee (2016, p. 12).

The third possible situation illustrated in the graph, F_3, corresponds to a unimodal distribution[11] where many agents have similar values of Ω (and the mode is somewhere between the extremes). If the initial user base is relatively small, i.e. below C, then F_3 is below the 45-degree line and users are disappearing. If we are instead at a point between C and E, more users will join. There are two stable equilibiria, point E and the origin, while point C is an unstable equilibrium. In this case, the notion of critical mass is imminent: the platform must somehow reach a participation level beyond the unstable equilibrium point C in order to get to point E. Failing to do so, participation will fade and eventually reach the origin.

We can consider the effect of a price change. Lowering the price level would make the platform more attractive to all users, lowering Ω_i for all i, and raising F_3. This would move point C to the left and point E to the right. As a consequence, it would be easier for the platform to attain critical mass, and there would be more users at the stable equilibrium. You could imagine a strategy, where a platform would initially set P low enough to make critical mass easier to achieve, and then gradually increase the price when enough people have joined and the network effects have become stronger.[12] Similar effect can be achieved through changes in the platform's attributes or customer tastes that raise F_3.

Hence, if a *potentially viable* single-sided platform business, such as the one depicted in F_3, reaches a critical mass of users, network effects will be strong enough to activate a self-reinforcing cycle of growth until the number of users reaches a stable equilibrium. Depending on the attributes of the population and the platform, it might be impossible (F_1) or trivial (F_3) to reach critical mass. The model shows that equilibrium participation is decreasing in price, and the level of critical mass is increasing in price.

3.2 Two-Sided Platform with Cross-Group Network Effects

We can already draw some important conclusions based on the first model, but it needs to be adjusted to understand the "chicken and egg" problem of multi-sided platforms. In this section, I go through a model by Evans and Schmalensee (2016) which is based on the same approach of fulfilled expectations, but now there are two customer groups that are drawn to the platform by cross-group network effects.[13]

Evans and Schmalensee motivate their analysis with an example of a content-sharing platform, although the model applies also in other contexts. In these platforms, some users upload content, for example, videos or photos, and some users download content. Uploaders value the popularity they can achieve by reaching as many viewers as possible, while downloaders value a large set of content creators to choose from. Some agents may be part of both groups if they both upload and download content.

The number of users who actively upload and download content at time t is denoted by

[11] If a distribution is unimodal, the mode of the variable peaks at only one point (e.g. normal distribution).

[12] P could be set negative in the form of a subsidy.

[13] The model does not take into account potential intra-group network effects.

$N^U(t)$ and $N^D(t)$, respectively, while the maximum number of active users by group is $\overline{N}^U$ and $\overline{N}^D$. As before, the model assumes easily reversible participation decisions: uploaders can stop uploading and downloaders can stop downloading content at any time. Users are indifferent about the identities of the users on the other side. A well-informed agent is expected to be an active *downloader*[14] at time t if

$$V_i^D[N^U(t)|\alpha_i^D] - \theta_i^D - P^D \geq 0, \quad or \quad \Omega_i^D \equiv V_i^{D-1}(\theta_i^D + P^D|\alpha_i^D) \leq N^U(t) \tag{18}$$

This is almost identical to (15) and (16), but, as opposed to previously, now the value for downloaders depends on the number of uploaders, i.e. cross-group network effects. Potential downloaders find the platform more valuable if the amount of uploaders N^U is higher. Again, the non-negative Ω_i^D measures resistance to participation, and is distributed according to a density function $f^D(\Omega|P^D)$ which corresponds to a distribution function $F^D(\Omega|P^D)$.

The number of agents who are willing to be active downloaders at time t is given by $F^D[N^U(t)|P^D]\overline{N}^D$. Due to imperfect information and inertia the number of downloaders gradually moves towards the equilibrium:

$$sgn\{\dot{N}^D = \frac{dN^D}{dt}\} = sgn\{F^D[N^U(t)|P^D]\overline{N}^D - N^D(t)\} \tag{19}$$

If there are more downloaders than agents willing to download, some users will stop downloading, and vice versa. The same logic naturally applies to uploaders.

[14] Note that the equations for *uploaders* are identical by changing places of the superscripts D and U.

