Competing Matchmakers: An Experimental Analysis

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Platform competition is ubiquitous, yet platform market structure is little understood. Theory models typically suffer from equilibrium multiplicity—platforms might coexist or the market might tip to either platform. We use laboratory experiments to study the outcomes of platform competition. When platforms are primarily vertically differentiated, we find that even when platform coexistence is theoretically possible, markets inevitably tip to the more efficient platform. When platforms are primarily horizontally differentiated, so there is no single efficient platform, we find strong evidence of equilibrium coexistence.

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1. Introduction

Platform competition has become increasingly economically important over the last decade. Platforms often play a matchmaker role, connecting market participants of various types. Familiar platforms include the online auction site eBay and the online dating site Match.com. However, platforms need not only match buyers to sellers or men to women. Video gaming consoles, such as the Wii, are platforms that match game developers to gamers. The search site Google is a platform that matches searchers with, among other things, relevant ad content provided by sellers. Credit cards, operating systems, and stock exchanges are yet other examples of platforms.[1]

Policy makers worry about the potential for a single dominant platform to emerge in such markets. To see why, consider competing online auction platforms. Clearly, the more buyers that are attracted to a platform, the more valuable the platform is to sellers and, consequently, the more sellers it attracts. Of course, this is a virtuous circle with increasingly many buyers and sellers being attracted. This intuition, which is easily formalized, suggests that tipping (i.e., all players selecting the same platform) is an equilibrium in these markets. Indeed, worries about a dominant

platform led to serious scrutiny by the U.S. Justice Department, which was sufficient to scuttle a deal in sponsored search between Google and Yahoo! in 2008.

Yet, casual observation suggests that tipping is not inevitable. Consumers enjoy more than one credit card "platform," and users seeking dates have many options besides Match.com. Theory models offer two key drivers for multiple platforms to gain positive market shares: The first is that "market impact effects" of increased competition from switching platforms are sufficient to offset scale advantages and prevent a single dominant platform from emerging. The second is that horizontal differentiation between platforms is sufficient to offset scale effects and thereby avoid the market tipping to a single platform.

This paper investigates both of these drivers of platform coexistence using laboratory experiments to explore the market structure of platforms. Laboratory experiments offer a unique opportunity to study how market shares of platforms evolve over the "life cycle" of a market. They have the advantage that, by controlling the payoff parameters, one can, in theory, turn platform coexistence on and off. They also allow for a "level playing field" for the platforms, thus removing the potential confounding effect of first-mover advantages.

Whereas most theory models analyze platforms that are either identical or horizontally differentiated, in practice, platforms often differ in quality. For instance,

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[1] See Armstrong (2006) and Evans and Schmalensee (2007) for many other examples.

Google has become a leader in bringing Internet users and advertisers to their websites because of their superior search technology. Through their Relationship Questionnaire, the dating site eHarmony touts their ability to provide more compatible matches than rival sites. In our experiments, we vary both access fees, matching efficiency, and the "fit" between a platform and a user. Thus, we precisely control vertical and horizontal differentiation of platforms along with the surplus provided to users.

We offer a class of platform competition games and derive some simple theoretical properties. The theory results provide a unifying framework for studying the market structure of competing matchmakers in the lab. We then conduct a series of experiments in platform competition in which subjects repeatedly participate in two-sided markets over time. Subjects choose one of two competing platforms, which differ from one another in access fees and matching technologies. In some treatments, coexistence of platforms is possible, whereas in others, only tipped equilibria arise. Our key finding is that competing platforms coexist only when they are highly horizontally differentiated. Markets, by and large, tip in other cases.

The remainder of this section reviews the related literature. Section 2 presents a theory model of platform competition that forms the basis for most of the games played in the experiment. Section 3 presents our experimental design. Section 4 presents the results of the experiments when platforms are vertically differentiated. Section 5 presents the results of experiments when platforms are undifferentiated or horizontally differentiated. Section 6 concludes. Proofs of all theoretical results are relegated to the appendix.

1.1. Related Literature
A key question addressed in the theory literature on platform competition is whether multiple competing platforms can coexist. In some of the earliest work in the area, Caillaud and Jullien (2001, 2003) found that coexistence is a knife-edge case when platforms are undifferentiated. These models exclude the possibility that additional "players" on a given side of the market might have an adverse "market impact" effect on others. Ellison and Fudenberg (2003) and Ellison et al. (2004) demonstrate that, when market impact effects are sufficiently large, platform coexistence is restored even when platforms are undifferentiated.[2] A separate line of the theory literature explores the possibility that platforms are horizontally differentiated. With sufficient differentiation, coexistence is possible even

when platforms have access to a rich set of pricing strategies.[3]

Although less theoretical attention has been paid to the case where competing platforms are vertically differentiated, much of the empirical work in the area has centered on this question.[4] Indeed, the QWERTY phenomenon—the idea that a vertically inferior platform might prevail owing to path dependence—has been profoundly influential and controversial (see, e.g., David 1985; Liebowitz and Margolis 1990, 1994). Recent empirical work by Tellis et al. (2009) suggests that when a dominant platform emerges, it tends to be of higher quality than its rivals. Of course, identifying causality is difficult—a platform might be dominant because it is of higher quality or, it may have higher quality through the resources gained by its dominance.

There has been little connection between the empirical studies, and the key features of the environment identified by the theory.[5] This disconnect stems from the difficulty in measuring the features highlighted in the theory. For instance, determining the exact magnitude of horizontal differentiation or market impact effects in a convincing fashion poses a substantial challenge. Laboratory experiments enable us to perturb key features of the environment that theory suggests are important in determining platform coexistence versus tipping. Relative to the literature on experimental industrial organization, our main contribution is to study two-sided markets rather than more conventional (one-sided) market structures.[6]

Crucial to the tipping phenomenon is the fact that there are gains from coordination in two-sided markets. There is an enormous experimental literature on coordination games (for a survey, see Ochs 1995). Much of this literature considers stag hunt-type games. Here, the tension is between a risk dominant and a Pareto dominant equilibrium. The main difference between our work and standard coordination games is that our markets are two sided. This matters because it creates the possibility for coexisting equilibria where some fraction of each side of the market goes to each platform. There is no analog in stag hunt. Likewise, scale and market impact effects are absent from most stag hunt games. A different strand

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[2] However, Ambrus and Argenziano (2009) point out that when players are atomistic and platforms are undifferentiated, only tipped equilibria remain.

