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Competing Matchmakers: An Experimental Analysis*

Tanjim Hossain
Rotman School of Management
University of Toronto

Dylan Minor
Haas School of Business
University of California, Berkeley

John Morgan
Haas School of Business
University of California, Berkeley

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Abstract

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. The role of a platform is to act as a matchmaker—that platform connects 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 scrutiny by the US Justice Department 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.

In this paper, we investigate both of these drivers of platform coexistence using

¹See Armstrong (2006), Hagiu, Evans, and Schmalensee (2006), as well as Evans and Schmalensee (2007) for many other examples.

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 have the advantage of allowing for a “level playing field” for the platforms; thus removing the potential confounding effect of first-mover advantages that a platform might enjoy.

Whereas most theory models analyze platforms that are either identical or horizontally differentiated, in practice, platforms often differ in quality. For instance, 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. That is, we can precisely control variations in vertical and horizontal differentiation of platforms along with the surplus provided to users net of access fees.

We begin by offering a class of platform competition games and derive some simple theoretical properties. We do not view this as an important theoretical contribution in its own right. Rather, the theory results provide a unifying framework for studying the market structure of competing matchmakers in the lab. Specifically, we 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 in equilibrium whereas in others, only tipped equilibria arise.

Our main findings are:

1. When platforms are primarily vertically differentiated, even when platform coexistence is theoretically possible, platform competition always leads to tipping. In short, market impact effects do not lead to platform coexistence in the lab.
2. While theory is (mainly) silent as to which platform the market will tip, the

market consistently converges to the Pareto dominant platform. We find little evidence of path dependent outcomes where the market gets locked into the “wrong” platform.

3. When platforms are primarily horizontally differentiated, so there is no Pareto dominant platform, platform competition does not lead to tipping. Markets converge to the outcome predicted under platform coexistence.

The paper proceeds as follows. The remainder of this section reviews the related literature on platform competition. Section 2 presents results from a simple theory model of platform competition which 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 growing theory literature on platform competition is market structure—whether multiple competing platforms can coexist or not. 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, however, 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, Fudenberg, and Möbius (2004) demonstrate that, when market impact effects are sufficiently large, platform coexistence is restored even when platforms are undifferentiated. Ambrus and Argenziano (2009) point out that this conclusion is sensitive to the “size” of the individual players on the platform. In particular, when players are atomistic and platforms are undifferentiated, only tipped equilibria remain. A separate line of the theory literature explores the possibility that platforms are horizontally differentiated. Here the conclusions are that, with

sufficient differentiation, coexistence is possible even when platforms have access to a rich set of pricing strategies (see, e.g., Rochet and Tirole, 2002, 2003; Armstrong, 2006; as well as Damiano and Li, 2008; and Ambrus and Argenziano, 2009). Using a somewhat different approach, Economides and Katsamakas (2006) analyze market competition between an open source technology platform and a proprietary platform and find that many different compositions of the market shares are possible depending on demand for each of the systems.

While 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.² 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). More recent work in the area uses consumer reviews to try to identify the “better” platform and then examine subsequent market share. (see, e.g. Tellis, 2009). The main conclusion of this work is that, when a dominant platform emerges, it tends to be of higher quality than its rivals. Of course, identifying causality is difficult—platform quality is a “moving target” that changes with the resources of the competing firms. Thus, 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.³ An important reason for this seeming disconnect is 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. Our approach of using laboratory experiments provides a useful complement. While obviously lacking the realism of field data, our controlled environments enable us to precisely measure and perturb key features of the model that theory suggest are important in determin-

²Brown and Morgan (2009) briefly examine this possibility in a competing auctions model and conclude that vertical differentiation in that setting leads to tipping.

³One exception we are aware of is Brown and Morgan (2009), which uses field experiments on eBay and Yahoo to test the predictions of the Ellison, Fudenberg, and Möbius (2004) model.

ing platform coexistence versus tipping. It also enables us to explore the QWERTY question without the problem of reverse causality.