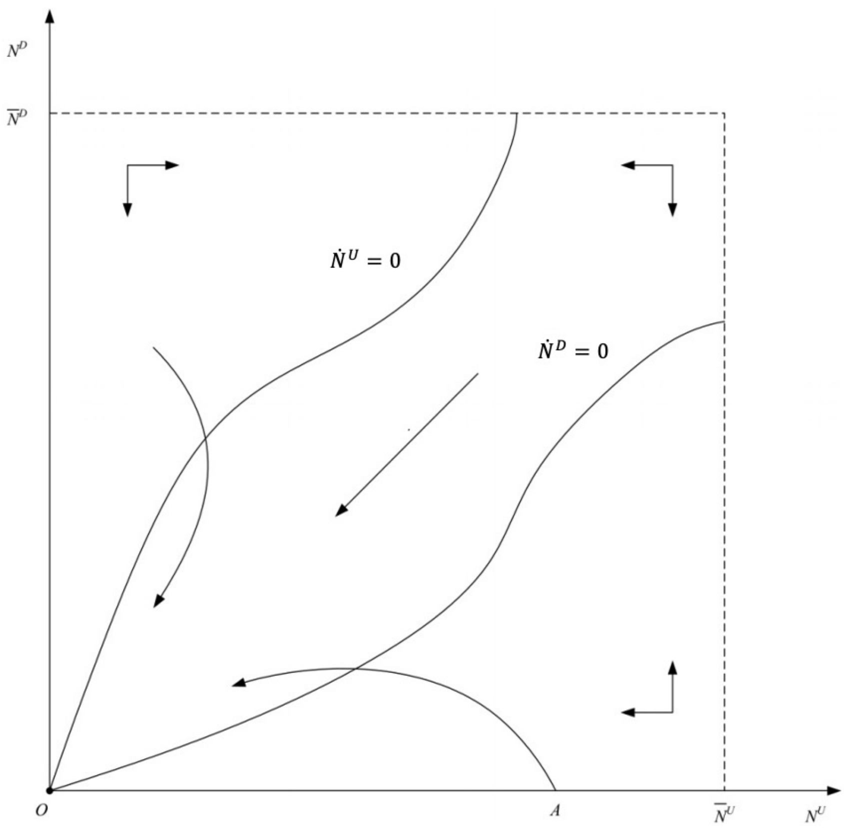

Figure 2: An Infeasible Two-Sided Platform, adapted from (Evans and Schmalensee, 2016, p. 15)

This dynamic process of an early-stage platform can be illustrated graphically, with the price fixed at some level. Figure 2 (Evans and Schmalensee, 2016) shows a two-sided platform with the number of active uploaders on the x-axis and the number of active downloaders on the y-axis. The $\dot{N}^D = 0$ ($\dot{N}^U = 0$) locus connects the points where the number of agents willing to actively download (upload) content is the same as the number of actual downloaders (uploaders). Thus, in these points, the number of active users in that group is not changing. Effectively, the curves show how many agents are willing to actively download (upload) content given the number of active users on the other side.

The short arrows show directions of motion based on (19), while the longer arrows show possible trajectories. The trajectories could look different depending on how quickly users respond to the actual user amount on the other side. Given the distribution that underlies Figure 2, there are only a few agents with low Ω_i on both sides of the market – most agents have a high resistance to participate. The curves only intersect at the origin, thus, the business cannot maintain a positive number of users from either group even if there was a large user base to begin with. Say, for example, that the platform starts at point A, with lots of uploaders but no downloaders. Uploaders are not happy without an audience and gradually leave the platform. At the same time, more people are starting to download content. The number of downloaders increases initially but turns downwards after enough uploaders have left. The only equilibrium is the origin, which is stable.[15] Thus, given the price underlying Figure 2, the platform cannot maintain a user base.

Figure 3 (Evans and Schmalensee, 2016) illustrates a more attractive platform. Given the price, many agents have a low resistance to download/upload content. Now, there is only one *stable* equilibrium at point G. Similarly to the F_2 distribution in Figure 1, a small launch effort suffices to activate a self-reinforcing cycle of organic growth in both user groups, which will continue until the equilibrium point G is reached.[16] Uploading one video on the platform, for example, will draw a few downloaders who will then draw more uploaders, and so on. It is hard to find platform businesses that have succeeded without a serious launch effort – without investing in attaining a user base on at least one side of the market. Hence, examples such as Figure 3 are unlikely to be common in reality.

