



“Aspects of Multi-sided Platforms”

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Failure to Launch: Critical Mass in Platform Businesses¹

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Abstract

Platform businesses add value by facilitating interactions between customers who are attracted in part by network externalities. Two-sided platform businesses with low costs of reversing participation status have become more important with the rise of the internet. This essay is concerned with new businesses of this sort and with the initial critical mass hurdle that they generally seem to face. In a very general model, we show how this hurdle depends on the nature of network effects, the dynamics of customer behavior, and the distribution of customer tastes. Weak, plausible assumptions about adjustment processes imply that platforms must get a sufficient number of members of both sides on board to launch successfully.

Keywords: network, two-sided, startup, platform

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1. Introduction

Platform businesses add value by facilitating interaction of various sorts between customers who are attracted to the platform at least in part by network externalities. Such businesses are important in many key industries such as financial exchanges, advertising-supported media, and video-game consoles. They are significant in many web-based businesses such as search, job boards, social networking, and e-commerce.⁴ Theory tells us that firms with substantial network effects may be able to grow rapidly from a small base, because customers attract more customers. Some do. MySpace grew to more than 2 million registered users in its first year.⁵ But most do not. Few of the numerous business-to-business exchanges that started in the late 1990s survived despite beginning with an initial base of buyers and sellers.⁶ Many banks launched similar credit card systems in the 1950s, and almost all failed.⁷ And, as we discuss below, many social networking sites have been started, but only a few grew explosively, and most, such as SixDegrees.com, the first such site, failed to become viable businesses.

Consistent with this experience, we show here why an important class of new two-sided platform businesses, those for which the costs of reversing participation decisions are negligible, generally face a critical mass constraint that must be satisfied if the business is to be viable. This constraint, which is two-dimensional for two-sided platforms, does not involve production scale economies or fixed costs. We show that it depends instead on the nature of the network effects linking the platform's two customer groups, the distribution of tastes among potential customers in both groups, and the nature of out-of-equilibrium dynamics.⁸ Because our focus here is on the fundamental nature and sources of this constraint, we do not impose additional assumptions that would enable us to derive profit-maximizing price (and/or non-price) strategies.

Multi-sided platforms on which it is easy to reverse participation decisions have become increasingly important since the rise of the internet. Users can readily reverse participation

⁴ For a general discussion of platform businesses see Evans and Schmalensee (2008).

⁵ ComScore MediaMetrix Report, August 2004.

⁶ See Lucking-Reiley and Spulber (2001).

⁷ See Evans and Schmalensee (2005, ch. 3).

⁸ We consider only regimes in which prices are not conditional on numbers of participants. Weyl (forthcoming) has shown that in a world of perfect information it is possible for a new platform to eliminate the critical mass constraint through an "insulating tariff" policy that makes the price of (or subsidy for) participation a function of the participation of others. Such policies do not seem to be common, however, and, as we discuss below we do not believe they are feasible for most new platform businesses.

decisions, for example, on social networking sites such as Facebook, MySpace, and LinkedIn.⁹ Many users, for example, switched from Friendster—one of the most popular early social networking sites—to MySpace as a result of dissatisfaction with Friendster and the appeal of MySpace.¹⁰ It is also easy to reverse participation decisions in many multi-sided platforms for which network effects are important.¹¹ These include older platforms such as payment cards and newspapers as well as newer ones such as video-sharing sites (e.g., Veoh) and auction sites (e.g., eBay).¹² Indeed, consumers often multi-home—participate on more than one competing platform—because of differentiation and despite indirect network effects.

The formal analysis of businesses in which *direct network effects* make participation more attractive to each individual the more other individuals participate began with the seminal paper by Rohlfs (1974). He assumed, as we do, that participants incur no costs when they change their participation status. This assumption makes myopic customer behavior rational, and we assume myopic behavior in what follows. Rohlfs (1974) showed how a critical mass constraint can arise for a single-sided platform business under this assumption. The subsequent literature on direct network effects, however, has focused primarily on situations in which the decision to participate in a network can be treated as irreversible.¹³ Myopic behavior is irrational in these situations, and expectations of non-participants play a key role. With strong network effects, new networks tend either to capture the entire market (e.g., Blu-Ray) or to fail completely (e.g., HD-DVD). This literature has modeled the launch of new networks as an

⁹These businesses attract “users” who want to connect with each other. We treat that as the sort of direct network effect that has been considered for communications platforms, e.g., by Rohlfs (1974). It is also possible, as discussed in Evans (2009), to characterize these as indirect network effects as a result of asymmetries between senders and receivers of friendship requests, but that detail is not relevant to the analysis here. (Facebook was partly designed to help college students find dates—so the two sides were men and women, while MySpace initially attracted musicians and their fans.) These businesses then make money from these users by providing access to them to advertisers. There is a positive indirect network effect from the advertisers to the users. We ignore advertisers in what follows and focus only on the startup phase that involves the acquisitions of users through the exploitation of network effects.

¹⁰ See Boyd and Ellison (2007).

¹¹ One can argue that it becomes harder for people to reverse participation decisions on social networking sites as they accumulate friends, but that is unlikely to be an issue during the startup phase on these sites.

¹² On payment cards, see Evans and Schmalensee (2005). Evans and Schmalensee (2008) discuss numerous examples of two-sided platforms.

¹³ See Katz and Shapiro (1994), Economides (1996), and Farrell and Klemperer (2007) for surveys of this mainly theoretical literature; Birke (2008) discusses related empirical work. Recent studies of competition in markets with direct network effects include Economides et al (2005) and Cabral (2008). The network games model of Jackson and Yariv (2007) is formally equivalent to a direct network effects model with zero costs of changing participation status.

event, not a process, and has examined competition among networks for dominance; it has not focused on the startup problems facing new networks or the dynamic process of network growth.

More recently, the groundbreaking work of Rochet and Tirole (2003) on “two-sided markets” has stimulated much theoretical work and an increasing amount of empirical work on multi-sided platform businesses that exploit *indirect network effects* between distinct customer groups.¹⁴ Video game console firms, for example, realize network effects from people who buy their consoles and publishers who build games on their platforms. Informal discussions in this literature emphasize the need for platform businesses to “get both sides on board” and to “solve the chicken-and-egg problem.” However, formal modeling has focused on characteristics of established, successful platforms, not on the launch of new platforms.

As far as we know, the critical mass constraint facing new multi-sided platforms, on which this essay focuses, has not been addressed systematically in the previous literature. The market microstructure literature occasionally alludes to the role of critical liquidity in establishing viable exchanges, but it contains no systematic analysis.¹⁵ Caillaud and Julien (2003) consider the launch of platforms that function as intermediaries; but they require that all customer decisions be made in a single period after prices are set, so that platform launch is treated as an event, not a process. Hagiu (2006) studies a two-stage start-up game with full information, though he allows for the possibility that customers on the two sides of the business may make their decisions in different periods. The only previous study of which we are aware of that explores the dynamics of starting up a business with significant indirect network effects and negligible switching costs is Fath and Sarvary (2003), which considers a specialized model of buyer-side business-to-business exchanges.

When it is launched, a typical platform start-up often uses venture funding to learn about demand and to attempt to build a viable business.¹⁶ A variety of more or less expensive

¹⁴ Notable theoretical contributions include Ambrus and Argenziano (2009), Armstrong (2006), Caillaud and Julien (2003), Hagiu (2006), and Weyl (2008a, 2008b); see Rochet and Tirole (2006) for an overview. Stremersch et al (2007) and Birke (2008) provide overviews of the empirical literature; see Argente and Filistrucchi (2007), Genakos and Valletti (2008), and Kaiser and Wright (2006) for recent contributions. We resist the “two-sided market” terminology because two-sidedness is a characteristic of individual business models, not of markets. We prefer the term “multi-sided platform” (Evans and Schmalensee (2008)) or “economic catalyst” (Evans and Schmalensee (2007)).

¹⁵ See Harris (2002) and O’Hara (1995) on this literature.

¹⁶ See Evans (2009) for some case studies. Since the distribution of tastes for new platforms’ offerings are generally unknown, one would expect the choice of startup policies generally to be liquidity constrained by investors, who

transitory devices are typically employed to build demand; these include low introductory prices, advertising, viral marketing, vendor-supplied content, and seeking marquee participants. If consumer tastes turn out to be favorable and the critical mass constraint can be satisfied, the business can then turn its attention to maximizing long-run profits. Our concern here is with the severity of this constraint, with how much must be done at the outset to make ultimate success possible, not with how it might best be satisfied. Accordingly, we do not make restrictive assumptions that would enable us to consider optimal launch or post-launch price or non-price policies.¹⁷

In Section 2 we consider single-sided platform businesses in order to introduce notation and assumptions in a familiar setting and to relate our analysis to the previous literature. We discuss social networking sites briefly in order to motivate the analysis. Then, building on Rholfs (1974), we show that for any given price and non-price policy, if a potentially viable business attains a critical mass of participants, network effects will drive subsequent growth until the business reaches a stable equilibrium.¹⁸ If the business finds itself with less than this critical mass of participants, however, network effects will drive a downward spiral toward a stable equilibrium with zero participation. For any given price and non-price policy, both the critical mass necessary for viability and the larger stable equilibrium participation depend on the distribution of consumer tastes. While equilibrium participation is a decreasing function of the platform's price, all else equal, as one would expect, critical mass is *increasing* in price.

In Section 3 we turn our main concern, the analysis of the critical mass constraint facing businesses that offers a single platform to two distinct customer groups and rely on indirect network effects connecting them.¹⁹ To motivate the analysis we provide brief discussions of the experience of new two-sided platforms of two types: business-to-business (B2B) exchanges and

might, for instance, reasonably refuse to fund widespread subsidies to participants on a platform that may ultimately be non-viable. We believe that the uncertainty generally faced by both investors and potential customers leads to liquidity constraints that generally rule out use of the “insulating tariffs” discussed by Weyl (forthcoming).

¹⁷ Similarly, we do not address whether a platform that attains critical mass would in fact be profitable; this would require the explicit consideration of costs and other revenue.

¹⁸ Economides and Himmelberg (1995) and Economides (1996) discuss “critical mass” in the context of direct network effects, but they do not explicitly consider the start-up problem, and their definition of “critical mass” is, as we demonstrate below, different from the quantity that emerges in the analysis of that problem.

¹⁹ Ambrus and Arrgenziano (2009) present equilibria in a model with two consumer types in which a monopolist offers two networks with different pricing patterns. These equilibria require substantial coordination among consumers, however, which seems absent in many markets. But see Ruffle, Weiss, and Etzioni (2010) for an interesting recent experimental study that finds buyer coordination in some circumstances.

payment systems. We show that in general two-sided platforms face a two-dimensional critical mass constraint. The shape of the critical mass frontier depends on the distribution of tastes within both groups as well as the relative speeds with which different sorts of disequilibria are eliminated. Increases in prices or reductions in desirable non-price attributes tend to shift this frontier out while lowering the system's higher stable equilibrium.

Section 4 provides some concluding observations and suggestions for further work.

2. Direct Network Externalities

This section considers the dynamics of a platform business that hopes to exploit positive direct network effects within a single customer group. For concreteness it is useful to think of a new social networking site.

2.1 Social Networking Sites

A number of such sites were started before the dot.com bust, but it does not appear that any have survived as significant entities. SixDegrees.com was one of the first. It was an open social network that anyone could join, and it grew to about three million users over three years.²⁰ Participation reportedly fell off thereafter because there was not enough to do on the site. In contrast, Facebook had over 50 million users after its first year as an open social network.²¹ SixDegrees.com imploded, while Facebook and MySpace exploded.