Our work adds to a growing literature that uses laboratory experiments to examine questions in industrial organization.⁴ Much of this literature concerns itself with “conventional” markets and traditional industrial organizational models. Many such papers study competition only on one side of the market. For example, oligopoly experiments of Huck, Normann, and Oechssler (2004) find that markets with four or more firms in the supply side are very competitive. Another somewhat similar, but much smaller, literature is the experimental study of competing auctions. Engelbrecht-Wiggans and Katok (2005) provide a recent example of this approach. However, once again these markets are experimentally one sided. To the best of our knowledge, we are the first to study two-sided markets under a wide array of treatments in the lab.⁵

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 (see Ochs, 1995 for a survey). Two key differences between our experiments and standard coordination games are the fact that there are *two* types of players trying to match with one another and, more importantly, the presence of market impact effects—more competitors on the same “side” of the market reduces payoffs to each player on that side—a feature not shared with commonly studied coordination game experiments.

2 Theory

In this section, we describe a class of platform competition games and study their equilibrium properties. The main purpose of this section is to provide a simple but general theoretical framework for the experiments—most of our treatments represent examples in this class of games. Consider a platform competition game where there

⁴See, Holt (1995) for a comprehensive survey.

⁵Note that Clemons and Weber (1996) experimentally analyze market share of competing stock exchanges under a very specific set of conditions.

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. Specifically, 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 , $u_i(n_1, n_2) - p_i = u_j(n_1, n_2) - p_j$. Finally, 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 $n_1, n_2 \in \{1, 2, \dots, N\}$, $u_i(n_1, n_2 + 1) > u_i(n_1, n_2)$.

Assumption 2 (market impact effect): Gross payoffs are decreasing in the number of players of own type. For all $n_1, n_2 \in \{1, 2, \dots, N\}$, $u_i(n_1, n_2) > u_i(n_1 + 1, n_2)$.

Assumption 3 (scale effect): Gross payoff increase when the number of players of both types on the platform increase equally. For all $n_1, n_2 \in \{1, 2, \dots, N\}$, $u_i(n_1 + 1, n_2 + 1) > u_i(n_1, n_2)$.

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. To see this, consider an online dating setting. Suppose more men than women join platform A

in equilibrium. Then it must be that, for a man on platform A , the cost saving from switching to platform B is outweighed by the loss in gross payoff from switching. But if the gross payoffs on platform B are so low, then surely it will be profitable for women on this platform to switch to A . After all, the gender ratio on A is even more favorable for women than it is for men. Thus, gender ratios must be equal across platforms in equilibrium.

As standard in the literature, 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. On the other hand, given the results of Lemma 1, a *coexisting equilibrium* is a Nash equilibrium where n players of each type locates on one platform and $N - n$ players of each type locates on the other platform where $0 < n < N$. While the model always has tipped equilibria, coexisting equilibria exist under specific conditions as described in Proposition 1.

Proposition 1 *Tipping is always an equilibrium. Furthermore, any $0 < n < N$ such that*

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

is an equilibrium where n players of each type to choose platform A with the remainder choosing platform B .

Tipping comprises an equilibrium for the usual reasons. However, since the model nests all of the effects described in the extant literature, coexistence can arise for two reasons. Along the lines of Caillaud and Jullien, fee differences can offset market size effects to produce coexistence. Along the lines of Ellison and Fudenberg, market impact effects can offset scale effects to produce coexistence. Equation (1) highlights the interaction of these two possibilities—the outside inequalities represent market impact effects while the center inequality represents the fee difference effect.

One might worry that interior equilibria arising in this model are “knife-edge” in the sense that any small perturbation in agent strategies leads to tipping. This is not the case. Generically, when a coexisting or interior equilibrium exists, it is a

strict Nash equilibrium, i.e., equation (1) holds with strict inequality for a dense set of parameter values. In the experiments, we choose parameter values such that any interior equilibrium is strict.

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

While 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 can be 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. While the theory model is static, platform competition in practice is dynamic. Individuals repeatedly choose on which platform to locate, so a platform’s market share can change over time. To gain some insight about what kind of outcomes the markets settle to in such a dynamic environment, we had the same set of individuals repeatedly interact in choosing platforms.

In total, 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 including reading instructions and paying subjects. 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, consisting of 15 periods.⁶ 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*.⁷ During each period, players in a market simultaneously chose which of two platforms, named “firm %” and “firm #,” to locate on. 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 re-matched 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 all but four sessions, subjects of a given type were homogeneous in the sense that all subjects were given the same gross payoff matrices and access fees. In sessions with heterogeneous subjects (sessions 23 to 28), the two subjects of a given type faced different sets of access fees to the platforms. The Appendix provides the instructions used in one of the sessions and payoff matrices used in all the sessions.