[3] See, e.g., Rochet and Tirole (2002, 2003), Armstrong (2006), Economides and Katsamakas (2006), Damiano and Li (2008), and Ambrus and Argenziano (2009).

[4] Brown and Morgan (2009) briefly examine this possibility in a competing auctions model and conclude that vertical differentiation in that setting leads to tipping.

[5] An exception is Brown and Morgan (2009).

[6] See, e.g., Huck et al. (2004) and Engelbrecht-Wiggans and Katok (2005). Holt (1993) provides a comprehensive survey of experiments in industrial organization.

of the experimental coordination literature concerns congestion games (sometimes called anticoordination games).[7] Platform competition differs from anticoordination games in two key respects. First, in our setting, the addition of more users of the same type reduces payoffs (i.e., congests the platform), whereas additional users of the opposite type raise payoffs (i.e decongests the platform). Second, interior equilibria anticoordination games arise because of the absence of scale effects—if twice as many users choose a given route, payoffs decline. In our setting, if twice as many users of each type opt for a given platform, then payoffs increase. Thus, platform games may simultaneously have interior as well as corner equilibria.

2. Theory

This section describes a class of platform competition games and studies their equilibrium properties. Our goal is to provide a simple but general theoretical framework for the experiments. Consider a platform competition game where there are $N \geq 2$ agents of each of two types. Agents simultaneously choose to locate on one of two platforms, labeled A and B. If an agent chooses to locate on platform i, she has to pay an up-front access fee of p_i. She earns a gross payoff of $u_i(n_1, n_2)$, where n_1 and n_2 respectively denote the number of agents of her own type and of the opposite type locating on platform i. An agent's net payoff from choosing platform i is then $u_i(n_1, n_2) - p_i$. Payoffs depend only on the platform an agent selects and numbers of her own and the complementary type that locate on that platform. The access fees are exogenously given, and neither access fees nor gross payoffs depend directly on the agent's type. Agents of the two types are symmetric and homogeneous in their preferences for the two competing platforms.

We restrict attention to games with generic payoffs: Suppose that $p_A > p_B$, $u_i(N, N) > p_i$, and it is not the case that for all i, j, n_1, and n_2, $u_i(n_1, n_2) - p_i = u_j(n_1, n_2) - p_j$. We make the following assumptions on gross payoff functions:

ASSUMPTION 1 (MARKET SIZE EFFECT). *Gross payoffs are increasing in the number of players of the opposite type. For all $n_1, n_2 \in \{1, 2, \ldots, N\}$, $u_i(n_1, n_2 + 1) > u_i(n_1, n_2)$.*

ASSUMPTION 2 (MARKET IMPACT EFFECT). *Gross payoffs are decreasing in the number of players of own type. For all $n_1, n_2 \in \{1, 2, \ldots, N\}$, $u_i(n_1, n_2) > u_i(n_1 + 1, n_2)$.*

ASSUMPTION 3 (SCALE EFFECT). *Gross payoffs increase when the number of players of both types on the platform increase equally. For all $n_1, n_2 \in \{1, 2, \ldots, N\}$, $u_i(n_1 + 1, n_2 + 1) > u_i(n_1, n_2)$.*

[7] See, e.g., Selten et al. (2004, 2007), Rapoport et al. (2006, 2009), and Morgan et al. (2009).

ASSUMPTION 4. *For all i, j, $u_j(1, 0) - p_j < u_i(N, N) - p_i$.*

Assumption 4 merely rules out the possibility that an agent would prefer to be alone on a platform rather than being on a platform in which all other agents are located. With these assumptions in place, one can show the following useful property of any Nash equilibrium for this class of games.

LEMMA 1. *In any equilibrium, the same number of both types select a given platform.*

This result comes from the symmetric nature of the two types. If this is not the case, then there will always be incentive for at least one type of player who is the majority on a platform to switch to the platform where they will be the minority. Given the results of Lemma 1, a *coexisting equilibrium* is a Nash equilibrium where n players of each type locate on one platform, and $N - n$ players of each type locate on the other platform, where $0 < n < N$. A *tipped equilibrium* refers to a Nash equilibrium where all players locate on one of the two platforms. No player locates on the other platform. Our next result shows that there are always tipped equilibria and identifies conditions where coexisting equilibria arise.

PROPOSITION 1. *Tipping is always an equilibrium. For any $0 < n < N$ such that*

$$u_A(n+1, n) - u_B(N-n, N-n)$$
$$\leq p_A - p_B \leq u_A(n, n) - u_B(N-n+1, N-n),$$

n players of each type choosing platform A and the remainder choosing platform B is an equilibrium.

Tipping comprises an equilibrium due to scale for the usual reasons. Along the lines of Ellison and Fudenberg (2003), market impact effects can offset scale effects to produce coexistence. One might worry that the interior equilibria arising in this model are "knife-edge" equilibria in the sense that any small perturbation in agent strategies leads to tipping. This is not the case. Generically, when a coexisting equilibrium exists, it is a *strict Nash equilibrium*, i.e., the relevant equations hold with strict inequality for a dense set of parameter values.

PROPOSITION 2. *There is a unique Pareto dominant equilibrium. It consists of tipping to platform i, where $u_i(N, N) - p_i > u_j(N, N) - p_j$.*

Although platform competition generally leads to equilibrium multiplicity, Proposition 2 shows that by applying the Pareto refinement, one always obtains a unique prediction. Of course, there are many coordination games where the unique Pareto dominant prediction performs poorly. In these games, applying a risk dominance refinement is often a better predictor.

For the class of games we study, one can show that the risk dominance refinement excludes interior equilibria but can offer no general results beyond this without imposing further restrictions on the gross payoff functions. When both platforms have the same matching technology, Pareto and risk dominance lead to the same prediction. When platforms are differentiated, this is not necessarily the case, a fact we exploit in some of our experimental treatments.

We do not analyze platform competition where agents have heterogeneous preferences over the platforms. A comprehensive study of such models is quite involved and is beyond the scope of this paper. We run a very specific set of experiments with heterogeneous agents, and we discuss equilibria in our particular experimental settings later in the relevant sections.

3. Experimental Design

We designed the experiments to operationalize the notion of different participant types choosing between platforms with varying access fees and levels of efficiency. Although the theory model is static, platform competition in practice is dynamic. Individuals repeatedly choose which platform to locate on, so a platform's market share can change over time. To gain some insight about market dynamics, we had the same set of individuals repeatedly interact in choosing platforms.