Facebook was launched in February, 2004 at Harvard College as a virtual place where students who saw each other in class and other settings could connect and possibly find dates. According to one of its founders, Mark Zuckerberg, “[W]ithin two weeks, two-thirds of Harvard were using it.”²² Facebook then launched similar closed social networks at other colleges. About 85 percent of students in those colleges had accounts as of September 2005.²³ Within these closed communities Facebook appears to have had an easy time obtaining significant

²⁰ See *Facebook*, Case E220, Stanford Graduate School of Business, May 2006.

²¹ See Facebook Timeline (available at <http://www.facebook.com/press/info.php?timeline>, last visited on March 23, 2009).

²² See *Facebook*, Case E220, Stanford Graduate School of Business, May 2006.

²³ See Yadav (2006).

participation quickly. Facebook opened its network in September, 2006, and it had more than 110 million users by October, 2008.²⁴

MySpace took a different approach. It was established from the beginning as an open social network. eUniverse, which operated a number of community-based websites, launched MySpace in August, 2003. To ignite the site it sent an email to its 250 employees describing MySpace and inviting them to join. It also sponsored a contest with a prize of \$1000 for the employee who attracted the largest number of friends.²⁵ The email said “If all 250 employees add 10 friends, we’ll have an instant base of 2500 and this will be the spark we need to jumpstart this service.”²⁶ At the same time, it started inviting the 18.5 million users who visited its various other sites. As of late September it was adding 4-6 thousand users a day.²⁷ Early marketing efforts focused on rock bands from Los Angeles area. The bands set up group profiles and invited fans to “friend” them.²⁸ Musicians, models, and their fans comprised many of the early users according to some accounts, and their presence continues to differentiate the site from its rivals today. MySpace grew explosively from these beginnings. It had 56 million users as of September, 2008.²⁹

Generally, entrepreneurs behind a social networking site want to secure a large group of consumers who will attract each other to visit the site regularly. If they obtain enough users, advertisers will pay enough to reach these users to offset the costs of establishing and running the

²⁴ See Facebook Timeline (available at <http://www.facebook.com/press/info.php?timeline>, last visited on March 23, 2008).and Facebook Statistics (available at <http://www.facebook.com/press/info.php?statistics>, last visited on March 23, 2009).

²⁵ Here we draw mainly on Brad Greenspan’s narrative. See “MySpace History,” available at <http://freemyspace.com/?q=node/13>, last visited on June 10, 2008. For a somewhat different perspective that skips over the details of the MySpace launch see, for example, M. Bosworth, “What’s Inside MySpace.com? Murdoch’s Latest Media Marvel May Be His Biggest Yet”, April 8, 2005, available at http://www.consumeraffairs.com/news04/2006/03/myspace_inside.html, last visited on June 10, 2008.

²⁶ A snapshot of the email is available at: <http://freemyspace.com/08-28-03.JPG>.

²⁷ <http://freemyspace.com/M.jpg>

²⁸ See “Indie Bands and Their Fans Flock to MySpace.com,” PR Newswire, 18 March 2004, available at http://goliath.ecnext.com/coms2/summary_0199-148035_ITM, last visited on June 10, 2008. See also “Thousands of Bands, 2 Million Users Kick Off MySpace Music Site,” PR Newswire, 25 May 2004, available at http://goliath.ecnext.com/coms2/gi_0199-384296/Thousands-of-Bands-2-Million.html, last visited on June 10, 2008.

²⁹ See [compete.com](http://www.compete.com), last visited on October 16, 2008.

site and generate a profit. Facebook, for example, waited until it had 50 million users, 44 months (three and a half years) after its inception, before it started selling advertising.³⁰

2.2 Assumptions

We now show how the distribution of consumer tastes can affect whether a social network experiences explosive growth like Facebook or a rapid decline into failure like most of its predecessors. Let $N(t)$ denote the number of individuals who participate on the platform at time t , and let \bar{N} be the maximum possible number of participants. Consistent with most of the literature, we assume that the attractiveness of participating on the site under consideration does not depend on the identities of the other participants. We assume that a typical individual, i , if she is well-informed, will want to participate on the site at time t if and only if

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

Here the V_i are increasing functions with $V_i(0) = 0$ and parameters α_i . These functions reflect differences among individuals in the attractiveness of being connected to others on the platform in question and thus reflect both individual- and site-specific attributes. Similarly, θ_i measures the non-pecuniary costs to individual i of participation on the site, net of any intrinsic willingness to participate on the site even if nobody else does. For an internet-based platform it will reflect ease of use as well as individual i 's reaction to such site-specific attributes as advertising, site design, and supplier-provided content.³¹ The pecuniary cost of participating on this site is P , which we take as constant along with the V_i , α_i , and θ_i . Clearly increasing P will increase Ω_i for all i . Advertiser-supported sites usually have no fees so $P = 0$; non-price attributes such as site design and advertising intrusiveness affect the distribution of the Ω_i .

We assume the non-negative quantity, Ω , which is a measure of the net resistance to participation, is distributed in the relevant population according to some smooth density function $f(\Omega|P)$, with corresponding non-decreasing distribution function $F(\Omega|P)$. What matters for market dynamics is the behavior of F in the interval $[0, \bar{N}]$, which may or may not coincide with

³⁰ See Facebook Factsheet, Press Release, available at <http://www.facebook.com/press/info.php?timeline>, last visited on March 23, 2009.

³¹ In some cases, increased participation might lower θ generally, if participants can add features or functionality to the platform.

its support. On these assumptions, the number of individuals who, *if they are well informed*, will want to participate on the platform at time t is simply $F[N(t)|P]\bar{N}$. When $N(t)$ equals this quantity, we have a fulfilled expectations equilibrium. Because Ω is increasing in P from equation (1), it follows that $F[N|P]$ is everywhere decreasing in P . If the V_i and θ_i vary among individuals, the shape of F may also depend on the level of P .

The entire target population is almost never well-informed at the launch of a new web site – or, for that matter, any other new business or new product. In the case of internet-based platforms, individuals who visit can learn about the features of the service and at least form a rough idea of the number of participants at that time. But there are always many new sites, and visiting all of them would take an enormous amount of time and effort. As with any new product, learning about platform businesses also takes place through word of mouth, and, perhaps, advertising. For our purposes, it suffices to assume only that $N(t)$ always tends smoothly toward its well-informed equilibrium:

$$(2) \quad \text{sgn} \left\{ \dot{N} \equiv \frac{dN}{dt} \right\} = \text{sgn} \left\{ F[N(t)|P]\bar{N} - N(t) \right\}.$$

This assumption is consistent with an extensive body of empirical work, much of it in marketing, on the launch of new products.³² The product diffusion models employed there assume, as we do here, that demand adjusts gradually toward equilibrium over time because of imperfect information and inertia.³³

2.3 The Critical Mass Problem

Figure 1 illustrates how, with price fixed, the dynamics of this model depend on the distribution of Ω in the population of potential participants. From (2), if $F(N|P)\bar{N}$ is above the 45-degree line OT , N is increasing; otherwise it is decreasing. If Ω is distributed according to F_1 for some post-initiation price, few in the population have low values of Ω , the origin is the only

³² The seminal paper is Bass (1969). For a survey of the subsequent literature through the late 1980s see Manajan et al (1990).

³³ We thus rule out the sort of coordinated behavior considered by Ambrus and Argenziano (2009) and studied experimentally by Ruffle, Weiss, and Etziyony (2010). Our treatment of dynamics generalizes that of Fath and Sarvary (2003). The model of this section is formally close to the network game model of Jackson and Yariv (2007).

equilibrium, and it is globally stable. This platform cannot be made successful at the level of P that underlies F_1 —which may be zero for an advertiser-supported website—no matter what value of N is attained initially. At the other extreme, if Ω is distributed according to F_2 , which corresponds to a monotonically decreasing density function, the corresponding business will reach point G even if the site starts with a value of N near zero. The origin is still an equilibrium in this case, but an unstable one. All that is necessary to launch this business is somehow to make N positive – perhaps by signing up the firm’s founders as users. Doing so will ignite a catalytic reaction that will drive the network to its globally stable equilibrium at point G. As discussed above, Facebook may be an example of this within the closed college networks with which it began.

****Figure 1****

The most interesting case is illustrated by F_3 in Figure 1, which corresponds to a unimodal distribution of Ω with mode between zero and \bar{N} . In this case there are two locally stable equilibria: the origin and point E.³⁴ In order to reach E, however, the business needs somehow to attain critical mass, to get participation beyond the unstable equilibrium at point C.³⁵ Even though the potential scale of this platform is nearly as great as that of the platform corresponding to F_2 , realization of that potential would require a much more serious initial launch effort. Note that in this case if $P > 0$, lowering P would raise F_3 and thus move the stable equilibrium point E to the right and the point C, which defines the critical mass constraint, to the left.³⁶ (If this is an advertiser-supported site with $P = 0$, however, this tactic may not be available if the platform faces liquidity constraints.³⁷) Following Jackson and Yariv (2007), any

³⁴ It is easy to see that if there are multiple equilibria in this model, stable and unstable equilibria alternate.

³⁵ Rohlfs (1974), Economides and Himmelberg (1995), and Economides (1996) discuss cases similar to this one, and they note the existence of an unstable equilibrium, but they do not relate it to the requirements for successful platform launch. Jackson and Yariv (2007) discuss formally identical cases in the context of network games.

³⁶ Economides and Himmelberg (1995) and Economides (1996) define “critical mass” in this context as the smallest possible stable equilibrium. In Figure 1, price increases would lower F_3 until it becomes tangent to the dotted OT line. These authors define “critical mass” as the value of N corresponding to the point of tangency; it gives the smallest possible stable equilibrium with positive participation. But this is only the scale that must be attained at launch by the network with the highest possible price. Networks with lower prices have lower critical mass requirements.

³⁷ More generally, one could imagine a launch strategy in which P (or, in the two-sided case, the price structure) is initially set low enough to induce increasing participation even with a very small initial N and then lowered over time as increases in N make the platform more attractive. Gabszewicz and Garcia (2005) consider strategies of this sort. Such strategies do not seem common in practice, however, perhaps because if θ is generally positive they

change in the attributes of the platform or the tastes of potential consumers that has the effect of raising F_3 (so that the old distribution of Ω first-order stochastically dominates the new one) will have this same effect.

If the origin is a locally stable equilibrium for given price and non-price policies, a single-sided platform must reach positive critical mass in order to reach a higher stable equilibrium. A necessary and sufficient condition for any equilibrium point n to be locally stable is

$$(3) \quad f(n|P)\bar{N} < 1.$$

To understand (3), consider increasing actual participation from n to $n+\delta$, where δ is small. The corresponding increase in equilibrium participation induced by direct network effects is $f(n|P)\bar{N}\delta$. Condition (3) then requires that network effects be locally weak enough that the increase in equilibrium participation is less than the increase in actual participation, so that actual participation will fall back toward the initial equilibrium. Conversely, condition (3) is violated at equilibria at which network effects are locally strong, and this leads to instability.