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

⁶In “Homogeneous” sessions, sets consisted of 10 periods.

⁷“Homogeneous-Large” and “Cloned Platform” sessions followed the same procedure but had eight-person markets with four players of each type.

these sessions are to test whether markets always tip in experimental illustrations of the discussed model. In subsequent experiments, conducted in February and March of 2009, we depart from the model to investigate if we can identify any settings in which our experimental markets converge to coexisting equilibrium. For expositional purpose, we only describe treatments in the first set of experiment in the remainder of this section. We introduce the second group experiments (sessions 21 to 26) in Section 5.

Treatments

Within each session, sets alternated as No Tip (**N**) or Tip (**T**). While tipping to either platform were Nash equilibria 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) while the other half began with a **T** set (referred to as a **TNTN** session). We opted for a within-subjects design for two reasons. First, this design allows for session level controls while varying the treatments. Second, compared to a between-subjects design, which would have repeated the same treatment 60 times, we felt varying the payoffs would lead subjects to be more attentive to the game.

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 the paper, where *B* denotes the platform with the cheaper access fee. We describe each treatment in detail in Section 4 below. The results of these treatments led us to run subsequent experiments conducted in 2009. Those are described in detail in Section 5.

Treatment	Number of Players in a Market	Number of Sessions	Cheap Heuristic Prediction	Risk Dominance Prediction	Pareto Dominance Prediction
Homogeneous	4	6	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>
Homogeneous-Large	8	2	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>
Differentiated	4	4	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>
Differentiated-Cheap	4	4	Tip to Platform <i>B</i>	Tip to Platform <i>A</i>	Tip to Platform <i>A</i>
Differentiated-RD	4	4	Tip to Platform <i>B</i>	Tip to Platform <i>B</i>	Tip to Platform <i>A</i>

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 where firms are not horizontally differentiated or are not identical in terms of both their matching technologies and access fees. Our two main findings are:

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 the 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), as well as 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 $u_i(n_1, n_2) = u_j(n_1, n_2)$ 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.

Homogeneous Although we are mostly interested in the market level results, we start by looking at entire sessions first.⁸ 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.⁹

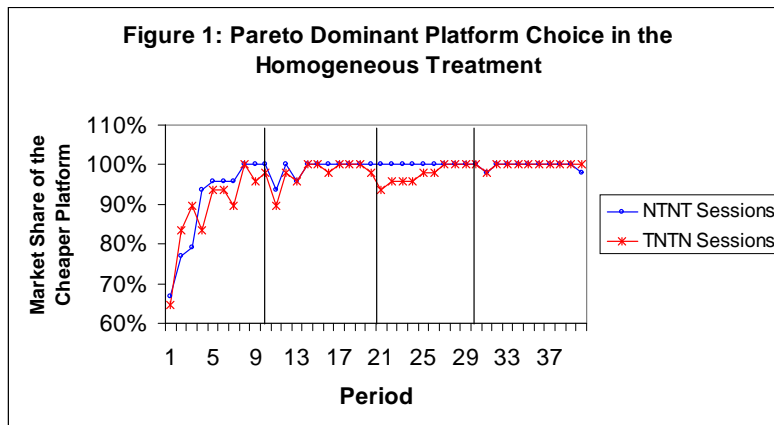
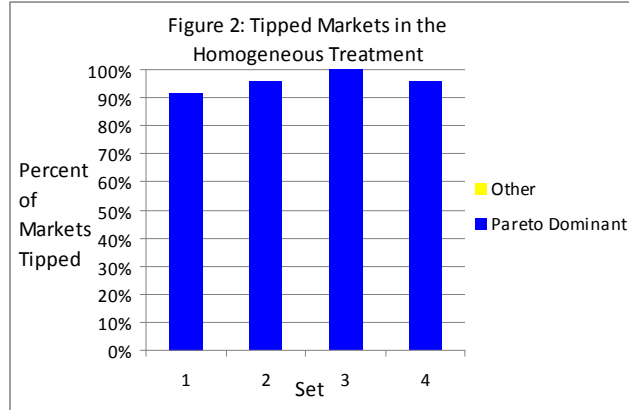