We conducted 26 sessions of the experiment between May 2006 and March 2009. Four hundred and eighty undergraduate students from Hong Kong University of Science and Technology participated, with none participating in more than one session. Each session took about 90 minutes in total. On average, a subject earned almost HKD 170 (about $22) from participating in a session—an amount considerably above most subjects' outside options. The experiments were programmed and conducted with the software z-Tree developed by Fischbacher (2007).

Each session consisted of four sets, each consisting of 15 periods.[8] At the beginning of a set, a participant was randomly assigned a *type* of either a "square" or a "triangle," and randomly matched with three other players. These four players, two of each type, comprised a *market*.[9] During each period, players in a market simultaneously chose which of two platforms, named "firm %" and "firm #," to locate. We informed subjects about the access fee for each platform and how much they would earn as a function

of how many of each type located on each platform. These gross payoffs were presented in the form of payoff matrices. After each period, subjects learned how many of each type located on each platform and how many points they earned. At the end of a set, each subject was randomly reassigned a new type, randomly rematched into a new market, and shown a new set of payoffs. At the conclusion of a session, each subject was compensated based on cumulative points earned. In most real-world platforms, user populations persist over time. For instance, eBay buyers and sellers repeatedly participate on the platform. To approximate this idea, we fixed the set of market participants over the life cycle of a competing platform (i.e., a set), rather than randomly assigning participants to a new market in each period. In reality, the user population will change slowly over time, but its inertia strikes us as closer to fixed rather than random pairings.

In all but four sessions, subjects were homogeneous in the sense that all subjects were given the same gross payoff matrices and access fees. In sessions with heterogeneous subjects, the two subjects of a given type faced different sets of access fees to the platforms. We divide the sessions into two groups. In the first 20 sessions, conducted between May 2006 and March 2007, we ran experiments under different settings that are consistent with the model described in the previous section. The main purpose of these sessions was to examine tipping versus coexistence when platforms are either homogeneous or vertically differentiated. In subsequent experiments, conducted in February and March of 2009, we depart from the model, adding horizontal differentiation, to further study platform coexistence. We describe treatments for the first set of experiments in the remainder of this section. We describe treatments for the second set of experiments in §5. The instructions used in all the sessions are available from the authors.

3.1. Treatments

Within each session, sets alternated as "no tip" (N) or "tip" (T). Although tipping to either platform was a Nash equilibrium in all treatments, the payoffs in N sets additionally supported a strict Nash equilibrium in the interior. To control for presentation effects, half of the sessions began with an N set (referred to as an NTNT session), whereas the other half began with a T set (referred to as a TNTN session). We opted for a within-subjects design for several reasons. First, although we wanted to have enough interactions that markets would have an opportunity to converge to an equilibrium, we worried that subjects would become bored making the same platform choice up to 60 times. We felt that by varying the players and the payoff matrix after each set, players

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[8] In "homogeneous" sessions, i.e., sessions 1 to 6, sets consisted of 10 periods.

[9] "Homogeneous-large" and "cloned platform" sessions followed the same procedure but had eight-person markets with four players of each type.

Table 1   Summary of Treatments in the First 20 Sessions

Treatment	Numbers of players in a market	Number of sessions	Cheap heuristic prediction	Risk dominance prediction	Pareto dominance prediction
Homogeneous	4	6	Tip to platform B	Tip to platform B	Tip to platform B
Homogeneous-large	8	2	Tip to platform B	Tip to platform B	Tip to platform B
Differentiated	4	4	Tip to platform B	Tip to platform B	Tip to platform B
Differentiated-cheap	4	4	Tip to platform B	Tip to platform A	Tip to platform A
Differentiated-RD	4	4	Tip to platform B	Tip to platform B	Tip to platform A

would be more attentive to the experiment. Second, we wanted players to think of each set as representing the "life" of a given market. Changing treatments after each set makes this time marker more vivid to subjects. Finally, we obtain the usual benefit that, even controlling for session-level variation, we can still identify how variation in market impact effects change subject behavior.

Platforms were either homogeneous or vertically differentiated in a given session. In homogeneous sessions, platforms had identical payoffs but different access fees. In differentiated sessions, platforms differed both in payoffs and access fees. Table 1 summarizes the treatments as well as several theoretical benchmarks in the first 20 sessions. The column labeled "Cheap heuristic prediction" is a prediction based on the heuristic strategy of simply choosing the platform with the lower access fee. We label the platforms A and B in the remainder of this paper, where B is the platform with the cheaper access fee.

4.   Market-Level Results

In this section, we treat behavior at the market level as the unit of observation and analyze the evolution of market share for each platform. Our two main findings are as follows:

FINDING 1. Tipping, usually to the Pareto dominant platform, is pervasive.

FINDING 2. Coexisting equilibria have little impact. Markets never converge to these equilibria.

The remainder of this section analyzes each treatment and shows that the two findings are robust to market size and platform differentiation.

4.1.   Homogeneous Platforms

We first consider the case where platforms are homogeneous—equally efficient in matching agents. These are the experimental analogs to the theory models of Caillaud and Jullien (2003), Rochet and Tirole (2003), and Ellison and Fudenberg (2003). For homogeneous treatments, the payoff structure as a function of the subject's choice and the proportions of each type locating on the subject's platform was identical for the two platforms; that is, $u_i(n_1, n_2) =$

Figure 1   Pareto Dominant Platform Choice in the Homogeneous Treatment
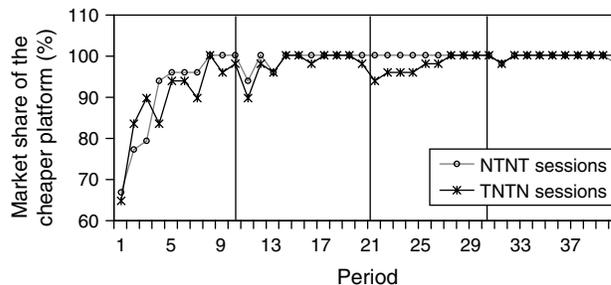
$u_j(n_1, n_2)$ for all n_1, n_2. However, the platforms did differ in their access fees. Both Pareto dominance and risk dominance offer the same prediction—tipping to the platform with the lower access fee. The cheap heuristic shares this prediction.