Focusing on the origin ($n = 0$), condition (3) says that some initial launch effort is required because the number of eager early adopters (those with very low Ω s) is insufficient to ignite growth to a viable equilibrium level. This seems consistent with the experience of many new platforms. Distribution function F_3 in Figure 1 also satisfies the following condition, which ensures the existence of at least one non-zero, locally stable equilibrium:

$$(4) \quad \max_{x \in [0, \bar{N}]} [F(x|P)\bar{N} - x] > 0.$$

Following Rohlfs (1974, Sect. 3), it is instructive briefly to consider the following specialization of equation (1):

$$(5) \quad \alpha_i N - P \geq 0, \quad \text{or} \quad \Omega_i \equiv P/\alpha_i \leq N.$$

require the new venture to pay participants. Venture capitalists and other early-stage investors in ventures with uncertain demand, as well as self-funded entrepreneurs, seem likely to resist financing such payments; larger companies that are launching platforms as separate product lines may be more likely to provide subsidies to spark growth.

where α is uniformly distributed in the population of potential participants from zero to A . (To transform this into a model of an advertiser supported site, set $P = 0$ and assume a constant $\theta > 0$ for all potential participants.) It is easy to show that the distribution of Ω is then given by

$$(6) \quad F(\Omega) = \begin{cases} 0, & \text{for } \Omega \leq P/A \\ 1 - (P/A\Omega), & \text{for } \Omega \geq P/A \end{cases}$$

For fixed P , equilibrium at a positive N requires

$$(7a) \quad N = F(N)\bar{N} = \left[1 - \frac{P}{NA}\right]\bar{N}, \text{ or } \mu = 1 - \frac{P}{\mu}, \text{ where}$$

$$(7b) \quad \mu \equiv \frac{N}{\bar{N}}, \text{ and } p \equiv \frac{P}{A\bar{N}}.$$

If p exceeds $1/4$, equation (7a) has no real roots. For $p < 1/4$, this equation has two real roots, on opposite sides of $\mu = 1/2$:

$$(8) \quad \mu = \frac{1}{2} \left[1 \pm (1 - 4p)^{1/2} \right].$$

****Figure 2****

Figure 2 illustrates the dynamics of this example when $p < 1/4$. The origin and point E, which corresponds to the larger solution to (8), are locally stable, while the point C, which corresponds to the smaller solution, is the unstable critical mass point. In order for the positive network externality to build participation up to point E, the platform needs to attract initial participation at least corresponding to C.

3. Indirect Network Effects

We now turn to the main focus of this essay: the more complex and interesting dynamics of a new platform business that aims to harness indirect network effects between two customer groups. We first consider the instructive experiences of business-to-business exchanges and payment systems and then develop a general model that builds on that presented in Section 2.

3.1 Business to Business Exchanges

More than 1500 business-to-business exchanges were started between 1995 and 2001.³⁸ Virtually all of them imploded in the early 2000s, and the notable ones that survived, such as Ariba, shifted focus from facilitating bilateral buyer-seller transactions. These sites failed in part because they could not attract enough suppliers. As one consultant noted about the proposed B2B exchanges for the airline industry:³⁹

[suppliers] continue to be reluctant to sign up to portals and other e-mechanisms created by the prime contractors. The key reason for this is that the primary objective of e-procurement is perceived to be a reduction in the purchase price, therefore forcing pressures on [supplier] margins.

A number of observers of the demise of the B2Bs opined that a major problem was that suppliers were scared, as one put it, "of comparison shopping and brand dilution."⁴⁰ Buyers did not necessarily find the sites attractive either. Sophisticated ones had considerable knowledge about the quality of suppliers and did not find auction methods of procurement attractive. Thus there were too few interested buyers and sellers to make viable markets.

Dell Marketplace, which opened in late 2000, is an example of a B2B exchange that failed to reach critical mass. Unlike some electronic marketplaces that focused on e-procurement in specific vertical markets, Dell Marketplace was designed to reach horizontally across multiple product segments to provide buyers access to items from a variety of suppliers.⁴¹ Customers could buy Dell personal computers, notebooks, servers and related hardware, along with other office products from selected suppliers. However, less than a year after its ambitious launch, Dell Marketplace closed in February, 2001. As explained by Dell, the exchange closed down due to "a limited readiness of customers to make use of an electronic marketplace."⁴² Lack of interest

³⁸ Harrington (2001).

³⁹ See, Odell (2001).

⁴⁰ See Nowshade Kabir, "E-marketplace; Facts and Fictions," WebProNews, posted on August 20th, 2003, <http://www.webpronews.com/topnews/2003/08/20/emarketplace-facts-and-fictions>.

⁴¹ See Bochner (2000).

⁴² See Mahoney (2001).

from customers was not the only problem, though: only three suppliers signed up to sell their products directly to customers in the four months Dell Marketplace was open.⁴³

3.2 Payment Card Systems

The modern payment card industry was started in the 1950s.⁴⁴ Diners Club launched the first successful network for consumers and merchants in 1950. It took a sequential geographic and segment approach beginning with New York City restaurants. To ignite the business it signed up 14 restaurants and a few hundred cardholders in Manhattan. The restaurants were charged seven percent of the meal tab. The cardholders paid no fixed or variable fees for the cards and, since they only had to pay their bills once a month, enjoyed free float for an average of about two weeks. Thus cardholders initially faced a negative price for using the card. According to press reports Diners Club increased the number of cardholders to 42,000 and number of merchants to 330 in a year. It expanded to other cities and to other travel-and-entertainment segments. By 1956, almost \$54 million of transactions had taken place nationally.⁴⁵

It appears that the ability to use payment cards in a wide geographic area was important to a substantial number of consumers. One bank tried to start a card network before Diners Club, and hundreds attempted afterwards. At the time, interstate banking restrictions limited most banks to operate solely within single states, and branch banking restrictions sometimes limited banks to operate solely within single communities. Despite easy access to consumers and merchants—both already bank customers—banks' attempts to launch payment cards failed. It appears that Bank of America was the only successful bank entrant. It launched a card network that covered California; this large network eventually evolved into the Visa card association.

3.3 Assumptions

For concreteness, in what follows we employ the now-familiar example of content-sharing platforms. In these platforms some individuals upload content such as videos, photos, or news stories while others download that content and view it.⁴⁶ The uploaders value the

⁴³ See Weiss (2001).

⁴⁴ For support for this section, see Evans and Schmalensee (2007, ch. 1) and Evans and Schmalensee (2005, ch .3).

⁴⁵ See Evans and Schmalensee (2005), pp 1-3.

⁴⁶ For an interesting discussion of YouTube's efforts to attract a critical mass of uploaded content and viewers and the explosive growth that occurred when it did so, see <http://www.youtube.com/watch?v=nssfmTo7SZg>.

popularity and reputation-building that come from attracting a large audience, while the downloaders value having a larger pool of content to choose from. Such platforms typically operate like media business sites in that they acquire viewers and then sell access to these viewers to advertisers.

Let $N^U(t)$ and $N^D(t)$, respectively, denote the number of individuals who regularly upload and download content at time t , and let \bar{N}^U and \bar{N}^D , respectively, denote the maximum number of potential regular uploaders and downloaders. Note that some individuals may participate both as uploaders and as downloaders. It is then appropriate to consider them as on both sides of the platform. Since downloaders are generally interested in new content, they will, if well informed, visit a site regularly only if new content is regularly uploaded, while uploaders, who want their work to be seen, will have no audience and thus no incentive to upload if downloaders do not visit regularly. We continue to assume that participation decisions are easily reversible and that only the number of participants on each side matters, not their identities.

In parallel with the development in Section 2, we assume that a typical individual i , if he is well informed, will want to be a regular downloader at time t if

$$(9) \quad V_i^D \left[N^U(t) | \alpha_i^D \right] - \theta_i^D - P^D \geq 0, \text{ or } \Omega_i^D \equiv V_i^{D-1} \left(\theta_i^D + P^D | \alpha_i^D \right) \leq N^U(t).$$

This is just equation (1) applied to a potential downloaders, except that the network effect here is *indirect*: downloaders care about the participation of uploaders, not the participation of other downloaders.

As in Section 2, we assume that the quantity Ω_i^D , which measures resistance to participation as a downloader, is distributed in the population according to the smooth density function $f^D(\Omega | P^D)$, with corresponding distribution function $F^D(\Omega | P^D)$. Then the number of households who, if they are well informed, will want to be regular downloaders at time t is simply $F^D \left[N^U(t) | P^D \right] \bar{N}^D$. F^D is non-increasing in P^D , and we assume that imperfect information and inertia yield gradual adjustment of downloading toward its well-informed equilibrium at each instant:

$$(10) \quad \text{sgn} \left\{ \dot{N}^D \right\} = \text{sgn} \left\{ F^D \left[N^U(t) | P^D \right] \bar{N}^D - N^D(t) \right\}.$$

We make qualitatively identical assumptions on the other side of the market. Thus individual j , if she is well informed, will want to be an uploader at time t if

$$(11) \quad V_j^U \left[N^D(t) | \alpha_j^U \right] - \theta_j^U - P^U \geq 0, \quad \text{or} \quad \Omega_j^U \equiv V_j^{U-1} \left(\theta_j^U + P^U | \alpha_j^U \right) \leq N^D(t).$$

We assume that Ω_j^U , which measures resistance to participation as an uploader, is distributed in the population according to the smooth density function $f^U(\Omega | P^U)$, with corresponding distribution function $F^U(\Omega | P^U)$, so that the number of households who will want to be regular uploaders at time t if they are well informed is simply $F^U \left[N^D(t) | P^U \right] \bar{N}^U$. For advertiser-supported content-sharing sites, $P^U = 0$. As above, we simply assume gradual adjustment of uploaders toward their well-informed equilibrium:

$$(12) \quad \text{sgn} \left\{ \dot{N}^U \right\} = \text{sgn} \left\{ F^U \left[N^D(t) | P^U \right] \bar{N}^U - N^U(t) \right\}.$$

3.4 The Two-Dimensional Critical Mass Problem

Three cases that correspond broadly to the three distribution functions illustrated in Figure 1 can be instructively analyzed graphically here. (As in Section 2, the shape of each of the curves considered here as well as its level may in general depend on the corresponding price.) Figure 3 shows a two-sided platform business that is not viable at the prices chosen, no matter how it is launched, because there are too few individuals on either side of the market with low values of Ω . The directions of motion over time implied by (10) and (12) are indicated by the short arrows, while the curved arrows show, qualitatively, typical trajectories. The origin is the only equilibrium, and it is globally stable.⁴⁷ Even if this system were launched with substantial uploading activity, as at point A, uploading would tend monotonically to zero, while after an initial increasing phase, downloading would also decline to zero.

Figure 3

⁴⁷ For simplicity, Figure 3 is drawn with $f^U(0)$ and $f^D(0)$ positive. If, instead, $F^U(F^D)$ were zero in a neighborhood of zero, the $\dot{N}^U = 0$ ($\dot{N}^D = 0$) locus would intersect the vertical axis above the origin (the horizontal axis to the right of the origin), and the origin would still be the only stable equilibrium.

Figure 4 illustrates a case in which at the prices chosen there are many individuals with low resistance to uploading and many with low resistance to downloading.⁴⁸ The intersection point G is a globally stable equilibrium. (If the curves were to hit the dashed lines before they intersected, the point T, with universal participation, would be the unique stable equilibrium.) In this case, as in the case of the F_2 distribution in Figure 1, all that is necessary to reach a trajectory tending toward the stable equilibrium at G is to move the system an arbitrarily small distance away from the origin—by uploading a single video, for example.

****Figure 4****

We suspect that the case illustrated in Figure 3 is very common, simply because lots of ideas for content-sharing and other platforms simply are not attractive enough to one or both sides of the market to be viable at prices that cover cost, no matter how they are launched. On the other hand, the apparent fact that very few successful two-sided platform businesses have been launched with essentially no effort—i.e., no initial investment in attracting a non-zero critical mass on at least one side of the market—suggests that the case illustrated in Figure 4 is very uncommon. The chicken-and-egg problem rarely seems to be trivial for real platforms.