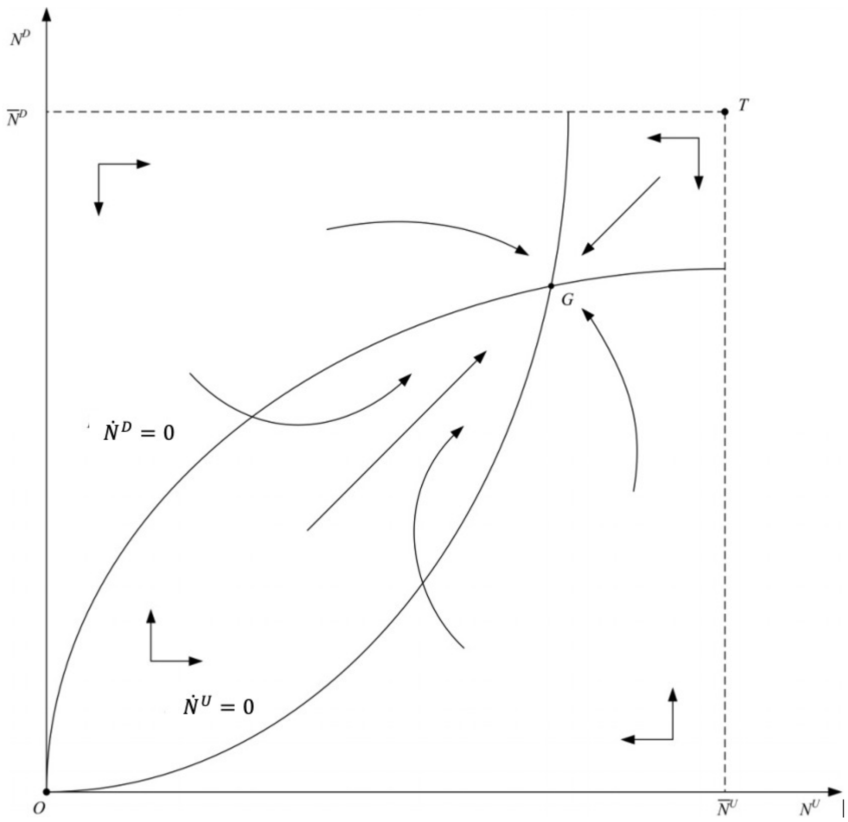

Figure 3: A Feasible Two-Sided Platform, adapted from (Evans and Schmalensee, 2016, p. 16)

Along with the examples in Figures 2 and 3, a two-sided platform can be feasible on the condition that critical mass is attained. A situation such as this, which is analogous to the one-sided example shown in Figure 1 and distribution F_3, is illustrated in Figure 4 (Evans and Schmalensee, 2016). The curves correspond to unimodal distributions of Ω^U and Ω^D, with the modes occurring somewhere between the extremes.

[15]For stability conditions, see Evans and Schmalensee (2016, p. 19).

[16]Whether the platform will be profitable when it reaches the higher equilibrium is uncertain.

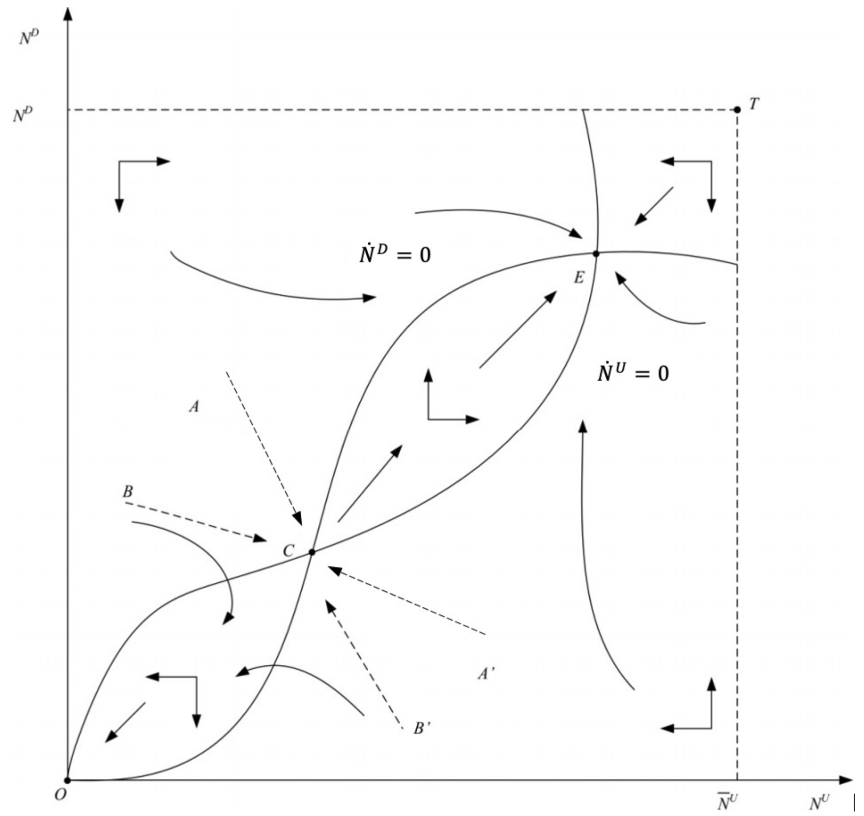

Figure 4: Two-Sided Platform and Critical Mass Frontier, adapted from (Evans and Schmalensee, 2016, p. 17)

Again, short arrows represent directions of motion and the long, curved arrows show trajectories. There are two stable equilibria – point E and the origin – while point C is a saddle point. Depending on the actual number of uploaders and downloaders the trajectories either tend towards point E or towards the origin. With few initial users, the platform will not attract new users and the existing users will leave, with trajectories pointing to the origin. With a large user base from both groups, on the other hand, the system will follow one of the trajectories pointing towards point E.