**4.1.1.   Homogeneous and Homogeneous-Large.** Although we are mostly interested in the market level results, we start by looking at entire sessions first.[10] Figure 1 presents a time series of the percentages of players choosing the cheaper platform in all the NTNT and TNTN sessions. Once a market converges to the cheaper platform, the market stays tipped there throughout the session. As the figure shows, there is little evidence of a presentation effect.[11]

Figure 2 displays the fraction of all markets that tipped by the end of each 10-period set, as well as the direction in which they tipped. We say that a market has tipped to a particular platform by the end of a set if *all subjects* in that market choose that specific platform in each of the last three periods of that set. Because we ran six sessions with four markets per session, each of the bars in the figure represents 24 markets. Tipping is prevalent (occurring more than 90% of the time in each set) and systematic—markets only tipped to the platform with the cheaper access fee. Existence of a nontipped equilibrium had virtually no effect on behavior. First, there were only three markets where tipping did not occur, and two

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[10] Recall that four separate markets operated at the same time in each session.

[11] This is more formally confirmed by individual-level regressions available from the authors upon request.

Figure 2   Tipped Markets in the Homogeneous Treatment

Figure 3   Tipped Markets in the Differentiated Treatment
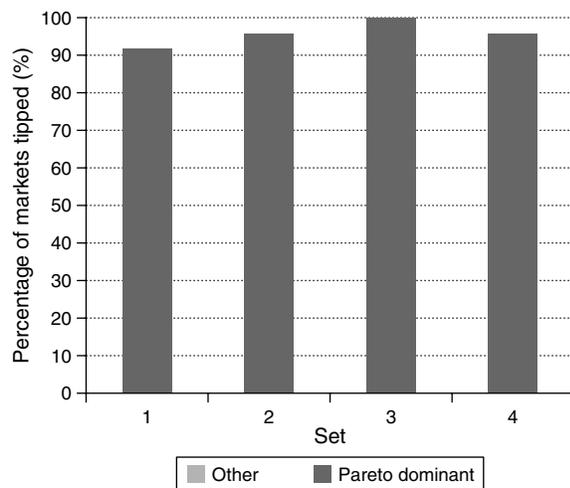

of these were in T sets, where there was no interior equilibrium. One might argue that tipping occurred because the markets were small, and hence coordination was easy. Our homogeneous-large treatment complicate the coordination problem by doubling the size of the market.

For homogeneous-large treatments, there were eight participants comprising a market. We also increased the length of a set to 15 periods, anticipating the coordination difficulties of a larger group. The sessionwise dynamics of platform choice are similar to the homogeneous treatment. Looking at market-level behavior in the last three periods of each set, we find that *every* market tipped to the cheaper platform. This was not because we extended the set length—even by the 10th period, all markets had tipped. This suggests that ease of coordination in smaller markets was not driving tipping. One might argue that tipping occurred because of the focality of the "better" platform in the homogeneous case. When platforms differ in both efficiency and access fees, identifying the "better" platform is more of a challenge. To study this possibility, we next investigate markets with vertically differentiated platforms.

4.2.   Vertically Differentiated Platforms
When a given number of own and other type agents receive different gross payoffs for the two platforms, we say that platforms are differentiated. A simple way in which this might occur is if one platform had a superior matching technology to the other. We model this by choosing payoffs such that $u_A(n_1, n_2) > u_B(n_1, n_2)$ for all (n_1, n_2) pairs, with $n_1, n_2 > 0$. As before, platforms differ in their access fees. Here we were able to test whether adding a second dimension, platform quality, changes market outcomes.
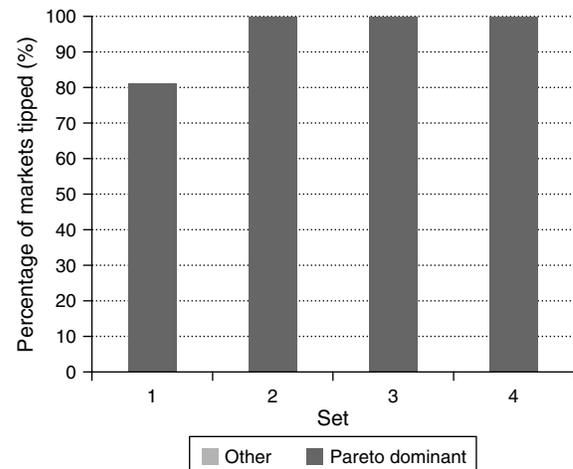
4.2.1.   Differentiated. As shown in Table 1, tipping to the cheaper platform B is still both a Pareto and risk dominant equilibrium in this treatment. Figure 3 shows that subjects overwhelmingly chose the more efficient platform B. Nevertheless, adding the quality dimension to platform competition slowed convergence, at least initially. In the first set, only 81% of markets converged, compared to 92% and 100% converging in the first sets of homogeneous and homogeneous-large treatments, respectively. From the second set onward, however, 100% of markets converged. In every case, when a market converged, it tipped to the Pareto dominant platform. Indeed, there is no evidence of platform coexistence, even when parameter values are such that an interior equilibrium exists.

Although we have been interpreting the results of the experiments as supporting the Pareto or risk dominant predictions with strategic players, the data are also consistent with nonstrategic players who merely locate on the platform with the cheaper access fee. Our next section seeks to distinguish between these two hypotheses.

4.2.2.   Differentiated-Cheap. By varying the difference in the access fees as well as the degree of vertical differentiation, there are parameter values where the Pareto dominant platform is not the cheaper one. Thus, we can distinguish strategic behavior from the "cheap" heuristic. In these sessions we chose the gross payoffs and platform subscription fees such that the market tipping to the *more* expensive platform is the Pareto dominant equilibrium.