Thus we suspect that most two-sided platforms that were ultimately successful—as well as more than a few that could have been successful if properly launched but that ultimately failed—have post-launch dynamics like those illustrated in Figure 5. The shapes of the two distribution functions illustrated correspond to unimodal density functions of Ω^U and Ω^D , with modes occurring before universal participation.⁴⁹ The origin and point E are locally stable equilibria,⁵⁰ while point C is a saddle-point. (As in Figure 4, if the curves do not intersect to the right of C, the universal participation point, T , is the non-zero locally stable equilibrium.) That is, there is a unique critical trajectory, like AA' or BB', that tends toward C. Trajectories beginning above this trajectory tend to E, while trajectories beginning below this path tend to the origin.

⁴⁸ As Figure 4 is drawn, the origin is not an equilibrium. It would be an unstable equilibrium if the two stationary curves intersected there

⁴⁹ To see this, note that the slope of the $\dot{N}^D = 0$ locus, for instance, is equal to $f^D(N^U)\overline{N}^D$.

⁵⁰ If there are multiple equilibria with positive N's, it is easy to see that locally stable equilibria and saddle-points must alternate. This same pattern appears in the two-sided search literature—see, e.g., Burdett and Wright (1998)—for broadly similar reasons. We are indebted to Andrei Shevchenko for calling this to our attention.

****Figure 5****

The need to reach a point above this critical trajectory in order for positive feedback to drive the system to the point E rather than to the origin is the critical mass constraint for two-sided platforms.⁵¹ If the critical trajectory looks like BB' the platform's critical mass constraint is essentially one-dimensional: it requires securing *either* enough chickens *or* enough eggs, to use the familiar metaphor. If, on the other hand, the critical trajectory looks like AA', the platform's critical mass constraint is two-dimensional: it requires securing *both* enough chickens *and* enough eggs.

We believe that frontiers like AA' are the normal case.⁵² Frontiers with shapes like AA' arise when the side of the market with participation above its well-informed equilibrium level adjusts downward faster than the other side, which has participation below its equilibrium level, adjusts upward. If a potential downloader, say, visits a video-sharing site and finds no content of interest, she can instantly decide not to participate – i.e., not to visit the site again, at least for some period of time. On the other side of the market, it is likely to take time for information regarding the number of regular downloaders – i.e., the size of the audience for video content – to diffuse among potential uploaders and for them to decide to begin uploading content.

In general, an increase in P^D (or any change in site characteristics or downloaders' tastes that results in a shift to a new Ω^D distribution that stochastically dominates the old) would shift the $\dot{N}^D = 0$ curve down, thus moving the point C, and with it the system's critical trajectory, away from the origin, while shifting the stable equilibrium point E toward the origin. If both densities (and thus the slopes of both curves) are strictly positive at these points, both N 's would be increased at positive saddle-points, and both would be decreased at stable equilibria. Raising P^U or otherwise reducing the attractiveness of the audience of downloaders would shift the $\dot{N}^U = 0$ curve to the left and thus have qualitatively similar effects. Resistance to participation on both sides of a two-sided platform can often be reduced significantly by platform design,

⁵¹ Fath and Sarvary (2003) show the existence of a constraint of this sort for their specialized model of buyer-side business-to-business exchanges.

⁵² See Evans (2009) for more on this point and its implications.

particularly on the internet,⁵³ and it is interesting to note that such reductions both enhance the size of a successfully launched platform and relax the critical mass constraint that it must satisfy.

The condition that the origin be a stable equilibrium as in Figures 3 and 5 is that the $\dot{N}^U = 0$ curve lie above the $\dot{N}^D = 0$ curve in a neighborhood of the origin. From (10) and (12), with smooth density functions this is equivalent to⁵⁴

$$(13a) \quad F^D(0) = F^U(0) = 0, \quad \text{and}$$

$$(13b) \quad \left[f^D(n^U) \bar{N}^D \right] \left[f^U(n^D) \bar{N}^U \right] < 1 \quad \text{at } n^U = n^D = 0.$$

Condition (13b) is necessary and sufficient for any non-zero (n^U, n^D) equilibrium point to be stable. Generalizing the discussion of condition (3) above, consider small increases δ^U and δ^D in actual participation from such a point. The increases in equilibrium participation that would be induced by indirect network effect are

$$d^U \equiv f^U(n^D) \bar{N}^U \delta^D \quad \text{and} \quad d^D \equiv f^D(n^U) \bar{N}^D \delta^U,$$

respectively. Condition (13b) says that local network effects, as measured by the geometric mean of the two cross-effects, must be *weak* enough that $d^U d^D < \delta^U \delta^D$: the new equilibrium point lies on a rectangular hyperbola strictly below the new actual point, so that actual participation must decline on average. Conversely, strong (geometric) average local network effects lead to saddle-point instability. At the origin, condition (13b) requires that the numbers of potential uploaders and downloaders with very low resistance is low enough that some initial effort is necessary to launch the platform successfully.

The condition that there exist at least one non-zero stable equilibrium, as in Figures 4 and 5, is that the $\dot{N}^U = 0$ curve lie below the $\dot{N}^D = 0$ curve somewhere in the relevant range, or

$$(14) \quad \max_{x \in [0, \bar{N}^U]} \left\{ F^D(x) \bar{N}^D - F^{U-1}\left(x / \bar{N}^U\right) \right\} > 0.$$

⁵³ The discussion of the role of the Flash media player in YouTube's launch at <http://www.youtube.com/watch?v=nssfmTo7SZg> illustrates this point nicely.

⁵⁴ See Weyl (2008) for similar stability conditions. We have not shown dependence on prices here and below to reduce notational clutter.

Clearly this condition will not be satisfied for all possible two-sided platforms, though it must be satisfied for all that are ultimately successful.

Finally, it is instructive to consider a two-sided version of the example analyzed in Section 2. Suppose a typical individual i participates as an uploader ($H=U$) or downloader ($H=D$) if and only if

$$(15) \quad \alpha_i^H N^K - P^H \geq 0, \quad \text{or} \quad \Omega_i^H \equiv P^H / \alpha_i^H \leq N^K, \quad H, K = U, D; H \neq K,$$

where α^H is distributed uniformly between 0 and A^H , for $H = U, D$. The two distributions of Ω are then given by

$$(16) \quad F^H(\Omega^H) = \begin{cases} 0, & \text{for } \Omega^H \leq P^H / A^H \\ 1 - (P^H / A^H \Omega^H), & \text{for } \Omega^H \geq P^H / A^H \end{cases}, \quad H = U, D.$$

Equilibrium at positive N^U and N^D requires

$$(17a) \quad N^H = F^H(N^K) \bar{N}^H = \left[1 - P^H / A^H N^K\right] \bar{N}^H, \quad \text{or} \quad \mu^H = 1 - P^H / \mu^K, \quad \text{where}$$

$$(17b) \quad \mu^H \equiv N^H / \bar{N}^H, \quad \text{and} \quad p^H \equiv P^H / A^H \bar{N}^K, \quad H, K = U, D; H \neq K.$$

Note that each price is now normalized by the maximum participation on the *other* side of the market, since own price and other-side participation determine resistance. Solving equations (17a) yields

$$(18a) \quad \mu^H = \frac{1}{2} \left[1 + p^K - p^H \pm \sqrt{T}\right], \quad \text{for } H, K = U, D; H \neq D, \quad \text{where}$$

$$(18b) \quad T = 1 + (p^U - p^D)^2 - 2(p^U + p^D).$$

In the single-sided example in Section 2, we needed $p \leq 1/4$ for non-negative demand, while in this case, (p^U, p^D) must lie on or below a convex frontier that passes through $(1,0)$, $(1/4, 1/4)$, and $(0,1)$ in order for T to be non-negative. In the single-sided example, the two roots were on opposite sides of $\mu = 1/2$, while here it follows from (18a) that this is true for the average of the two μ s:

$$(19) \quad \frac{\mu^U + \mu^D}{2} = \frac{1}{2} \pm \frac{\sqrt{T}}{2}.$$

****Figure 6****

Figure (6) illustrates the dynamics of this example. The origin and the point E, which corresponds to the larger solution to (19a), are locally stable, while the point C, which corresponds to the smaller solution, is the saddle-point to which the critical trajectory AA' tends. That trajectory defines the critical mass constraint that must be satisfied at start-up. It follows directly from (18a) that at either C or E,

$$(20) \quad \mu^U - \mu^D = p^D - p^U.$$

Straightforward differentiation of (18b) demonstrates that as long as T is strictly positive, both μ s at the stable equilibrium, E, are decreasing functions of both ps , while at the saddle-point, C, both μ s are increasing functions of both ps .

4. Concluding Remarks

We have shown that when participation decisions are easily reversible, platform businesses, which rely on direct or indirect network effects to attract customers, confront demand-side constraints when they are launched that other businesses do not. On the one hand, as the histories of such businesses as American Express charge cards, eBay's auction platform and Facebook's social networking platform illustrate, some platforms have been able to harness network effects to fuel truly explosive growth. On the other hand, we have shown here why even without fixed costs or economies of scale, platform businesses typically need to attain critical mass when they are launched in order even to survive. This may be an easy requirement or a difficult one, depending on the distribution of consumer tastes and the dynamics of adjustment to equilibrium.

In the case of direct network effects, the basic problem is that the level of participation on the platform affects the quality of the product it offers to participants, and if quality is too low, participation falls, which reduces quality further, and participation declines toward zero. In the case of indirect network effects, which is our primary concern, participation by each customer group affects the quality of the product experienced by the other group, and, though the

dynamics are more complicated, participation levels below critical mass will set off a similar downward spiral. Whether this is a chicken-*and*-egg or a chicken-*or*-egg problem depends on whether participation adjusts more rapidly downward toward equilibrium or upward.

There is much more work to be done on the launch of platform businesses, particularly multi-sided platforms. Empirical work that would justify imposing particular restrictions on taste distributions and disequilibrium dynamics would permit the analysis of optimal price policies. The analysis of optimal non-price policies would be more challenging but potentially at least as important.

A natural next step would be to study the effects of competition with incumbent platforms and/or other new entrants on the startup dynamics of platform businesses. Because of their growing importance and the complexity of their strategies, multi-sided platforms are likely to be an important subject of antitrust scrutiny, as discussed in Evans and Schmalensee (2008). Since new platform businesses face particular difficulties at launch, strategies for deterring their entry by denying them critical mass seem likely to be particularly attractive privately attractive and harmful socially. The role of exclusivity restrictions and related strategies would seem to be especially worth investigating.

Another natural next step would be to relax our assumption that there are zero costs of reversing participation decisions.⁵⁵ Much of the previous literature on network effects has made the opposite extreme assumption, that participation or adoption decisions are irreversible, and has focused on the adoption of standards and the possibility of tipping into inefficient standards. We suspect that the importance of tipping, which results when one network attains a marginal lead that becomes an unstoppable competitive advantage, has been overstated, in part because of the literature's general assumption that switching costs make participation decisions irreversible. Our sense is that participation is not irreversible in most markets and poor outcomes more commonly reflect the difficulty of getting efficient platforms to critical mass at all. While our analysis does not preclude the possibility that inefficient platforms become established through tipping, it does suggest that success or failure may depend most importantly on both the value

⁵⁵ Fath and Sarvary (2003) provide an interesting analysis of switching costs in their model of buyer-side business-to-business exchanges.

that the platform brings to participants as well as the steps that platform entrepreneurs take early on to push adoption past the critical mass frontier.