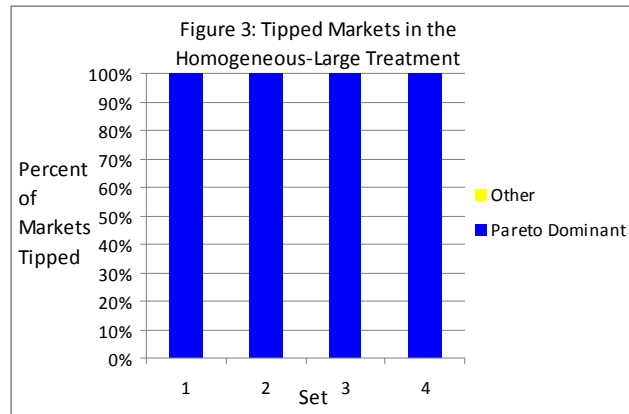
Figure 2 displays the fraction of all markets that tipped by the end of each 10-period set, as well as to where they tipped. We say that a market has tipped to a particular platform by the end of a set if *all subjects* in that market choose that specific platform in each of the last three periods of that set. Since we ran six sessions with four markets per session, each of the bars in the figure represents twenty-four 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 non-tipped equilibrium had virtually no effect on behavior. First, there were only three markets where tipping did not occur, and two of these were in Tip (**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 next set of treatments complicates the coordination problem by doubling the size of the market.

⁸Recall that, four separate markets operated at the same time in each session.

⁹This is more formally confirmed by individual level regressions available from the authors upon request.



Homogeneous-Large For these 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. Since the session-wise dynamics of platform choice are similar to the homogeneous treatment, we only present market-level behavior in the last three periods of each set. Figure 3 reproduces the analysis of Figure 2 for the Homogeneous-Large treatment and shows that every market tipped to the cheaper platform. This was not due to extending set length—even by the 10th period, all markets had tipped. Once again, the non-tipping treatment had no effect.



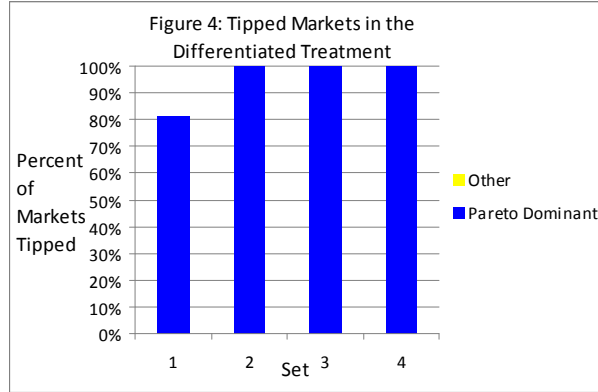
We were surprised to find the markets reaching the Pareto dominant outcome as quickly as in the Homogeneous treatment, if not faster, when we increased the size of each market. This suggests that ease of coordination in smaller markets was not driving tipping. Of course, one might argue tipping occurred because of the focality

of the “better” platform in the homogeneous case. When platforms differ in their 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

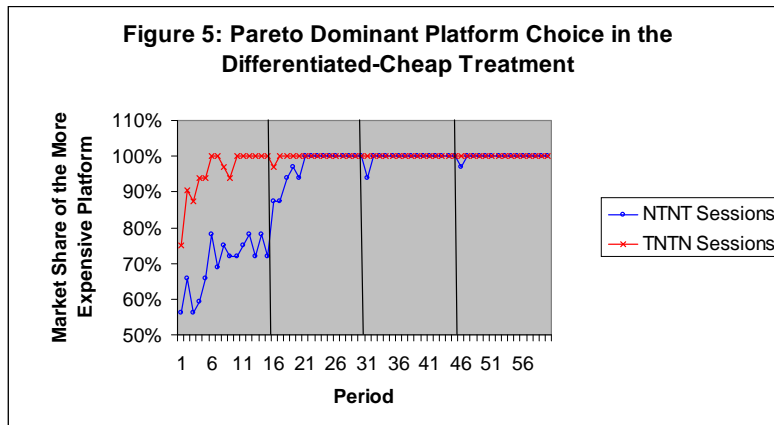
When a given number of own and other type agents receive different gross payoffs for the two platforms, we say that platforms are differentiated. A simple way in which this might occur is if one platform had a superior matching technology to the other. We model this by choosing payoffs such that $u_A(n_1, n_2) > u_B(n_1, n_2)$ 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.