The sessionwise dynamics for this treatment are shown in Figure 4. Interestingly, in the first set of the NTNT sessions, approximately 75% of subjects chose the Pareto dominant platform, giving the overall market a "nontipped" look. It is, however, instructive to examine each of the four-player "markets" separately,

Figure 4   Pareto Dominant Platform Choice in the Differentiated-Cheap Treatment
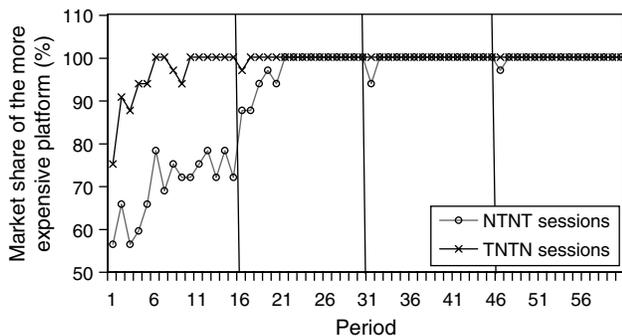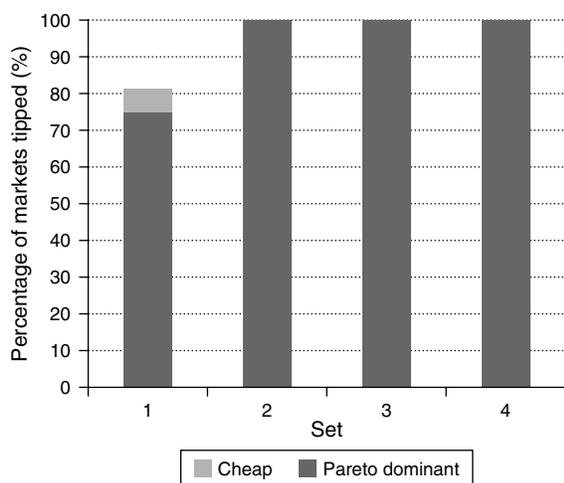

**Figure 5**   Tipped Markets in the Differentiated-Cheap Treatment

as shown in Figure 5. In the first set, we find that 75% of markets tipped to the Pareto dominant platform, and 6% tipped to the cheap platform. Thus, at least initially, there is some evidence of market tipping to the less efficient (in net terms) platform. From Set 2 onward, however, 100% of markets tipped to the Pareto dominant, but more expensive, platform. Interestingly, three of the four players from the market tipping to the cheaper platform in the first set chose the Pareto dominant platform from the beginning of the second set after having been randomly reassigned to a new market group. As with all the previous treatments, there is no evidence of platform coexistence.

None of the treatments offered so far has the flavor of a "stag hunt"-type game—the Pareto prediction corresponds exactly to the risk dominant prediction. Both theory and experiments suggest that when these two predictions diverge, the risk dominant prediction often prevails.[12] The next set of sessions seeks to differentiate between these two predictions.

[12] For example, see van Huyck et al. (1990) and Young (1993).

Figure 6   Pareto Dominant Platform Choice in the Differentiated-RD Treatment
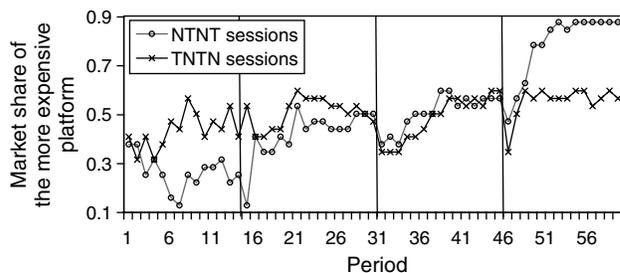
4.2.3.   Differentiated-Risk Dominant. A simple way to separate the Pareto and risk dominant predictions without disturbing the rest of the structure of the game is to increase the "upside" from mistakes on the Pareto inferior platform. To operationalize this, we simply change a single (off equilibrium) payoff cell to increase the market size effect for this platform. Because the risk dominance prediction is influenced by payoffs from mistakes, whereas the Pareto refinement is not, this change has the effect of separating the two. In our experiments, tipping to the more expensive platform is the Pareto dominant equilibrium, whereas tipping to the cheaper platform is the risk dominant equilibrium.

The results are much more nuanced in this treatment. The sessionwise dynamics, as seen in Figure 6, do not suggest convergence. We denote risk dominant as RD in Figure 6 and in later figures and tables. Nevertheless, a much higher percentage of subjects chose the Pareto dominant platform at the end of each session than at the beginning. When we look at four-player markets separately in Figure 7, we see that a majority of markets did in fact converge. In the first set, the majority of tipped markets converged to the risk dominant platform. However, as subjects gained experience, tipping increasingly favored the

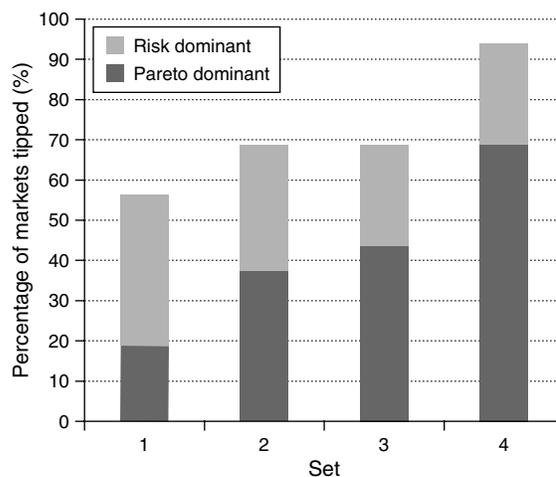**Figure 7**   Tipped Markets in the Differentiated-RD Treatment

Table 2   Counts of Coexistence in Set 1

Treatment	Tipped		Not tipped		Total
	Count	Percent (%)	Count	Percent (%)	
Homogeneous	4	3.33	5	4.17	120
Homogeneous-large	1	1.67	1	1.67	60
Differentiated	3	2.50	5	4.17	120
Differentiated-cheap	1	0.83	3	2.50	120
Differentiated-RD	9	7.50	10	8.33	120
Total	18	3.33	24	4.44	540

Notes. "Count" denotes total number of periods in which each platform obtains a 50% market share of each type. "Total" denotes the total number of market periods in Set 1 for each treatment (tipped or not tipped).

Table 3   Probit of Dynamic Platform Choice

	Dependent variable: Choice of PD platform		
Treatment	Time trend	Trend × Rematch	Obs.
Homogeneous	0.079***	−0.039***	3,840
Homogeneous-large	0.140***	−0.084***	3,840
Differentiated	0.072***	0.013	3,840
Differentiated-cheap	0.084***	−0.036***	3,840
Differentiated-RD	0.018***	−0.011***	3,840

Note. Rematch is a dummy for if players were randomly rematched. Standard errors are clustered at the individual level.
    ***Significant at the 1% level.