Therefore, there is an area where trajectories tend towards the origin and an area where they tend towards point E. Between these areas exists a unique *critical trajectory*, which could look like AA' or it could look like BB', which tends towards point C. To maintain a positive number of users, the two-sided platform needs to attain a large enough user base from both customer groups so that it surpasses the critical trajectory – or the *critical mass frontier*. Surpassing this frontier, cross-group network effects will be strong and drive growth towards point E.

The shape of the critical trajectory depends on customer tastes and disequilibrium dynamics. For example, if the customer groups are quicker to leave the platform than to join the platform when they are out of their well-informed level of participation, the frontier looks more like AA'. To illustrate, it does not suffice to have a lot of uploaders (and no downloaders) if all of them immediately stop uploading content when they notice the lack of downloaders. In this case, the platform startup should focus on getting both sides on board from the start. On the other hand, if participation adjusts *upwards* quicker than *downwards*, with the critical trajectory looking more like BB', it might be possible to reach the critical mass frontier by securing a moderate amount of users from one side, knowing that the other side will quickly follow suit.

The critical mass frontier, by definition, determines how many users are needed from each side in order to reach the critical mass of users. Understanding what affects the shape of the frontier is important for choosing the appropriate launch strategy. A newly built shopping mall is better off by first securing retailers as leaseholders, rather than inviting customers before there are any shops. If shoppers were the first side to participate – visit the shopping mall – they would quickly stop participating after noticing the lack of shops. Retailers are less likely to terminate their lease agreement after seeing an underwhelming amount of people on the first day. Thus, consumers have time to learn about the shopping opportunities offered by the mall.

Evans and Schmalensee (2016) suggest that frontier such as AA' are more common in reality – participation usually adjusts downwards quicker than upwards – implying that most platforms should focus on both sides. This is arguably the case for most internet platforms where participation status can be reversed easily and without delay. However, the platform might be able to slow down the speed at which unsatisfied users leave the platform (e.g. long term subscriptions) or encouraging non-participating agents to join the platform quickly (e.g. promoting the quantity and quality of users on the other side, or offering better deals for those who sign up quickly).

Increasing the price for downloaders P^D (or reducing desirable non-price attributes) would make the platform less attractive for downloaders at any given point, shifting the $\dot{N}^D = 0$ locus downwards. This would move point E towards the origin and point C (and the critical trajectory) away from the origin. Effectively, reaching critical mass would now require a larger N^D and N^U, and equilibrium participation would decrease in both groups. Likewise, raising the price for *uploaders* N^U would shift the $\dot{N}^U = 0$ locus upwards, point E towards the origin, and point C with the critical trajectory away from the origin.

Decreasing the price would naturally have the opposite effects as the effects of raising the price as described above, therefore, the critical mass frontier would move towards the origin. A potentially viable platform could in theory lower the prices for both groups so that the critical mass frontier approaches the origin. Therefore, a platform with sufficient resources to maintain low prices (or subsidies) for some time could solve the critical mass problem by utilizing dynamic pricing. The platform could enter the market with artificially low prices and gradually increase them as more people start participating on the platform.

In order to reduce the resistance to participation on either side of the market and make it easier to reach critical mass, the platform operator has to lower its price offering for that side or make the platform more attractive through site design, communications, and ease of use. The model shows that improvements in site design not only make the critical mass easier to achieve but also increase the size of the user base in case the launch is successful.

4 Strategies for Attaining Critical Mass

The following section builds on academic literature in economics, management and information science, and practitioner articles related to the strategies for building critical mass in multi-sided platform businesses. Many of the strategies relate to the pioneering work by Rochet and Tirole (2003) and Armstrong (2006) on pricing decisions, as well as the insights that Evans and Schmalensee (2016) offer on the critical mass dilemma.

In general, multi-sided platforms that attempt to secure a critical mass of users should decide whether to target all customer groups from the beginning or only some of them. This problem was illustrated in Figure 4 for a two-sided platform. However, regardless of the number of sides on the platform, figuring the optimal strategy requires the platform operator to understand, among other things, how much do users on each side value users on other sides, and how quickly users and non-users react to the perceived user amounts. Depending on the situation, two-sided platforms should choose one of two basic strategies (Evans and Schmalensee, 2016):

1. A *zigzag* strategy focuses on attracting both customer groups from the beginning. For example, a ride-hailing platform such as Uber should arguably promote its platform to both sides from the beginning to attract both drivers and riders.