Finally, as Evans (2009) and the brief case studies herein indicate, a variety of tactics have been employed during the launch of platform businesses. But while case studies do suggest some common themes—including the continuing prevalence of very different markups over marginal cost on the two sides—very little rigorous empirical work has been done on the launch of platform businesses. Both the histories of successful platforms and the analysis here suggest that such work could yield very interesting results that would enrich theory and inform both business strategy and public policy.

REFERENCES

- Ambrus, A, Argenziano, R, 2009. Asymmetric Networks in Two-Sided Markets,” *American Economic Journal: Microeconomics*, 1 (1), 17-52.
- Argentesi, E, Filistrucchi, L, 2007. Estimating Market Power in a Two-Sided Market: The Case of Newspapers, *Journal of Applied Econometrics*, 22 (7), 1247-1266.
- Armstrong, M, 2006. Competition in Two-Sided Markets, *Rand Journal of Economics*, 37 (3), 668-691.
- Bass, F M, 1969. A New Product Growth Model for Consumer Durables, *Management Science*, 15 (5), 215-227.
- Birke, D, 2008. The Economics of Networks – A Survey of the Empirical Literature, Nottingham University Business School, Occasional Paper 2008-22, available at <http://www.nottingham.ac.uk/~lizecon/RePEc/pdf/22.pdf>.
- Bochner, P, 2000. “Channel Chatter: How Will Dell’s E-Procurement Site Affect Solution Providers? posted on ChannelWeb, on September 21, 2000 (available at <http://www.crn.com/it-channel/18817598>, last visited on March 23, 2009).
- Boyd, DM., Ellison, NB, 2007. Social Network Sites: Definition, History, and Scholarship, *Journal of Computer-Mediated Communication*, 13 (1), available at <http://jcmc.indiana.edu/vol13/issue1/boyd.ellison.html>.
- Burdett, K, Wright, R, 1998, Two-Sided Search with Nontransferable Utility, *Review of Economic Dynamics*, 1, 220-245.
- Cabral, L, 2008. Dynamic Price Competition with Network Effects, unpublished manuscript, Stern School of Business, New York University, January.
- Caillaud, Bernard and Bruno Julien. 2003. “Chicken & Egg: Competition Among Intermediation Service Providers,” *Rand Journal of Economics*, Vol. 34(2): 309-328.
- Economides, N, 1996. The Economics of Networks, *International Journal of Industrial Organization*, 16 (4), 673-699.

- Economides, N, Himmelberg, C, 1995. Critical Mass and Network Evolution in Telecommunications. In: Brock, G (Ed), *Toward a Competitive Telecommunications Industry*, Mahwah, NJ: Lawrence Erlbaum.
- Economides, N, Mitchell, M, Skrzypacz, A, 2005. *Dynamic Oligopoly with Network Effects*, unpublished manuscript, New York University.
- Evans, DS, 2009. How Catalysts Ignite: The Economics of Platform-Based Start-Ups.,” In: Gawer, A (Ed) *Platforms, Markets And Innovation*, Northampton, MA: Edward Elgar.
- Evans, DS, Schmalensee, R, 2005. *Paying with Plastic*, 2nd Ed., Cambridge: MIT Press.
- Evans, DS, Schmalensee, R, 2007. *Catalyst Code*, Boston: Harvard Business School Press.
- Evans, DS, Schmalensee, R, 2008. Markets with Two-Sided Platforms. In: Collins, WD, et al (Eds), *Issues in Competition Law and Policy*, Chicago: American Bar Association, 667-694.
- Farrell, J, Klemperer, P, 2007. Coordination and Lock-In: Competition with Switching Costs and Network Effects. In: Armstrong, M, Porter, R (Eds), *Handbook of Industrial Organization*, Vol. 3, Amsterdam: North-Holland, 1967-2072.
- Fath, G, Sarvary, M, 2003. Adoption Dynamics in Buyer-Side Exchanges, *Quantitative Marketing and Economics*, 1 (3), 305-335.
- Gabszewicz, JJ, Garcia, F, 2005. A Note on Expanding Networks and Monopoly, CORE Discussion Paper 2005/95, Catholic University of Louvain, Belgium.
- Genakos, C, Valletti, T, 2008. Testing the Waterbed Effect in Mobile Telephony, CEIS Working Paper 110, University of Rome, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1114856.
- Hagiu, A, 2006. Pricing and Commitment by Two-Sided Platforms, *Rand Journal of Economics*, 37 (3), 720-737.
- Harrington, A, 2001. *The B2B Super Markets*, Management Consultancy, May 7, 2001.
- Harris, L, 2002. *Trading and Exchanges: Market Microstructure for Practitioners*, Oxford: Oxford University Press.

- Jackson, MO, Yariv, L, 2007. Diffusion of Behavior and Equilibrium Properties in Network Games, *American Economic Review Papers and Proceedings*, 97, 92-98.
- Kabir, N, 2003. "E-marketplace; Facts and Fictions, *WebProNews*, posted on August 20th, 2003, <http://www.webpronews.com/topnews/2003/08/20/emarketplace-facts-and-fictions>.
- Kaiser, U, Wright, J, 2006. Price Structure in Two-Sided Markets: Evidence from the Magazine Industry, *International Journal of Industrial Organization*, 24, 1-28.
- Katz, ML, Shapiro, C, 1985. Network Externalities, Competition, and Compatibility, *American Economic Review*, 75 (3), 424-440.
- Katz, ML, Shapiro, C, 1994. Systems Competition and Network Effects, *Journal of Economic Perspectives*, 8 (2), 93-115.
- Lucking-Reiley, DF, Spulber, DF, 2001. Business-to-Business Electronic Commerce, *Journal of Economic Perspectives*, 15 (1), 55-68.
- Mahoney, M, 2001. Dell B2B Marketplace Unplugged, *E-Commerce Times*, posted on February 7, 2001, available at <http://www.ecommercetimes.com/story/7303.html>, last visited on March 23, 2009.
- Manajan, V, Muller, E, Bass, FM, 1990. New Product Diffusion Models in Marketing: A Review and Directions for Research, *Journal of Marketing*, 54 (1), 1-26.
- Odell, M, 2001. B2B Struggle to Achieve Take-off, *Financial Times*, June 18.
- O'Hara, M, 1995. *Market Microstructure Theory*, Cambridge: Blackwell.
- Rochet, J-C, Tirole, J, 2003. Platform Competition in Two-Sided Markets, *Journal of the European Economic Association*, 1 (4), 990-1029.
- Rochet, J-C, Tirole, J, 2006. Two-Sided Markets: A Progress Report, *Rand Journal of Economics*, 37 (3), 645-667.
- Rohlf's, J, 1974. "Theory of Interdependent Demand for a Communications Service, *Bell Journal of Economics and Management Science*, 5 (1), 16-37.

- Ruffle, BJ, Weiss, A, Etziony, A, 2010, Coordination and Critical Mass in a Network Market: An Experimental Investigation, manuscript, Department of Economics, Ben-Gurion University, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1550723.
- Stremersch, S, Tellis, G, Franses, P, Bincken, J, 2007. Indirect Network Effects in New Product Growth, *Journal of Marketing*, 71 (3), 52-74.
- Weiss, TR, 2001. Update: Dell closes online marketplace after just four months, *ComputerWorld*, posted on February 7, 2001 (available at <http://www.computerworld.com/managementtopics/ebusiness/story/0,10801,57480,00.html>, last visited on March 23, 2009).
- Weyl, EG, 2008, Monopolies in Two-Sided Markets: Comparative Statics and Identification, Working Paper, Harvard Society of Fellows, October.
- Weyl, EG, forthcoming, A Price Theory of Two-Sided Markets, *American Economic Review*.
- Yadav, S, 2006. Facebook -The Complete Biography, posted on Mashable, *The Social Media Guide*, on August 25, 2006 (available at <http://mashable.com/2006/08/25/facebook-profile/>, last visited on March 23, 2009).