Pareto dominant platform. By Set 4, 94% of markets had tipped, and of these, 69% tipped to the Pareto dominant platform. For the first time in the experiment, the market converged to a coexisting outcome: once in an N set and once in a T set (where this outcome was not an equilibrium).

In our experiment, markets were more likely to tip to the Pareto dominant rather than the risk dominant platform by the end of each session. We can use a Pearson chi-squared test to examine the null hypothesis that, conditional on market tipping, there is an equal chance of tipping to either platform. Although we cannot reject this null hypothesis for the first three sets, we can reject it with a *p*-value of 0.07 for Set 4. In other words, there is modest statistical support that Pareto dominance is a better predictor of (experienced) market-tipping behavior.

4.2.4.   Coexistence. Although the evidence points to tipping as the long-run consequence of platform competition, initially, market participants do not immediately coordinate on this outcome. For instance, even under the homogeneous treatment, the market shares of the two platforms were initially volatile (see Figure 1). Perhaps periods of coexistence characterize early stages of platform competition, and tipping only arises as the market matures.

To examine this possibility, we counted the number of periods in the first set where both types of users were split equally between the two platforms competing in a market.[13] Table 2 presents these counts for when there is no coexisting equilibrium (i.e., T sets) as well as for when there is a coexisting equilibrium (i.e., N sets). Markets were rarely in a configuration consistent with coexistence. Moreover, coexistence was only slightly more likely when coexistence is an equilibrium than when it is not. These differences do not come close to statistical significance. Not only did markets not *converge* to the coexisting outcome, they rarely entered this configuration even

transiently independent of whether coexistence was an equilibrium.

4.2.5.   Speed of Convergence. When there is no conflict between risk dominance and Pareto dominance, the market rapidly tips to the Pareto dominant platform in a setting where the same market participants repeatedly interact. The reality of platform competition is that, in each "period," there is a mix of new and experienced participants. We argue, however, that the composition of participants tends to change only slowly and hence is reasonably approximated by our design. Nevertheless, one may wonder how differences in the turnover of market participants affect the dynamics of platform competition. To investigate how turnover in market participants affects the speed of tipping, we exploit the fact that subjects are randomly rematched at the conclusion of each set. We estimate an individual's propensity to choose the Pareto dominant platform as a (linear) function of time, interacted with a dummy variable for periods in which the market participants are randomly rematched using a probit regression. Because N and T sets yield similar behavior, we pool over this dimension of the experimental design. Table 3, where PD denotes Pareto dominant, reports the results of this analysis.

Over time, individuals are increasingly likely to choose the Pareto dominant platform in all treatments. Nevertheless, the time trend is cut approximately in half when there is turnover in the set of market participants.[14] The overall trend is still statistically significant. Thus, even if the set of market participants changed every period, we would still see tipping to the Pareto dominant platform, but it would take approximately twice as long as when there is no turnover.

5.   Is Tipping Inevitable?
Our previous results suggest that tipping is an inevitable consequence of platform competition. Regardless of whether markets are large or small, whether

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[13] In later sets, tipping occurred quickly for most treatments, and hence coexistence occurred even more rarely, if at all.

[14] The exception is the differentiated treatment, where the interaction term has the opposite sign and is not statistically significant.

platforms are homogeneous or vertically differentiated, or whether there is a coexisting equilibrium or not, platform competition eventually gave way to tipping—mainly to the Pareto dominant platform. Perhaps the mere presence of a Pareto dominant platform is the main driver for tipping. To investigate this possibility, we modified payoffs in two ways to eliminate a Pareto dominant equilibrium.

5.1. Cloned Platforms

With homogeneous platforms, when access fees differ, there is a Pareto dominant equilibrium, and the market quickly tips to it. But suppose that the access fees were the same. In that case, the platforms would be clones, and neither would be Pareto dominant. Because the platforms are symmetric, one might speculate that the outcome would be symmetric as well—each platform would enjoy a 50% market share.

To examine this possibility, we ran two additional sessions of our homogeneous-large treatment, but with *identical* access fees. Equal market share is always an interior equilibrium in this setting. In T sets, this is the only interior equilibrium. In N sets, unequal market shares also comprise three interior equilibria. Thus, at least one coexisting equilibrium existed in every period of these sessions. Because coordination is important in this game, we randomized the order in which we displayed the radio buttons for platform choice. In one session, "platform #" is on top, whereas, in the other, "platform %" is on top.

Our results may be easily summarized: Despite the existence of coexisting equilibria, markets never converged to these outcomes. Instead, most markets did not converge in the first set and tipped in Sets 2–4. As subjects gained experience, they learned to coordinate on whichever platform was displayed on the top of the screen, as Figure 8 illustrates.

Figure 8   Cloned Platform Tipping
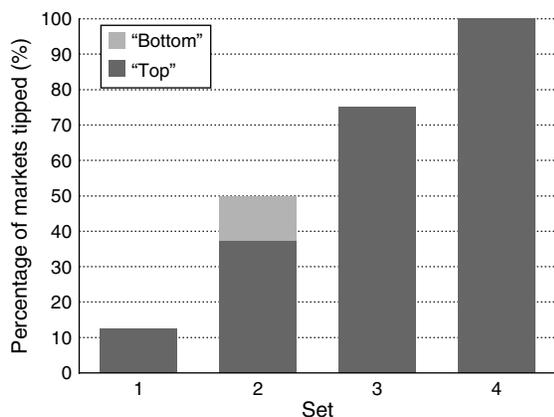
To summarize, when platforms are homogeneous, even when the focality of a Pareto dominant platform is removed, markets still tend to tip. Subjects learn to coordinate on other features of the game, such as the locations of the radio call buttons on the interface, to select a single *winning* platform. Thus, the "top" platform appears to be a focal point; that is, it is a decision label used for coordination. However, first period choices are consistent with a model in which "top" has no particular attraction. This suggests that the focality of "top" seems to be socially determined—it arises over time as market participants interact with one another—rather than being the obvious (focal) choice from the outset.

5.2. Horizontal Differentiation

In practice, platforms differ from one another not only vertically, but also horizontally. The "right" platform may well differ from user to user. For example, the platform Jdate.com matches individuals seeking dates. It is fairly easy to use, has reasonable rates for access, and enjoys reasonable market share. Yet there is little reason to think that the online dating market will eventually tip to Jdate.com for one simple reason—Jdate.com only matches individuals who happen to be Jewish.