2. A *two-step strategy* focuses on only one group in the beginning. After enough users from that group have joined, the platform will persuade users from the other group. This strategy is attractive, for example, for platforms that are supported by advertising, since they need to first attract a large enough audience that is interested in the content provided by the platform before advertisers will be willing to pay for reaching that audience.

Some platforms choose a combination of a zigzag strategy and a two-step strategy. YouTube used a zigzag strategy to attract people who upload videos and people who view them but also started to show ads after two years in business. All in all, these two basic ideas provide the foundation for more concrete strategy alternatives, which are discussed next in more detail. The launch strategies available for multi-sided platforms can be divided into three categories: pricing, design, and communications.

4.1 Pricing

Multi-sided platforms caught the interest of economists due to their unusual pricing behavior. Traditional businesses would never set prices permanently below marginal cost, however, this is a widespread practice among firms with a platform business model. Pricing decisions of multi-sided platforms have been researched rigorously after Rochet and Tirole (2003) showed that one side is typically subsidized when the other side faces a higher mark-up.

Whereas low prices on one side may maximize profits in the long term, early-stage platform businesses can also use *temporary subsidies* to make it easier to reach critical mass. These subsidies are typically costly and require the platform to have enough resources. The subsidy can take many forms, for example, temporary penetration prices and discounts can be used to create early demand. One option is to directly pay early users (Evans, 2003), however, there is a risk of misuse – users taking the subsidy and not participating – if monitoring is insufficient. The common feature of these strategies as opposed to permanent profit-maximizing prices is that the subsidies are reduced or stopped after acquiring a critical mass of users. Nevertheless, the subsidies might be continued in competitive markets with high multi-homing costs that tend towards a ”winner-take-all” outcome in order to pursue winning the whole market (Eisenmann et al., 2006).

Traditional firms face the trade-off between growth and profitability, however, this decision becomes more crucial for platform startups who yearn for early growth to attain a critical mass of users. One option is to offer a free product that can be later (or from the start) complemented with a premium version. Businesses affected by network effects, especially, should launch with the free version only in order to allocate resources (e.g. product lines, marketing budget) to growth (Bhargava, 2014).

To attain critical mass platforms try to *secure marquee customers* who are highly influential for the demand of another customer group. These ”superstar users” create extraordinary network effects by either bringing more valuable interactions or being particularly active on the platform (Binken and Stremersch, 2009). Theory suggests that platforms will set lower prices for the side with marquee customers, however, the platform may also want to incentivize individual marquee customers to join. Before payment card networks became common, they persuaded supermarkets with high transaction volumes to adopt their payment cards by offering low interchange fees. The possibility for consumers to use a card for daily grocery shopping would presumably raise usage elsewhere (Rysman, 2009). Hence, multi-sided platforms have a new way for price discrimination: offering different prices for agents that differ in attractiveness to the other side.

The platform can, of course, offer marquee users other incentives besides prices, for example, entrants in the game console industry have offered popular video game publishers *category exclusivity* in certain game categories (Parker and Van Alstyne, 2014). A particularly attractive option for platforms that enter a competitive market is to make *exclusive dealing contracts* with marquee customers (Evans, 2013) so that they cannot multi-home. Securing marquee buyers can also increase demand on the side of the marquee customers, for example, the presence of marquee tenants in a shopping mall will persuade other retailers to rent space because they expect many shoppers to visit the shopping mall (Evans and Schmalensee, 2016).

A related strategy is to focus on *loyal users*, who are likely to participate on the platform for a longer time. These users could be price inelastic (Rochet and Tirole, 2003), have longer contracts or higher sunk costs (Evans, 2003), or have high expectations of platform growth (Zhu and Iansiti, 2012). Securing these users could mean that the well-informed level of participation will adjust upwards quicker than downwards (i.e. new users joining at a higher rate than existing users leave), which will make it easier to reach critical mass (Evans and Schmalensee, 2010).

4.2 Design

Platforms are in charge of their rules and architecture. One of the factors that early-stage platforms need to consider is *openness* – who is allowed to participate. A commonly used strategy is to launch exclusively in a small but closely integrated community where network effects will be particularly strong and a large part of the population will participate. Facebook used this *micro-market launch* strategy and restricted early adoption to Harvard students, then expanded to high-school students and finally to the whole population (Ellison et al., 2007). OpenTable, which connects restaurants and diners through a reservation platform, first focused on a limited selection of high-end restaurants in San Francisco before expanding to other cities and internationally (Evans and Schmalensee, 2016). Once the platform has been established in a sub-population, it can open up to new users. Beginning with a single target group or geographical area also allows time for the platform to improve and build capacity before expansion.

Platforms usually offer first-party content (e.g. technical support and information) that makes interactions more valuable. *Seeding strategy* is used to attract participants from one side by offering them intrinsically valuable (stand-alone) content, "seed interactions". The aim is to solve the chicken and egg problem on one side before opening up to the other side. For instance, financial companies have typically established themselves by offering their own products, and later opened up a platform for third-party financial instruments (Parker and Van Alstyne, 2014).