Differentiated As shown in Table 1, the market tipping to the cheaper platform B is still both a Pareto and risk dominant equilibrium in this treatment. Figure 4 shows subjects overwhelmingly chose the more efficient platform B . Nevertheless, adding the quality dimension to platform competition slowed convergence, at least initially. After the first set, only 81% of markets converged compared with 94-100% convergence when platforms are homogeneous. From the second set onwards, 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.



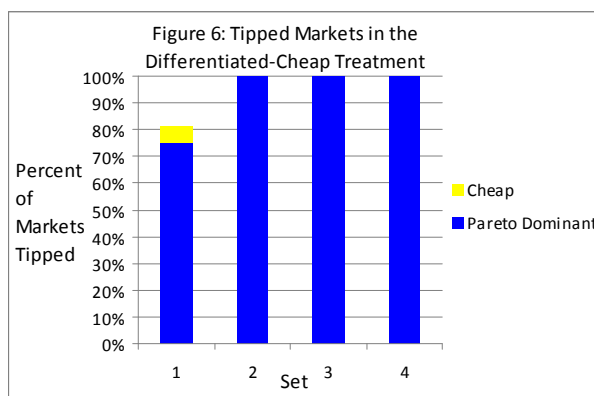
While we have been interpreting the results of the experiments as supporting the Pareto or risk dominant predictions with strategic players, the data is also consistent with non-strategic players who merely locate on the platform with the cheaper access fee. Our next section seeks to distinguish between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

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 market tipping to the *more* expensive platform is the Pareto dominant equilibrium.



The session-wise dynamics for this treatment are shown in Figure 5. Interestingly, in the first set of the **NTNT** sessions, around 75% of subjects chose the Pareto

dominant platform giving the overall market a “non-tipped” look. It is, however, instructive to examine each of the 4-player “markets” separately, as shown in Figure 6. In the first set, we find 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 two onwards, however, 100% of markets tipped to the Pareto dominant, but more expensive, platform. Interestingly, 3 out of the 4 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.

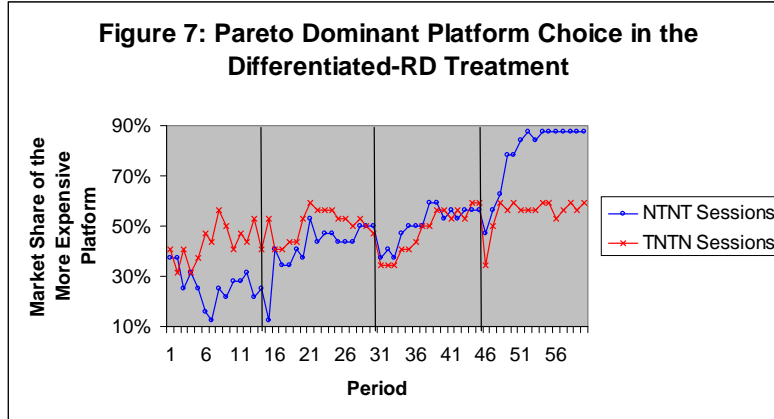


None of the treatments offered so far have the flavor of “stag hunt” type games—the Pareto prediction corresponds exactly to the risk dominant prediction. Both theory and experiments suggest that when these two predictions diverge, the risk dominant prediction often prevails.¹⁰ The next set of sessions seeks to differentiate between these two predictions.

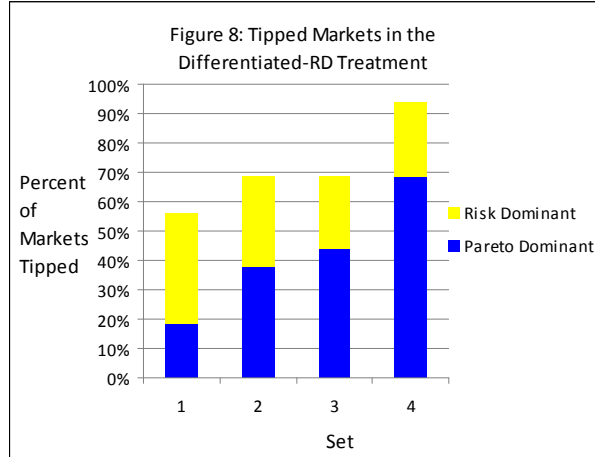
Differentiated-Risk Dominant A simple way to separate the Pareto and risk dominant predictions without disturbing the rest of the structure of the game is to increase the “upside” from mistakes on the Pareto inferior platform. To operationalize this, we simply change a single (off equilibrium) payoff cell to increase the market size effect for this platform. Since the risk dominance prediction is influenced by

¹⁰For example, see van Huyck, Battalio and Beil (1990) and Young (1993).

payoffs from mistakes while 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, while tipping to the cheaper platform is the risk dominant equilibrium.