From a theory standpoint, horizontal differentiation admits a new possibility—for generic parameter values, it may be that neither platform is Pareto dominant when tipped. To investigate how horizontal differentiation affects platform competition, we conducted four additional experimental sessions with 16 subjects in each session. We amended our original experimental design as follows: In each market, a pair of agents, one of each type, received a discount for choosing platform #, whereas the other pair received a discount for choosing platform %. The discounts reflect the idea of horizontal differentiation—each pair of square and triangle types prefers to coordinate on their discounted platform.

We chose parameters such that four interior equilibria, in addition to the tipped equilibria, always existed. In one such equilibrium, each agent goes to the platform where she gets a discount. In the other coexisting equilibrium, each agent goes to the platform that is more expensive for her. In the remaining two coexisting equilibria, agents of one type go to their preferred platform, whereas the agents of the other type go to their nonpreferred platform. In half of the sets, the parameters were such that a tipped equilibrium was Pareto dominant. In the other half, there was no Pareto dominant tipped equilibrium. Sets alternated between these treatments. We examined eight markets in each of four sets under each of these two treatments.

Figure 9   Tipping with a PD Tipped Equilibrium
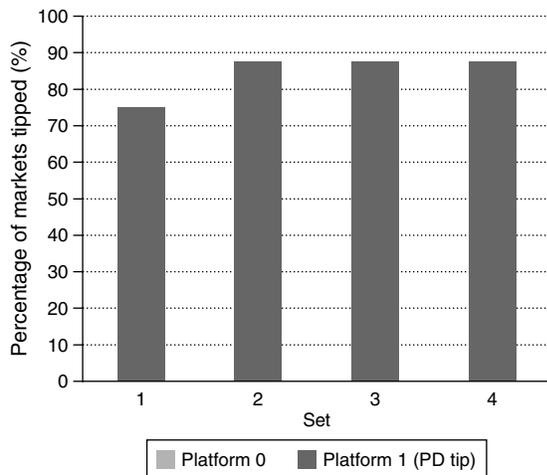

Figure 10   Coexisting Platforms

Figure 9 displays the impact of horizontal differentiation when there is a Pareto dominant tipped equilibrium. Merely adding horizontal differentiation does not alter the broad tendency of these markets to tip. In Set 1, six of the eight markets converged to the Pareto dominant platform ("Platform 1" in the figure), whereas in each of Sets 2–4, seven of eight converged.
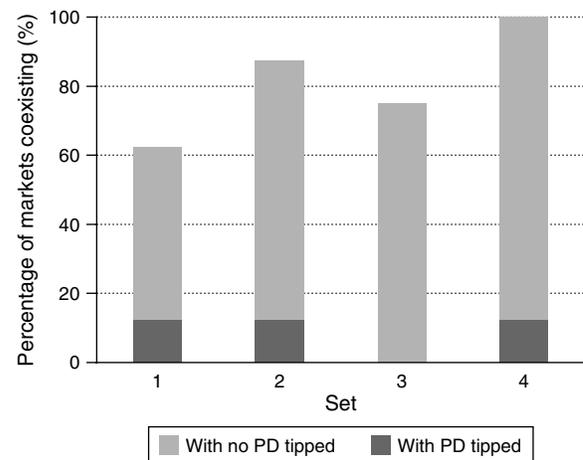
If we increase the degree of horizontal differentiation to the point where it dominates the vertical differentiation, then neither platform is universally preferred (i.e., there is no Pareto dominant equilibrium). Under this treatment, tipping is infrequent, occurring only 18.75% of the time.

What happened when markets did not tip? One possibility, suggested by the results under the differentiated-RD treatment, is that these markets simply never converged at all. Another possibility is that they converged to a coexisting equilibria. Figure 10 displays the frequency with which the market converged to the coexisting equilibrium where agents go to their discounted platforms. Out of the five markets that did not tip to the Pareto dominant platform (in the treatment where there was such a platform), three converged to this coexisting equilibrium, and the remaining two did not converge at all. When there was no Pareto dominant platform, most markets converged to this coexisting equilibrium. By Set 4, seven of eight markets converged to this outcome. Thus, with sufficient horizontal differentiation, tipping is not the inevitable outcome of platform competition. Instead, coexistence is the most likely outcome.[15] This suggests the following:

FINDING 3. *Markets predominantly converge to a coexisting equilibrium only when platforms are suffi-*

ciently horizontally differentiated, so that there is no Pareto dominant platform.

6.   Discussion and Conclusion

When do competing matchmakers coexist in a two-sided market? Casual empiricism suggests that, in many markets, a dominant platform has emerged. For instance, despite inroads by Apple and Linux, Windows currently enjoys an 87% share of the U.S. operating systems market (Global Stats 2010). For all practical purposes, this market has tipped.[16] Similarly, Google commands a 66% market share in the U.S. search market, and its share has been steadily growing over time (Hitwise 2011a). Facebook controls at least 64% of the U.S. market for social platforms. Its nearest social networking rivals, including MySpace, all hold under 1% market share (Hitwise 2011b). In the market for MP3 players, Apple enjoys 73% market share. Its nearest rival, Sandisk, lags with only 7% share (Delahunty 2009). Finally, eBay has an estimated 85% share in U.S. online auctions (The Business Link 2010).

This is not to say that all two-sided markets tip. The market for gaming consoles is fairly evenly split with Xbox enjoying 43% share, compared to 30% for Nintendo, and 27% for Sony (diTii.com 2010). The market for job posting is also split, with CareerBuilder accounting for a 33% share, Yahoo! at 27%, and Monster at 22% (Fixcv.com 2011).[17] Finally, the quintessential matchmaker market, online dating, is even less concentrated, with the leading firm, True.com managing to capture only an 11% share (Hitwise 2007).

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[15] None of the markets ever converged to a coexisting equilibrium where some agents go to their nonpreferred platform.

[16] A consensus definition for monopoly under the Sherman Act is that a firm that enjoys 70% market share or more. Under that definition, Microsoft is a monopolist in operating systems.

[17] Subsequent to this report, Yahoo! outsourced its job listings to Monster.

We investigated competition between matchmakers or platforms using laboratory experiments. When platforms were undifferentiated or vertically differentiated, markets did not converge to an interior equilibrium regardless of the size of these forces. Instead, the overwhelming majority of markets tipped to a single platform. Even when coexistence was theoretically possible, it poorly described market behavior.