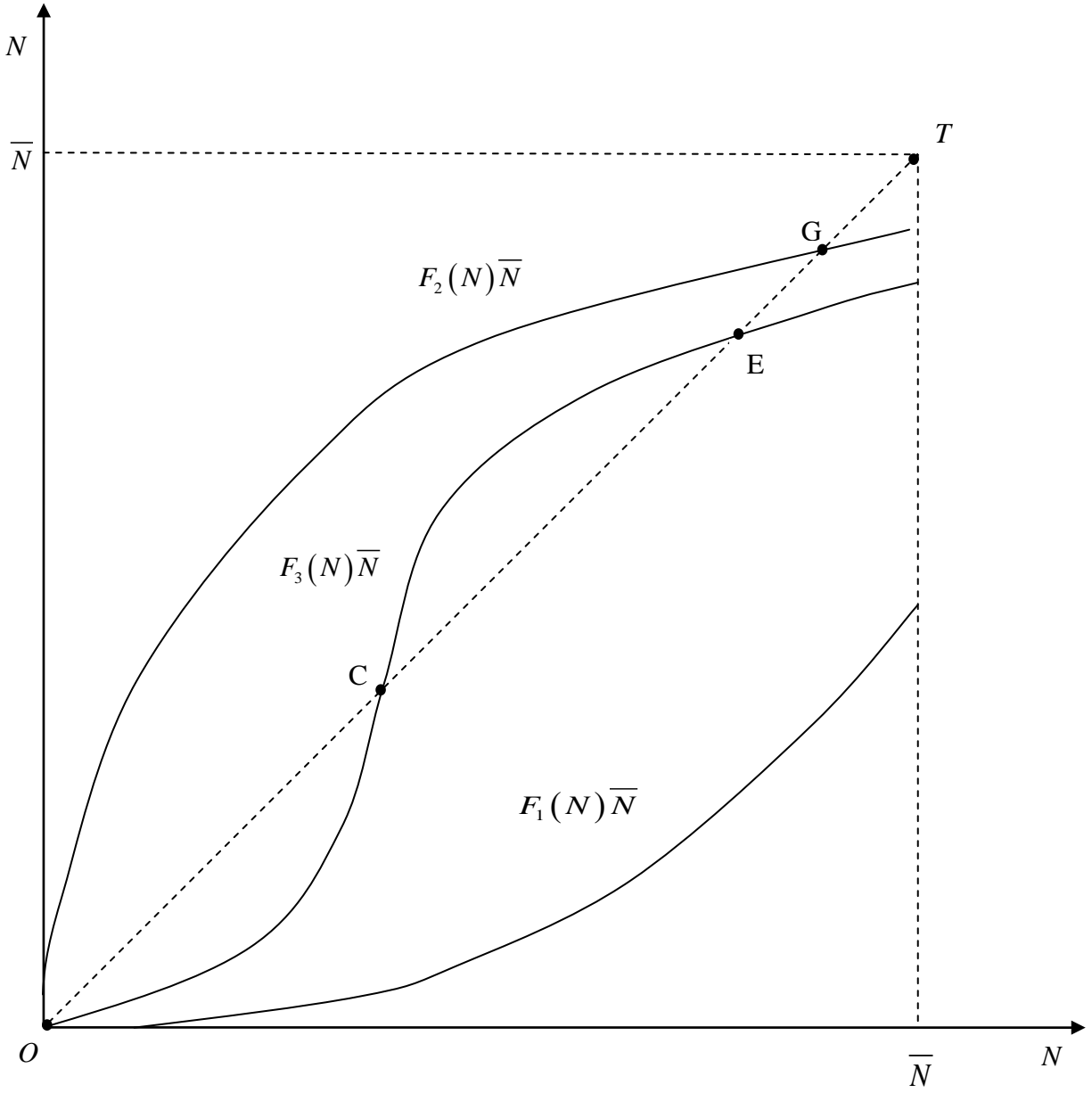


Figure 1. Critical Mass and Equilibria for Platforms with Direct Network Effects

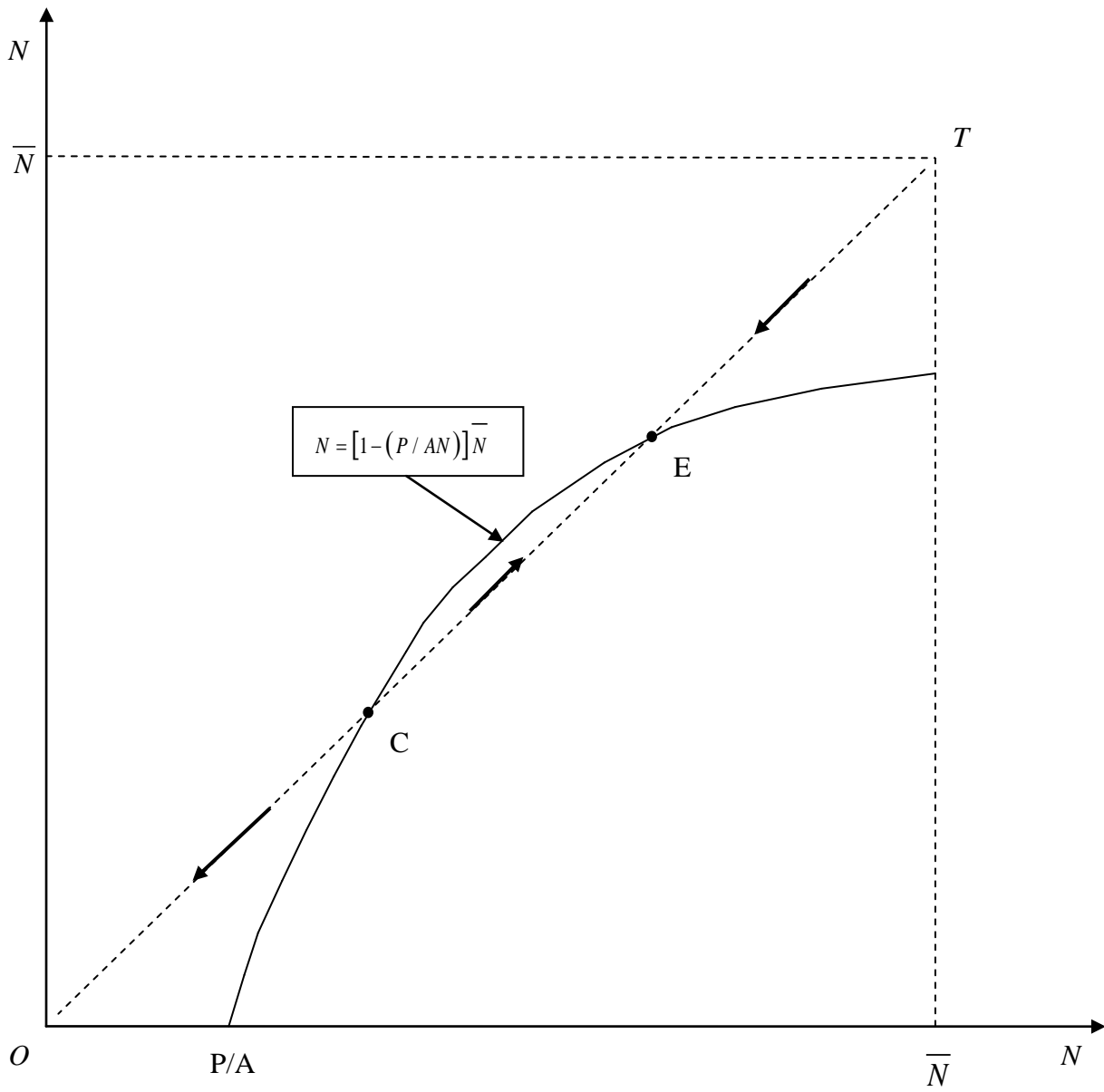


Figure 2. An Example of Critical Mass and Equilibria with Direct Network Effects

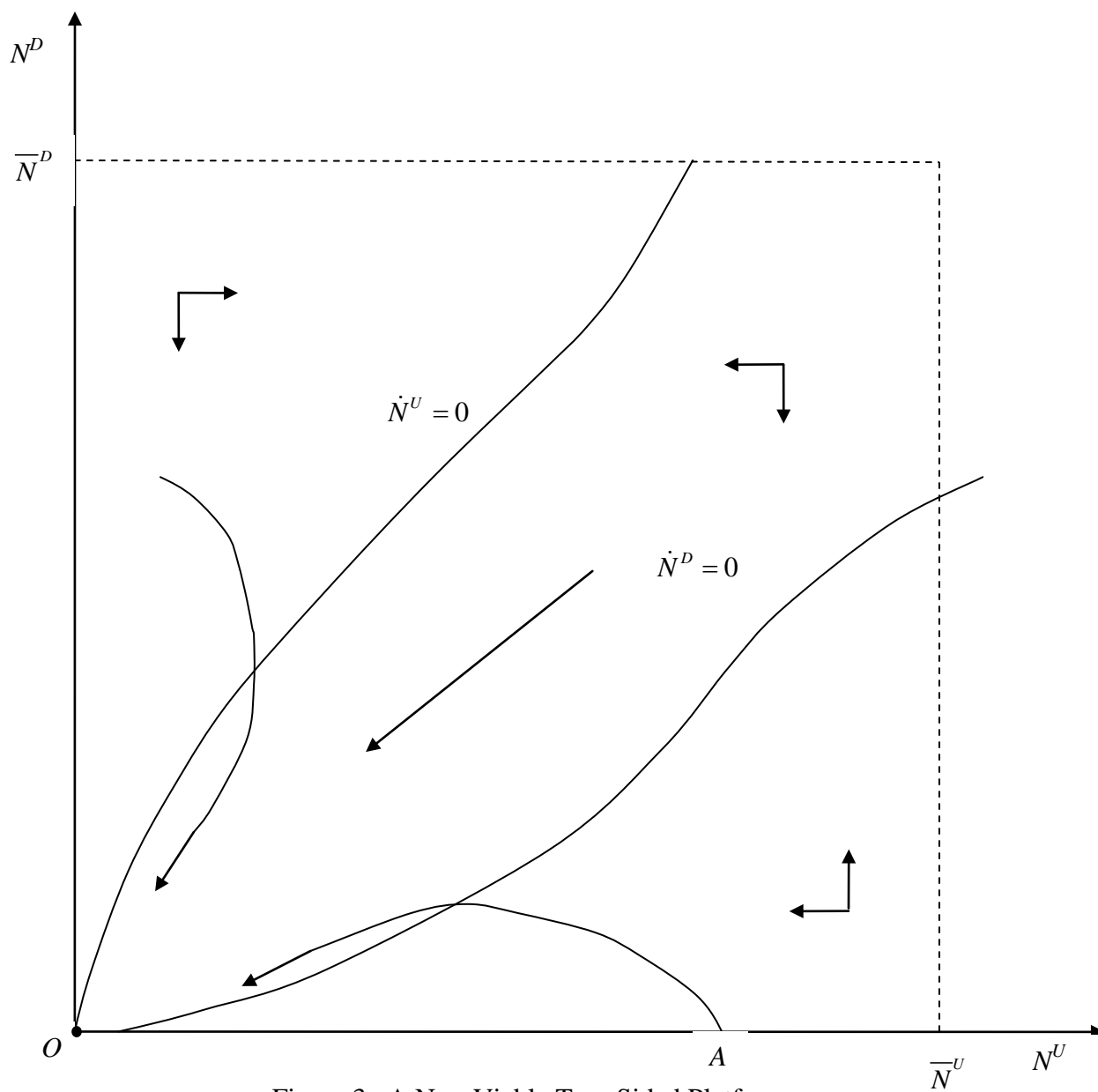


Figure 3. A Non-Viable Two-Sided Platform

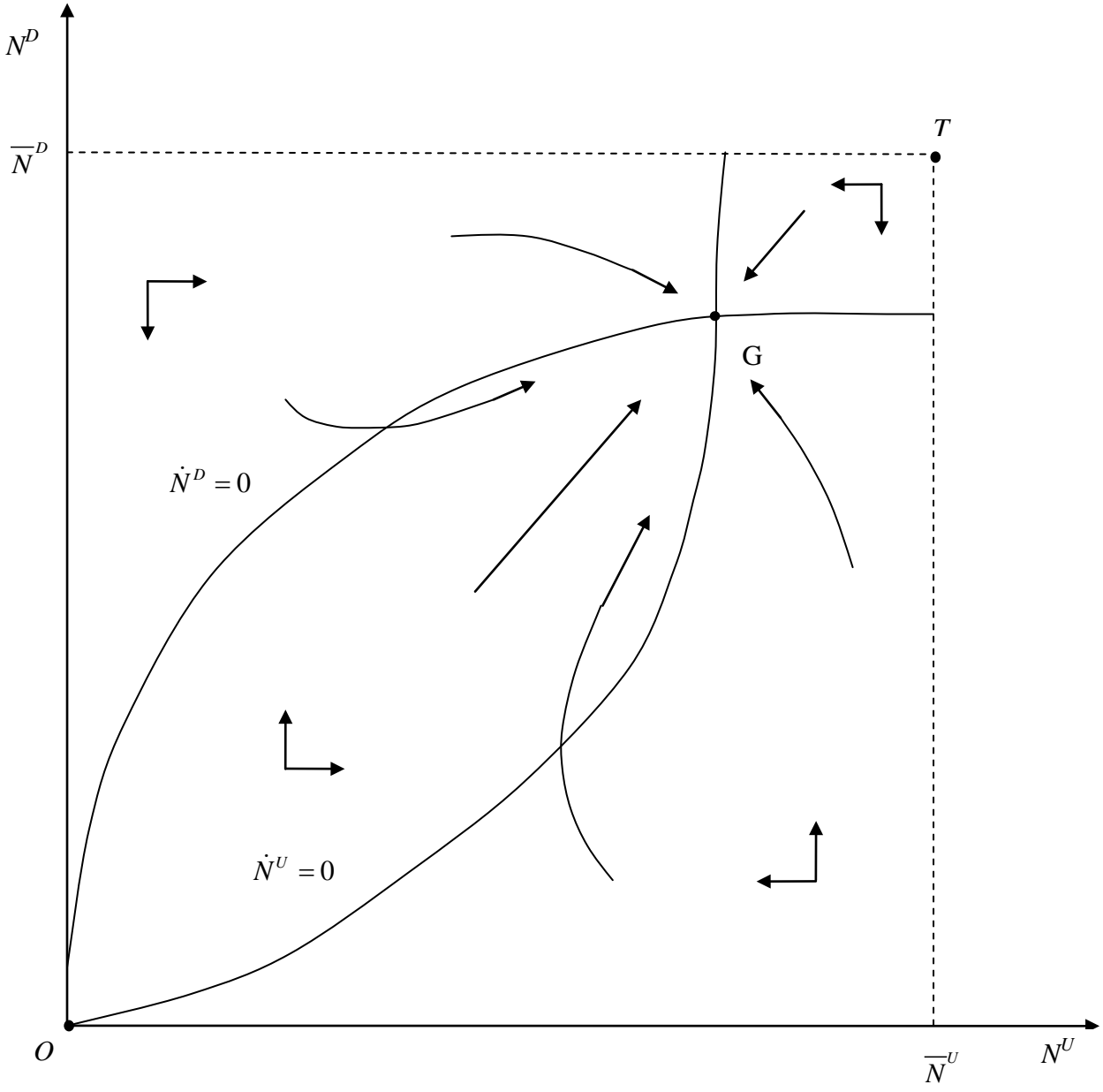


Figure 4. A Viable Two-Sided Platform

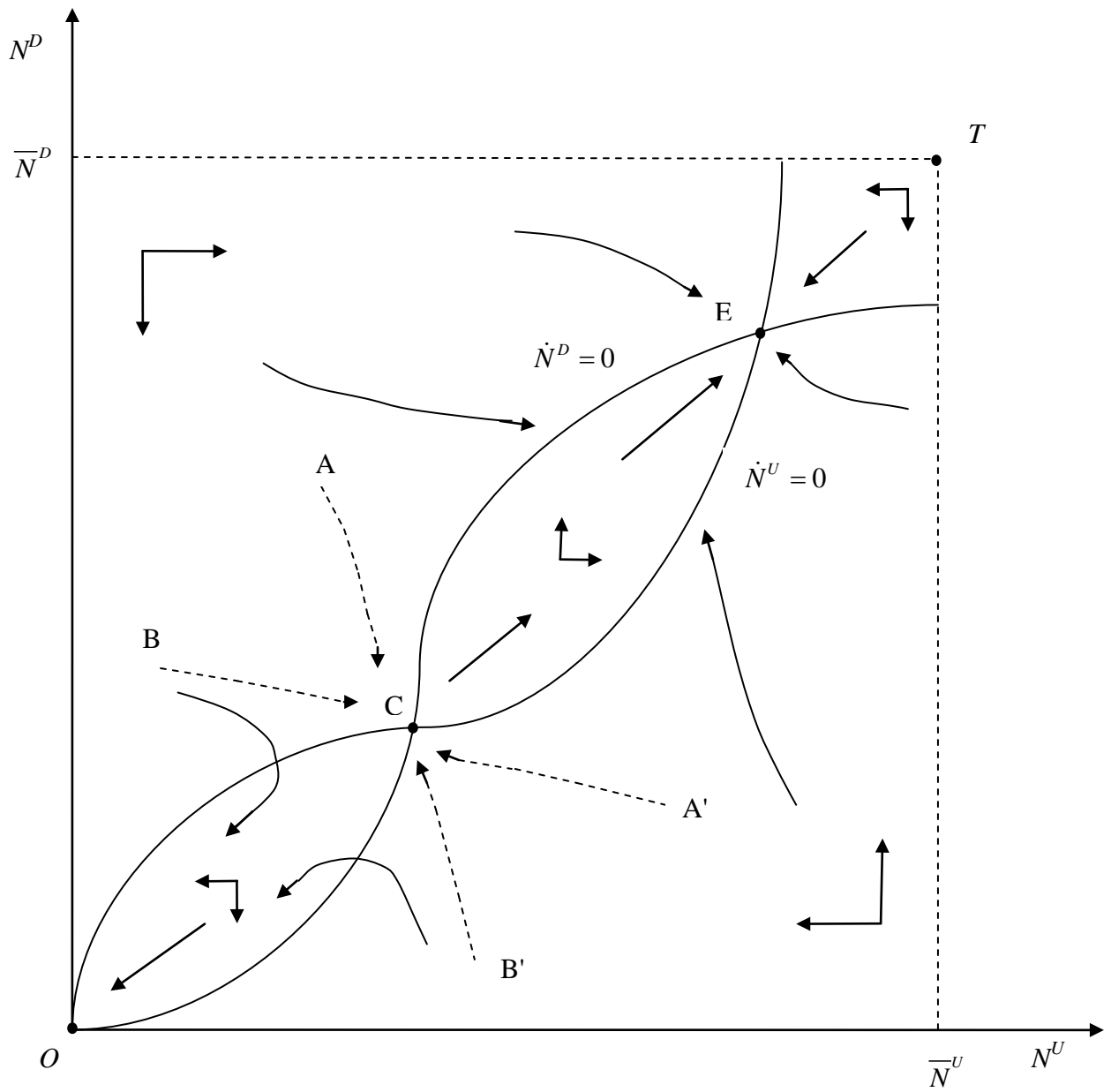


Figure 5. A Potentially Viable Two-Sided Platform

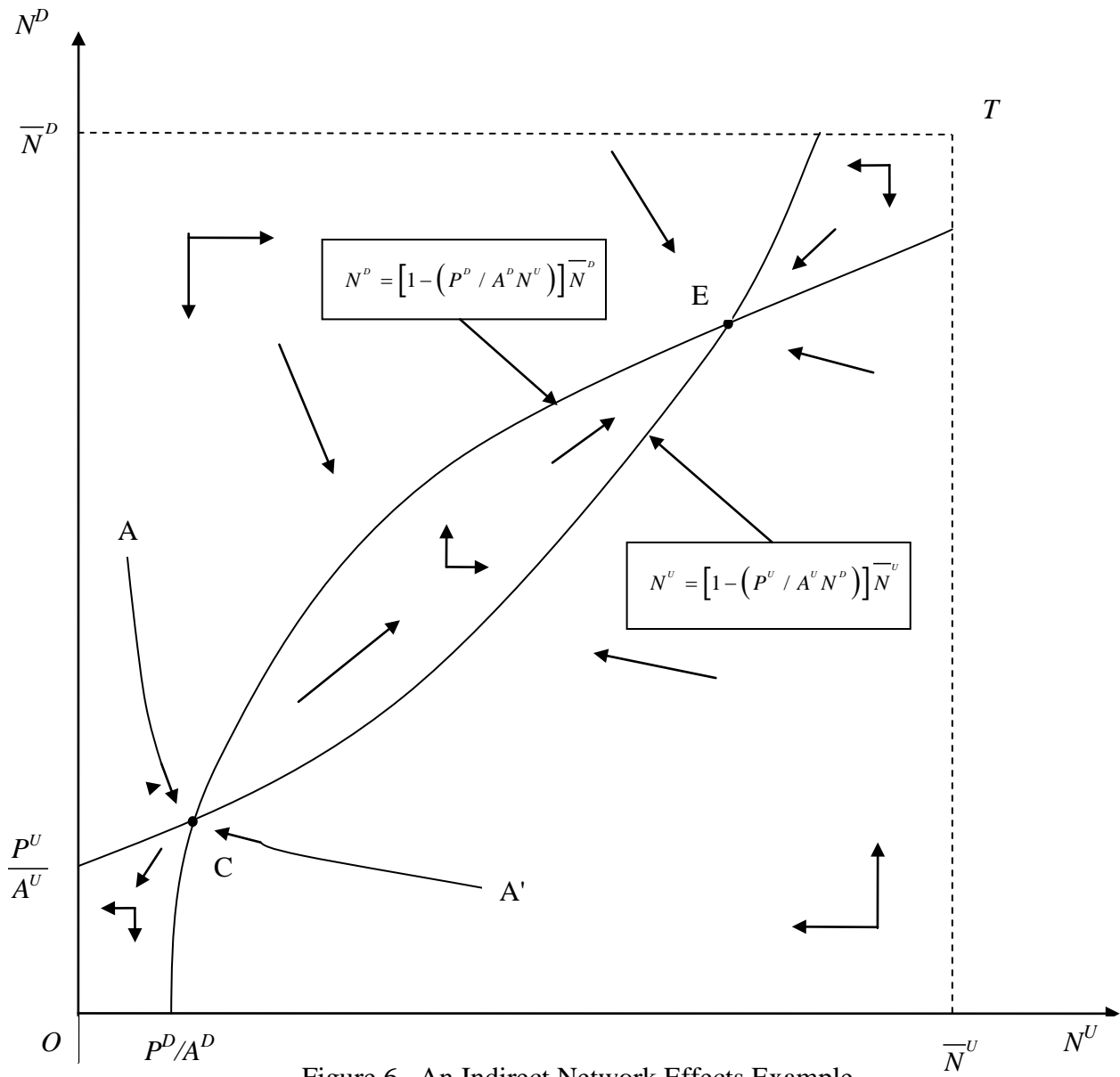


Figure 6. An Indirect Network Effects Example

Skewed Pricing and Non-Concavity in Two-Sided Platforms

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Bolt and Tieman (2008) have shown that the profit function in the Rochet-Tirole (2003) two-sided platform model is non-concave if the demands of the two sides have constant elasticities. They suggest that such non-concavities may account for the prevalence of highly skewed platform pricing. If demands are linear in that model, however, the profit function is always concave. Highly skewed pricing can nonetheless arise if demand curves differ sufficiently. In the two-sided model of Armstrong (2006), if demands are linear the profit function is non-concave if indirect network effects are strong, but non-concavity is neither necessary nor sufficient for highly skewed pricing. Highly skewed platform pricing more plausibly reflects substantial differences in demand characteristics.

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¹ Massachusetts Institute of Technology. I am indebted to Glen Weyl for extremely insightful comments on a much earlier version of this paper, which led to fundamental changes. Of course, only I can be blamed for mistakes that remain.

Two-sided platform businesses (often labeled two-sided markets) commonly set price at or below marginal cost to one of the groups they serve, and some groups may even pay a zero price even though positive costs are incurred to serve them – see, e.g., Evans (2003) or Evans and Schmalensee (2007) for lists of examples. Thus Suarez and Cusumano (2009, p. 84) speak in generic terms of “the subsidy side” and “the money side” of such businesses. The usual first-order conditions for profit maximization in standard models of multi-sided platforms do not immediately reveal why such highly skewed pricing should be the norm, however.