The results are much more nuanced in this treatment. The session-wise dynamics, as seen in Figure 7, do not suggest convergence. 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 4-player markets separately in Figure 8, 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 Pareto dominant platform. By set four, 92% 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 the sessions. 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 four. In other words, there is modest statistical support that Pareto dominance is a better predictor of (experienced) market tipping behavior.

5 Is Tipping Inevitable?

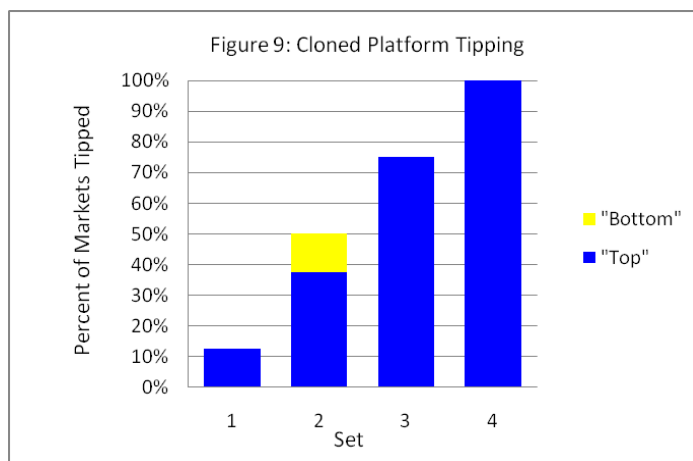
Our previous results suggest that tipping is an inevitable consequence of platform competition. Regardless of whether markets are large or small, whether platforms are homogeneous or vertically differentiated, or whether there is a coexisting equilibrium or not, platform competition eventually gave way 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.

Cloned Platforms Let us return to the homogeneous platforms. As we saw, 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. Since the platforms are symmetric, one might speculate that the outcome would be symmetric as well—each platform would enjoy 50% market share.

To examine this possibility, we ran two additional sessions of our homogeneous-large treatment in February 2009, but with *identical* access fees. When platforms are homogeneous and access fees identical, both platforms having equal market share always comprises an interior equilibrium. For the erstwhile “T” treatment, this is the only interior equilibrium while under the “N” treatment, unequal market shares also comprise interior equilibria. Since 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, while, in the other, platform “%” is on top.

Our results may be easily summarized: Despite the existence of multiple interior equilibria, markets never converged to these outcomes. Instead, most markets tipped. As subjects gained experience, they learned to coordinate on whichever platform was displayed on the top of the screen. Figure 9 illustrates the pattern of tipping.



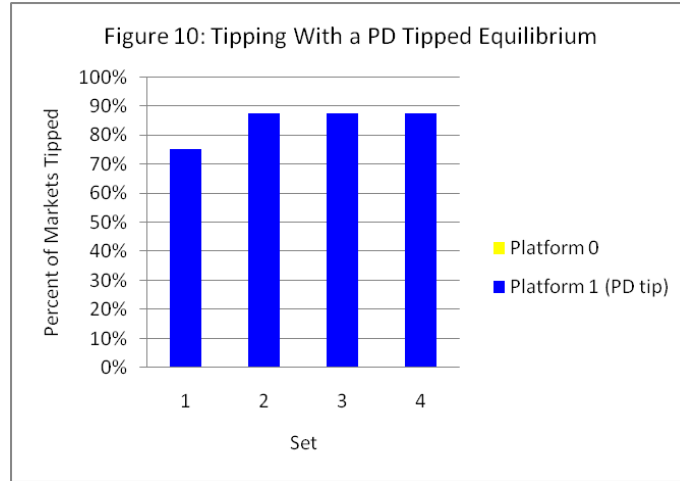
To summarize, when platforms are homogeneous, even when the focalty of a Pareto dominant platform is removed, markets still tend to tip. Subjects coordinate on other features of the game to select the *winning* platform.