But which platform emerged as the winner? A source of continuing fascination to economists is the possibility that markets will tip to an inefficient platform. Anecdotes along these lines abound, ranging from the QWERTY keyboard to the VHS format for videocassettes (see Katz and Shapiro 1994). Underlying this worry is the simple observation that, in the presence of scale effects, tipping to either platform comprises an equilibrium. Although tipping to the inferior platform was theoretically possible in our experiments, it too was a poor description of market behavior. Indeed, the market *never* tipped to the inferior platform when the more efficient platform was also less risky.[18] When there was a trade-off between risk and efficiency, some markets did initially converge to the inferior platform; however, with experience, markets increasingly tipped to the efficient platform.

Allowing for horizontal as well as vertical differentiation led to more nuanced conclusions about tipping. When the vertical dimension dominated, markets still overwhelmingly tipped to the efficient platform. However, when the horizontal dimension dominated (to the point where there was no efficient platform), coexistence was the most likely outcome. This is consistent with the observation from gaming console and online dating markets—Nintendo's Wii platform appeals to a younger and more female demographic than rival Microsoft, whose flagship game, the first-person shooter Halo, mainly appeals to younger males. Dating markets also seem to be segmented by geographic and demographic characteristics.

Our results shed light on the varied market structures of platforms across a number of industries. For instance, online auction markets, where the vertical dimension dominates, tend to be highly concentrated. In contrast, online dating markets, where there is a large horizontal component, tend to be more fragmented. From an antitrust perspective, our results indicate that measuring the magnitudes of horizontal versus vertical differentiation among competing platforms is crucial for assessing the likelihood of tipping and eventual market power.

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[18] Also see Hossain and Morgan (2009) for an illustration of the QWERTY phenomenon not occuring even when the inferior platform has a first-mover advantage in the market.

Obviously, there are a number of limitations to using our study as a basis for understanding real-world platform competition. One limitation is that, owing to space constraints in the laboratory, our experimental markets are small relative to their real-world counterparts. Small markets might seem to bias the results in favor of tipping because coordination is easier. At the same time, however, small markets might also bias the results in favor of coexistence because the competitive impact of an additional individual on a platform is likely to be more pronounced. Interestingly, when we doubled the size of the experimental market, we found more evidence of tipping in the larger market. A second potential limitation of our study is the external validity of the subject pool. In our view, undergraduate students are not all that dissimilar to typical platform users. Undergraduates are large consumers of video gaming consoles, online auctions, online dating sites, and search engines. Finally, participants in most two-sided markets can multihome, unlike in our setting. We plan to tackle this issue in the future.

Appendix

PROOF OF LEMMA 1. Suppose the two types of agents are labelled as triangles and squares. Let us consider an equilibrium where n_1 triangle and n_2 square agents locate on platform A. If agents of triangle type in platform A do not have incentives to deviate, then

$$u_A(n_1, n_2) - p_A \geq u_B(N - n_1 + 1, N - n_2) - p_B$$
$$\Rightarrow u_A(n_1, n_2) - u_B(N - n_1 + 1, N - n_2) \geq p_A - p_B. \quad (1)$$

Now, if $n_1 > n_2$, then it follows that

$$u_A(n_1, n_2) \leq u_A(n_2 + 1, n_2) < u_A(n_2 + 1, n_1), \quad (2)$$

where the weak inequality follows from Assumption 2, and the strict inequality follows from Assumption 1. Similarly,

$$u_B(N - n_1 + 1, N - n_2) \geq u_B(N - n_2, N - n_2)$$
$$> u_B(N - n_2, N - n_1). \quad (3)$$

Combining Equations (2) and (3), we have that

$$u_A(n_2 + 1, n_1) - u_B(N - n_2, N - n_1)$$
$$> u_A(n_1, n_2) - u_B(N - n_1 + 1, N - n_2).$$

Using Equation (1), we obtain

$$u_A(n_2 + 1, n_1) - u_B(N - n_2, N - n_1) > p_A - p_B$$

$$\Rightarrow \; u_A(n_2 + 1, n_1) - p_A > u_B(N - n_2, N - n_1) - p_B.$$

But, this implies that a square-type agent located on platform B can profit from unilaterally deviating to platform A. This is a contradiction that arises from the assumption that $n_1 > n_2$. Therefore, $n_1 = n_2$ in any equilibrium. $\square$

PROOF OF PROPOSITION 1. First we show that if all agents are located at the same platform, there is no incentive to deviate. Without loss of generality, assume all agents are located on platform A earning net payoffs of $u_A(N, N) - p_A > 0$. If an arbitrary agent instead locates at platform B, she will be the only agent of either type on platform B, and, by Assumption 4, this is not profitable. Thus, tipping to platform A is an equilibrium. An identical argument shows that tipping to platform B is an equilibrium.

Now suppose there exists an interior equilibrium. By Lemma 1, we know that any interior equilibrium is generically characterized by $n < N$ of each type choosing platform A, and $N - n$ of each type choosing platform B. Such an equilibrium will exist if the market impact effect and the fee differences are strong enough to deter tipping. This just requires that there exists $n < N$ such that

$$u_A(n, n) - p_A \geq u_B(N - n + 1, N - n) - p_B$$

and

$$u_B(N - n, N - n) - p_B \geq u_A(n + 1, n) - p_A;$$

that is, players at neither platform have any incentive to unilaterally change their locations. This also implies that there is $n < N$ such that

$$p_A - p_B \in [u_A(n + 1, n) - u_B(N - n, N - n), u_A(n, n)$$
$$- u_B(N - n + 1, N - n)].$$

Here the price differential is such that unilaterally relocating to a different platform does not increase net payoff for any player. $\square$

PROOF OF PROPOSITION 2. We first show that tipping is a necessary condition for Pareto dominance. Consider some interior equilibrium where n of each type of agent visit platform A. By Assumption 3, $u_A(n, n) - p_A < u_A(N, N) - p_A$. Because tipping to platform A is also an equilibrium, this contradicts the notion that the interior equilibrium is Pareto dominant.

Thus, if a Pareto dominant equilibrium exists, it consists of tipping to one of the platforms. With generic payoffs, suppose that for some i, $u_i(N, N) - p_i > u_j(N, N) - p_j$. Hence, tipping to platform i Pareto dominates tipping to platform j. Because this exhausts the set of equilibria, Pareto dominance always selects a unique equilibrium—tipping to platform i. $\square$

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