A recent paper by Bolt and Tieman (2008) shows that the second-order conditions for a maximum are violated in the Rochet-Tirole (2003) two-sided platform model if the demands of the two sides have constant elasticities.² In this example, the first-order conditions identify a saddle-point of the profit function, not a maximum, and profits are maximized at a corner solution, on the boundary of the set of feasible prices. Bolt and Tieman suggest that this result may be general, so that the prevalence of highly skewed pricing in multi-sided platforms may be explained by the prevalence of such non-concave profit functions. This note examines the plausibility of that intriguing suggestion using two additional examples.

Section 1 shows that if demands are linear in the Rochet-Tirole (2003) model instead of having constant elasticity, the usual first-order conditions *always* identify a profit maximum. Thus non-concavity of the profit function is not a general feature of this model; it seems to reflect second-order curvature properties of demand functions without an obvious economic interpretation. Moreover, I also show that highly skewed pricing can nonetheless arise at interior optima under linear demand if demand curves differ sufficiently.

Section 2 considers the alternative two-sided platform model of Armstrong (2006).³ If demands are linear in this model, the profit function may be non-concave if indirect network effects are sufficiently strong. But it is easy to demonstrate that non-concavity is neither necessary nor sufficient for highly skewed pricing in this example.

In short, the analysis that follows strongly suggests that skewed pricing by two-sided platforms is not prevalent because profit is generally maximized at corner solutions for these

² See Hermalin and Katz (2004) for a closely related result.