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. Similarly, ChristianMingle.com specializes in matching committed heterosexual Christian singles.

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 4 additional experimental sessions with 16 subjects in each session in March, 2009. 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 #, while 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.

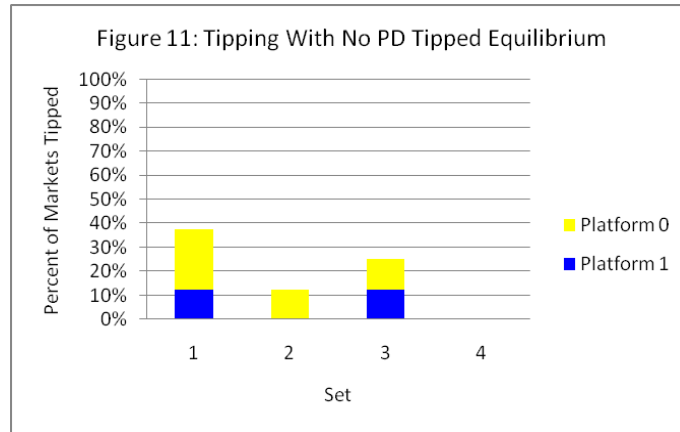
We chose parameters such that two interior equilibria, in addition to the tipped equilibria, always existed. In one such equilibrium, each agent goes to the platform where she gets a discount. In the other coexisting equilibrium, each agent goes to the platform that is more expensive for her. Moreover, in half 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.



To begin, we examine the impact of horizontal differentiation when there is a Pareto dominant tipped equilibrium. That is, the discounts players receive for their preferred platform do not dominate payoff difference between platforms on the vertical dimension. Figure 10 displays the results. As the figure makes clear, 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), while in sets 2-4, seven of eight converged. Below, we will account for the non-tipping markets.

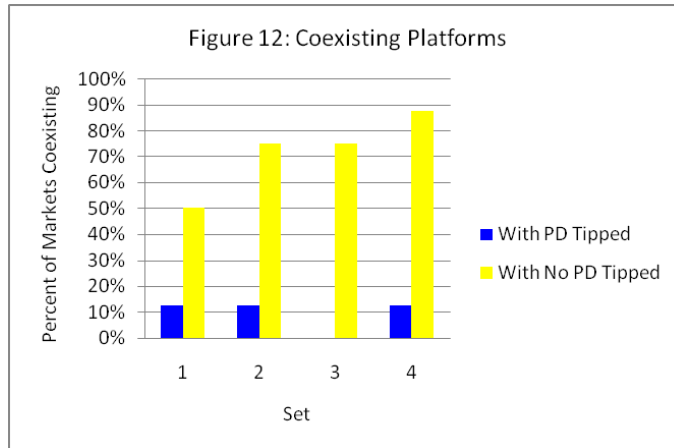
If we increase the degree of horizontal differentiation to the point where it dominates the vertical differentiation, this leads to a situation in which neither platform is universally preferred. Figure 11 below displays the results for this treatment. While tipping was the norm in Figure 10, it is the exception in Figure 11. Strikingly, by the fourth set, none of the markets tipped. When the horizontal differentiation dominates vertical differences, the tipped equilibria lose much of their attractive power.



What happened when markets did not tip? One possibility, suggested by the results above under the Differentiated-RD treatment, is that these markets simply never converged at all. Another possibility is that they converged to one of the two coexisting equilibria. Figure 12 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 of these converged to this coexisting equilibrium while 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.¹¹ Analyzing this figure together with Figures 10 and 11, our final result emerges:

Finding 3. Markets predominantly converge to a coexisting equilibrium only when platforms are sufficiently horizontally differentiated, so that there is no Pareto dominant platform.

¹¹None of the markets ever converged to the coexisting equilibrium where each agent goes to the platform that is more expensive for her.



6 Discussion and Conclusion

Despite network effects that would seem to favor coordination on a single platform, in many markets, multiple platforms coexist. Recent theory models rationalize coexistence by appealing to two forces that restrain consolidation: fee differences between platforms and market impact effects. When these forces are large, they are sufficient to offset the scale benefits to a user joining the larger platform, thus allowing different size platforms to coexist. When these forces are small, however, network effects dominate and equilibrium predicts that the market will tip to a single platform. We investigated this explanation for coexistence using laboratory experiments. Our main treatment was to vary the strength of these forces, thus turning on and off the presence of an interior equilibrium.