Hence, platforms can decide how many sides to serve. Similarly to the micro-market launch strategy described above, the platform could begin on a smaller scale – serving only one side – before deploying new connections and sources of value (Van Alstyne et al., 2016a). This set of strategies is called *platform staging*, with a traditional one-sided business model in the first stage evolving into a platform business model after reaching critical mass (Stummer et al., 2018). One option is to begin as a merchant that buys and resells goods, and gradually give suppliers more responsibility for inventory and pricing, in effect becoming a two-sided marketplace (Hagiu and Wright, 2015). The platform may or may not continue offering its own products as a substitute for the goods sold by suppliers. For instance, Amazon utilized this "merchant to two-sided-platform" strategy by starting as an online book retailer before opening up a marketplace for sellers and buyers to trade (Eisenmann and Hagiu, 2007). Nowadays, a large variety of goods is sold on the marketplace, and Amazon also retails its in-house products.

Some two-sided platforms have opted for a *side switching* strategy, where the platform design allows the same users to participate in both groups (Stummer et al., 2018). When a majority of users participate in both groups, the platform turns into a one-sided platform with only one customer group. Airbnb is a well-known example, which targeted users who would offer both the supply and the demand for short-term rental apartments. When traveling, they could rent out their apartment on Airbnb while staying in another apartment in the destination. If AirbnB were instead targeting real estate investors who only provide the supply, the strategy would have failed. Etsy, on the other hand, targeted users who would both buy and sell handmade items. When enough users had joined, Etsy had successfully filled both sides of the market. After that, they began attracting users who only participate on one side, such as large suppliers.

To escape the problem of creating demand from zero, a platform startup could use a "piggyback" strategy urging users on another platform to sign up to the startup (Parker and Van Alstyne, 2014). AirbnB offered hosts the opportunity to post their apartments also on Craigslist, a popular online "notice board". The high quality of these listings got Craigslist users interested in joining AirbnB. Another good example is PayPal, which "borrowed" the user base of the eBay marketplace. PayPal set up bots to buy and sell goods at market price on eBay, requiring the counterpart of the trade to set up a PayPal account for the payment. After becoming the standard payment method on the marketplace, PayPal was acquired by eBay in 2002, and is now an accepted payment method on many other websites.

Platform envelopment strategy can be used by an existing platform to launch a new multi-sided platform into another platform's market by bundling the new service with an existing service (Eisenmann et al., 2011). For instance, to compete with Monster.com, LinkedIn built a job-listing platform along with its original networking site to benefit from its existing user base. Similarly, Microsoft launched Windows Media Player (WMP) to consumers by bundling it with the Windows operating system and succeeded in overtaking RealNetworks which was then the dominant streaming media platform. Thus, both of these "envelopment attacks" succeeded in building a multi-sided platform without initial users against a dominant incumbent firm. Platform envelopment allows existing businesses to enter into new platform markets by utilizing overlapping user bases. Launching as a completely new startup without a user base would be difficult even if the platform had superior functionality.

4.3 Communications

The models analyzed in Section 3 (Evans and Schmalensee, 2010) emphasize the role of customer behavior under imperfect information and inertia, assuming that both sides adjust their participation gradually after noticing the number of users on the other side. The platform might be able to encourage new users to quickly join the platform by promoting the number of users currently on the platform through information provided on the website or advertising. For instance, Tucker and Zhang (2010) use a field experiment to study the effect of displaying information about the number of buyers and sellers in an online exchange. The results indicate, intuitively, that buyers prefer a large pool of sellers and vice versa. If information about both user bases is available, a large number of sellers will discourage future seller listings due to more competition. However, if only the amount of sellers is displayed, sellers will not deter further listings, presumably because a large quantity of sellers is an indication of a large pool of buyers. Tucker and Zhang (2010) conclude that it is typically better to only emphasize the number of users on one side.

Customer decisions about participation on the platform are also affected by their expectations about the future size of the platform. Evans and Schmalensee (2010) fail to grasp this because their model assumes customers to be myopic – making decisions period-by-period without factoring in utility from future conditions. This assumption is a good approximation in markets with easily reversible participation such as video sharing sites. If customers need to make large investments to participate, however, future expectations become important. The platform can affect these expectations through ambitious advertising or credible commitments such as contracts (Zhu and Iansiti, 2007). For instance, a game console manufacturer has to convince video game developers about the quality of the console as well as the number of purchases it will achieve. That is why game consoles have committed to low buyer-side prices through early announcements to assure game developers that the demand for consoles (and compatible games) will be strong (Hagiu, 2006).