³ Rochet and Tirole (2006) present a more general model that includes both these models as special cases and in which both access and interactions may be priced. See Weyl (2010) for an extensive analysis of that model.

businesses, but rather because the demand characteristics of the two groups involved generally differ substantially.

1. The Rochet-Tirole (2003) Model

In this model, the monopoly's profit function can be written as

$$(1) \quad \Pi = (P_1 + P_2 - C)D_1(P_1)D_2(P_2),$$

where the P_i are the per-transaction prices charged to each of the two participating groups, C is the constant marginal cost of executing a transaction, and the D_i are (partial) demand functions. This model may be most directly relevant to payment cards, with the volume of transactions proportional to the product of the number of merchants accepting a particular card brand and the number of consumers carrying cards of that brand and the participation decisions of merchants and consumers assumed to depend only on the per-transaction prices they face.⁴

As noted above, Bolt and Tieman (2008) consider the case in which the distributions of benefits from transacting in the two groups are such that the D_i have constant elasticities. Suppose, instead, that individual h in group i , $i=1,2$, will participate if and only if

$$\theta_i^h \geq P_i,$$

where the θ_i^h are uniformly distributed between 0 and $A_i > 0$. If the number of potential participants (mass) in group i is N_i , the two demand functions can be written as

$$(2) \quad D_i(P_i) = N_i - b_i P_i, \quad i=1,2,$$

where $b_i = N_i/A_i$, $i=1,2$. The first-order conditions for maximizing expression (1) in this case have a unique solution:

$$(3) \quad P_i^* = \frac{4}{3} \left[P_i^m - \frac{P_j^m}{2} \right], \quad i, j \in \{1,2\}, i \neq j,$$

where the P_i^m are given by

$$(4) \quad P_i^m = \frac{N_i + b_i C_i}{2b_i} = \arg \max \{ \Pi^i(P) \equiv (P - C_i) D_i(P) \}, \quad i=1,2.$$

⁴ See, for instance, Schmalensee (2002).

If we let M^* be the total markup implied by (3)

$$(5) \quad M^* \equiv P_1^* + P_2^* - C = \frac{1}{3} \left(\frac{N_1}{b_1} + \frac{N_2}{b_2} - C \right),$$

the second-order necessary conditions for (3) to signal a maximum can be written as

$$(6a) \quad \Pi_{11} = -2b_1b_2M^* < 0, \quad \Pi_{22} = -2b_1b_2M^* < 0, \quad \text{and}$$

$$(6b) \quad T \equiv \Pi_{11}\Pi_{22} - (\Pi_{12})^2 = 3(b_1b_2M^*)^2 > 0,$$

where subscripts indicate partial differentiation. Thus as long as $M^* > 0$, the prices given by (3) *always* maximize profit when demands are linear.

Even though there is no failure of concavity, however, the pricing implied by (3) can be highly skewed if demands differ substantially:

$$(7) \quad P_1^* - P_2^* = \frac{N_1}{b_1} - \frac{N_2}{b_2}.$$

Similarly, there is no guarantee that the prices given by (3) are feasible: one of the other may be less than the corresponding marginal cost or even negative if the demand functions are sufficiently different. If one of the prices given by (3) is negative, for instance, and negative prices are ruled out, profits are necessarily maximized at a point on the boundary of the set of feasible prices, even though the usual second-order conditions are not violated. In situations well described by the Rochet-Tirole (2003) model, it thus seems more likely that the prevalence of skewed pricing simply reflects the prevalence of substantial differences in demand functions rather than the pervasive failure of second-order conditions because of the curvature of demand functions.⁵

2. The Armstrong (2006) Model

To produce a tractable special case of the Armstrong (2006) model, in which participation is priced but transactions are not, and participation is influenced by indirect network

⁵ In the case of payment cards, recent work by Bedre-Defolie and Calvano (2009) makes a strong case that the observed skewness in transaction pricing in card systems (i.e., merchants pay, consumers do not) reflects the facts that consumers decide what means of payment to use and have available alternatives (cash and, generally, checks) for which consumers typically pay nothing to use.

effects as well as price, suppose that typical individual h on side i , $i=1,2$, participates if and only if

$$(8) \quad \theta_i^h \geq P_i - b_i Q_j, \quad i, j \in \{1, 2\}, i \neq j,$$

where price of participation is P_i , Q_j is participation on (the other) side j , and the b_i are positive constants. Suppose $N_i > 0$ is the maximum number of potential participants on side i , and the θ_i^h are uniformly distributed between $a_i - N_i$ and a_i .⁶ Then the demands for participation are given by

$$(9) \quad Q_i = a_i - P_i + b_i Q_j, \quad i, j \in \{1, 2\}, i \neq j,$$

where

Solving for the prices, the profit function becomes

$$(10) \quad \Pi = Q_1(a_1 + b_1 Q_2 - Q_1 - C_1) + Q_2(a_2 + b_2 Q_1 - Q_2 - C_2),$$

where C_i is the constant marginal cost of providing participation to a member of group i . Using subscripts to indicate partial differentiation as above, the first-order conditions for maximization of Π are

$$(11) \quad \Pi_i = (a_i - C_i) + (b_1 + b_2)Q_j - 2Q_i = 0, \quad i, j \in \{1, 2\}, i \neq j,$$

and the second-order necessary conditions for (11) to yield a maximum are

$$(12a) \quad \Pi_{11} = \Pi_{22} = -2 < 0, \quad \text{and}$$

$$(12b) \quad T \equiv \Pi_{11}\Pi_{22} - (\Pi_{12})^2 = 4 - (b_1 + b_2)^2 < 0.$$

If indirect network effects are relatively weak, so that $(b_1 + b_2)/2 < 1$, conditions (12) are satisfied, and, solving (11) and (9), profit is maximized by

$$(13) \quad P_i^* = P_i^m + (b_i - b_j) \frac{(b_1 + b_2)(a_i - C_i) + 2(a_j - C_j)}{2[4 - (b_1 + b_2)^2]}, \quad i, j \in \{1, 2\}, i \neq j.$$

As above, the first term on the right is the stand-alone monopoly price for side i : it maximizes profit from side i in the absence of indirect network effects,

⁶ Relaxing the restrictions on lengths of these intervals yields linear demand functions in which the price coefficients differ and adds considerable algebraic clutter. The main features of the analysis are unchanged. Condition (12b) on the mean of the b_i is replaced by a condition on their weighted mean, where the weights depend on the ratio of the price coefficients.

$$(14) \quad P_i^m = \frac{a_i + C_i}{2} = \arg \max \{ \Pi^i(P) \equiv (P - C_i)(a_i - P_i) \}, \quad i = 1, 2.$$

In the symmetric case, $a_1 = a_2 = a$, $b_1 = b_2 = b$, and so on, the firm charges P_i^m to both sides. Sales and profits are of course increased by the presence of indirect network effects if $b > 0$.

More generally, if $a_1 > C_1$ and $a_2 > C_2$, and if, without loss of generality, $b_1 > b_2$, P_1^* will be above P_1^m , and P_2^* will be below P_2^m . Conditions (13) may imply highly skewed pricing if the b_i differ substantially and their sum is not far below 2. And, as above, if the solution to these first-order conditions yields a price outside the feasible set of prices, profits will necessarily be maximized on the boundary of the feasible set even though there is no failure of concavity. Thus such a failure is not necessary for highly skewed pricing.

Now suppose that indirect network effects are strong, so that $(b_1 + b_2)/2 > 1$ and condition (12b) is not satisfied. In this case the unique solution to conditions (11) corresponds to a saddle-point, not a maximum. It is interesting to note (and relatively straightforward to show) that if a related but stronger condition on the strength of indirect network effects, $b_1 b_2 > 1$, is satisfied, the solution to (11) is a saddle-point of any dynamic demand system involving gradual adjustment to the demands given by (9):

$$(15) \quad \text{sgn}[dQ_i / dt] = \text{sgn}[(a_i - P_i + b_i Q_j) - Q_i], \quad i, j \in \{1, 2\}, i \neq j.$$

See Evans and Schmalensee (2010) for analysis of more general systems of this sort and discussion of their implications.

To see most clearly that violation of (12b) is not sufficient for highly skewed pricing, consider the symmetric case, as defined above. If $Q_1 = Q_2 = Q$, profits are given by

$$(16) \quad \Pi = 2Q[(a - C) + Q(b - 1)].$$

Since this expression is convex in Q , profits are either maximized at $Q = 0$ or $Q = N$. If

$$(17) \quad (a - C) + N(b - 1) > 0,$$

the maximum occurs at $Q = N$. (Note that (17) can be satisfied even if $a \leq 0$, so that there is no demand on either side in the absence of participation by the other side, as long as indirect network effects are strong enough.) It is straightforward to show that if (17) is satisfied and if, say, $Q_2 = N$, then profits are maximized by setting $Q_1 = N$ also. Thus even though the profit

function is maximized on the boundary of the feasible set of quantities, pricing is symmetric, not skewed:

$$(18) \quad P_1^* = P_2^* = a + N(b-1).$$

More generally, if condition (12b) is violated, pricing is unconstrained, and positive profits are feasible, it is straightforward to show that profit may be maximized at the point $Q_1 = N_1$ and $Q_2 = N_2$ or at a point at which $Q_i < N_i$ for $i = 1$ or 2 and $Q_j = N_j$ for $i \neq j$. At a maximum of either sort, one of the prices may be below the corresponding marginal cost or even below zero, and if such prices are ruled out the maximum will accordingly occur on the boundary of the set of feasible prices. Thus violation of (12b) may indeed lead to highly skewed pricing, but, as the paragraph just above demonstrates, it will do so only if the demand functions differ sufficiently – exactly as when (12b) is satisfied.

References

- Armstrong, Mark (2006), "Competition in Two-Sided Markets," *Rand Journal of Economics*, v. 37, n. 4 (Autumn), pp. 668-691
- Bedre-Defolie, Özlem, and Emilio Calvano (2009), "Pricing Payment Cards," Working Paper 1139, European Central Bank, December. Available at http://ssrn.com/abstract_id=1284648.
- Bolt, Wilko, and Alexander F. Tieman (2008), "Heavily Skewed Pricing in Two-Sided Markets," *International Journal of Industrial Organization*, v. 26, n. 5 (September), pp. 1250-1255.
- Evans, David S. (2003), "The Antitrust Economics of Multi-Sided Platform Markets," *Yale Journal of Regulation*, v. 20, n. 2, pp. 325-381.
- _____ and Richard Schmalensee (2007), *Catalyst Code*, Boston: Harvard Business School Press.
- _____ and _____ (2010), "Failure to Launch: Critical Mass in Platform Businesses," working paper, September, available at <http://ssrn.com/abstract=1353502>.
- Rochet, Jean-Charles, and Jean Tirole (2003), "Platform Competition in Two-Sided Markets," *Journal of the European Economic Association*, v. 1, n. 4, pp. 990-1029.
- _____ and _____ (2006), "Two-Sided Markets: A Progress Report," *Rand Journal of Economics*, v. 37, n. 4 (Autumn), pp. 645-667.
- Schmalensee, Richard (2002), "Payment Systems and Interchange Fees," *Journal of Industrial Economics*, v. 50 (June), 103-122.
- Suarez, Fernando F., and Michael A. Cusumano (2009), "The Role of Services in Platform Markets," in Annabelle Gawer, ed., *Platforms, Markets, and Innovation*, Northampton, MA: Edward Elgar, pp. 77-98.
- Weyl, E. Glenn (2010), "A Price Theory of Two-Sided Platforms," *American Economic Review*, v. 100 (September), 1642-72.