The platform could be innovative in building customer expectations and momentum. For instance, persuading a highly respected and well-known person to be part of the platform startup as a founder/investor/spokesperson can persuade customers to join the platform in hope of future success. Some platforms could also be able to sign binding contracts with the customer groups which would oblige them to join on the condition that other groups also join (Evans and Schmalensee, 2016).

5 Conclusion

Businesses in various industries have been successful with a business model where they connect distinct customer group through a platform and rely on network effects to attract users. These multi-sided platforms have become ever more important in the last half-century due to the rapid development of information technologies that have increased the speed and scope of connections between different sides of a platform. Research shows that multi-sided platforms may be able to grow rapidly, but only after they have reached a critical mass of users who increase the value users get from the platform. Most platforms do not reach a large enough user base to ignite and instead end up on a downward cycle.

Hence, the objective of this review is to explain the distinctive characteristics of multi-sided platforms, examine what makes it easy or difficult to reach the critical mass of users, and demonstrate what strategies can be helpful in the early stages of a platform startup.

Since the early 2000s, multi-sided platforms have been researched rigorously in industrial organization to understand why they make decisions that would be irrational or even absurd from the point of view of ”traditional” economics. This literature offers interesting insights into multi-sided platforms and the markets where they operate, showing, for example, that pricing, design, and investment decisions tend to favor one customer group and harm the other. A platform may even offer subsidies for some customers to join the platform in order to persuade customers from another group to participate.

The critical mass problem of two-sided platforms – also called the chicken and egg problem illustrating the question of ”which side joins first” – has been addressed particularly in the fields of economics, management and information science, and to some extent marketing. This literature emphasizes the presence of a ”critical mass frontier” consisting of all the possible combinations of customers from different groups that will enable the platform to enter the stage of rapid growth. Depending on the situation it might be best to persuade customers from all groups to join at launch or focus on a single target group first. Based on earlier literature I present several concrete strategies that can be used by early-stage platforms to acquire a user base, with real examples to illustrate.

Multi-sided platforms have been studied for less than twenty years and, although the research has been fruitful, there remain many areas that require further studying. It is easy to predict that multi-sided platforms will only increase in importance: this new business model seems to keep disrupting new industries, especially those that are information-intensive.

Hence, there will be an increasing number of new multi-sided platforms that need to solve the issue of critical mass in their relevant market. These startups might benefit from a combination of strategies mentioned in this paper, however, there is a profound lack of empirical research on the effectiveness of different strategies. Research around early-stage platform strategies could focus on specific industries – what makes some platforms succeed and others fail in a specific setting – or investigate whether certain strategies are worthwhile in general. Until now, most empirical findings have stemmed from case studies, either qualitative or quantitative, thus further insights could be achieved through quantitative experiments with a larger sample.

Nowadays the driving force for many platform businesses is the ability to extract data from customer interactions. I touched on this issue in Section 2.2 by explaining the challenge of measuring the sign and strength of the data externality. Further research on this topic could help determine whether platform interactions should be increased or decreased to adjust the amount of data, and to what extent is this question affected by the type of platform, the type of customer, and the type of data.

References

D. Acemoglu, A. Makhdoumi, A. Malekian, and A. Ozdaglar. Too much data: Prices and inefficiencies in data markets. Technical report, National Bureau of Economic Research, 2019.

M. Armstrong. Competition in two-sided markets. *The RAND Journal of Economics*, 37(3): 668–691, 2006.

Y. Bakos and E. Katsamakas. Design and ownership of two-sided networks: Implications for internet platforms. *Journal of Management Information Systems*, 25(2):171–202, 2008.

D. Bergemann, A. Bonatti, and T. Gan. The economics of social data. 2019.

H. K. Bhargava. Platform technologies and network goods: insights on product launch and management. *Information Technology and Management*, 15(3):199–209, 2014.

J. L. Binken and S. Stremersch. The effect of superstar software on hardware sales in system markets. *Journal of Marketing*, 73(2):88–104, 2009.

W. Bolt and A. F. Tieman. Heavily skewed pricing in two-sided markets. *International Journal of Industrial Organization*, 26(5):1250–1255, 2008.

B. Caillaud and B. Jullien. Chicken & egg: Competition among intermediation service providers. *RAND journal of Economics*, pages 309–328, 2003.

T. Eisenmann, G. Parker, and M. W. Van Alstyne. Strategies for two-sided markets. *Harvard business review*, 84(10):92, 2006.

T. Eisenmann, G. Parker, and M. Van Alstyne. Platform envelopment. *Strategic Management Journal*, 32(12):1270–1285, 2011.

T. R. Eisenmann and A. Hagiu. Staging two-sided platforms. 2007.

N. B. Ellison, C. Steinfield, and C. Lampe. The benefits of facebook "friends:" social capital and college students' use of online social network sites. *Journal of computer-mediated communication*, 12(4):1143–1168, 2007.

D. S. Evans. Some empirical aspects of multi-sided platform industries. *Review of Network Economics*, 2(3), 2003.

D. S. Evans. How catalysts ignite: The economics of platform-based start-ups. *Platforms, markets and innovation*, 416, 2009.

D. S. Evans. Economics of vertical restraints for multi-sided platforms. *University of Chicago Institute for Law & Economics Olin Research Paper*, (626), 2013.

D. S. Evans and R. Schmalensee. The industrial organization of markets with two-sided platforms. Technical report, National Bureau of Economic Research, 2005.

D. S. Evans and R. Schmalensee. Failure to launch: Critical mass in platform businesses. *Review of Network Economics*, 9(4), 2010.

D. S. Evans and R. Schmalensee. *Matchmakers: The new economics of multisided platforms*. Harvard Business Review Press, 2016.

J. Farrell and P. Klemperer. Coordination and lock-in: Competition with switching costs and network effects. *Handbook of industrial organization*, 3:1967–2072, 2007.

J. Farrell and G. Saloner. Standardization, compatibility, and innovation. *the RAND Journal of Economics*, pages 70–83, 1985.

J. Farrell and G. Saloner. Installed base and compatibility: Innovation, product preannouncements, and predation. *The American economic review*, pages 940–955, 1986.

A. Hagiu. Pricing and commitment by two-sided platforms. *The RAND Journal of Economics*, 37(3):720–737, 2006.

A. Hagiu and H. Hałaburda. Information and two-sided platform profits. *International Journal of Industrial Organization*, 34:25–35, 2014.

A. Hagiu and J. Wright. Multi-sided platforms. *International Journal of Industrial Organization*, 43:162–174, 2015.

B. Jullien. Competition in multi-sided markets: Divide and conquer. *American Economic Journal: Microeconomics*, 3(4):186–220, 2011.

M. L. Katz and C. Shapiro. Network externalities, competition, and compatibility. *The American economic review*, 75(3):424–440, 1985.

M. L. Katz and C. Shapiro. Systems competition and network effects. *Journal of economic perspectives*, 8(2):93–115, 1994.

C. R. Knittel and V. Stango. Incompatibility, product attributes and consumer welfare: evidence from atms. *The BE Journal of Economic Analysis & Policy*, 8(1), 2008.

R. S. Lee. Vertical integration and exclusivity in platform and two-sided markets. *American Economic Review*, 103(7):2960–3000, 2013.

A. P. Lerner. The concept of monopoly and the measurement of monopoly power. *Review of Economic Studies*, 1(3):157–175, 1934.

G. Parker and M. W. Van Alstyne. Platform strategy. 2014.

J.-C. Rochet and J. Tirole. Platform competition in two-sided markets. *Journal of the european economic association*, 1(4):990–1029, 2003.

J.-C. Rochet and J. Tirole. Two-sided markets: a progress report. *The RAND journal of economics*, 37(3):645–667, 2006.

J. Rohlfs. A theory of interdependent demand for a communications service. *The Bell journal of economics and management science*, pages 16–37, 1974.

M. Rysman. The economics of two-sided markets. *Journal of economic perspectives*, 23(3): 125–43, 2009.

R. Schmalensee et al. An instant classic: Rochet & tirole, platform competition in two-sided markets. *COMPETITION POL'Y INT'L*, 10:173–175, 2014.

N. Srnicek. The challenges of platform capitalism: Understanding the logic of a new business model. *Juncture*, 23(4):254–257, 2017.

C. Stummer, D. Kundisch, and R. Decker. Platform launch strategies. *Business & Information Systems Engineering*, 60(2):167–173, 2018.

C. Tucker and J. Zhang. Growing two-sided networks by advertising the user base: A field experiment. *Marketing Science*, 29(5):805–814, 2010.

M. W. Van Alstyne, G. G. Parker, and S. P. Choudary. Pipelines, platforms, and the new rules of strategy. *Harvard business review*, 94(4):54–62, 2016a.

M. W. Van Alstyne, G. G. Parker, and S. P. Choudary. Reasons platforms fail. *Harvard business review*, 31(6):2–6, 2016b.

E. G. Weyl. Monopoly, ramsey and lindahl in rochet and tirole (2003). *Economics Letters*, 103 (2):99–100, 2009.

E. G. Weyl. A price theory of multi-sided platforms. *American Economic Review*, 100(4): 1642–72, 2010.

F. Zhu and M. Iansiti. *Dynamics of platform competition: Exploring the role of installed base, platform quality and consumer expectations*. Division of Research, Harvard Business School, 2007.

F. Zhu and M. Iansiti. Entry into platform-based markets. *Strategic Management Journal*, 33 (1):88–106, 2012.