When platforms were undifferentiated or vertically differentiated, markets *never* converged to an interior equilibrium regardless of the size of these forces. Instead, the overwhelming majority of markets tipped to a single platform. Thus, even when coexistence was theoretically possible, it was a poor description of 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. This is true in our experiments as well.

While tipping to the inferior platform was theoretically possible, it too was a poor description of market behavior. In our experiments, outcomes where users got locked into the inferior platform were fairly rare and typically remedied over time. Indeed, the market *never* tipped to the inferior platform when the more efficient platform was also less risky. 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.

Our results shed light 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.

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 since coordination is easier. At the same time, however, small markets might also bias the results in favor of coexistence since 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, undergraduates are not all that dissimilar to a typical platform user. Undergraduates are large consumers of video gaming consoles, online auctions, online dating sites, and search engines.

In our experiments, platforms compete on an even playing field—neither platform enjoys the first-mover advantage of an existing base of users. QWERTY effects are often attributed to a first-mover advantage enjoyed by the inferior platform. In the situation of pure vertical differentiation, we showed in a companion paper (see Hossain and Morgan, 2009) that our conclusions are substantially unaltered by introducing first-mover advantage: Even if the inferior platform enjoys a monopoly at the start of the game, the introduction of competition still quickly leads to tipping to efficient platform. One common feature of many two-sided markets that we do not explore is the issue of multi-homing, which we plan to tackle in the future.

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A Appendix

Proof of Lemma 1

Proof. Suppose in an equilibrium n_1 triangle agents and n_2 square agents with $n_1 > n_2$ locate on platform A . For the agents of triangle type in platform A not to have an incentive to deviate requires

$$\begin{aligned} u_A(n_1, n_2) - p_A &\geq u_B(N - n_1 + 1, N - n_2) - p_B \\ \Rightarrow u_A(n_1, n_2) - u_B(N - n_1 + 1, N - n_2) &\geq p_A - p_B. \end{aligned} \quad (2)$$

Since $n_1 > n_2$, it then follows that

$$u_A(n_1, n_2) \leq u_A(n_2 + 1, n_2) < u_A(n_2 + 1, n_1) \quad (3)$$

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

$$u_B(N - n_1 + 1, N - n_2) \geq u_B(N - n_2, N - n_2) > u_B(N - n_2, N - n_1). \quad (4)$$

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

Therefore, combining equations (3) and (4), we have that

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

Then, using equation (2), we obtain

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

which may be rewritten as

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

But this implies that a square type agent located on platform B can profit from unilaterally deviating to platform A . This is a contradiction; therefore $n_1 = n_2$ in any equilibrium.

Proof of Proposition 1 ■

Proof. 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 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. ■

Proof of Proposition 2

Proof. 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,

$$u_A(n, n) - p_A < u_A(N, N) - p_A$$

and since 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 . Since this exhausts the set of equilibria, Pareto dominance always selects a unique equilibrium—tipping to platform i . ■

A Sample Instruction Sheet from a Homogeneous *NTNT* Session

Name: _____

Student ID: _____

Instructions

General Rules

This session is part of an experiment in the economics of decision making. If you follow the instructions carefully and make good decisions, you can earn a considerable amount of money. You will be paid in private and in cash at the end of the session.

There are sixteen people in this room who are participating in this session. They have all been recruited in the same way as you and are reading the same instructions as you are for the first time. It is important that you do not talk to any of the other participants in the room until the session is over.

The session will consist of 40 periods, in each of which you can earn points. At the end of the experiment you will be paid based on your total point earnings from all 40 periods. Each point is worth 50 cents. Thus, if you earn y points from the experiment then your total income will be HKD $y/2$. Notice that the more points you earn, the more cash you will receive.

Description of a Period

At the start of period 1, you will be randomly matched with exactly three other subjects in the room and will be designated as either a square or a triangle player. You and these three others form a “market” consisting of exactly two triangle players and two square players. During periods 1 through 10 you will be playing with the same three other people and retain the same type (square or triangle). At the start of period 11, you will be randomly matched with three other people in the room and randomly designated the types square or triangle and will play in a new market. The same thing will happen at the start of periods 21 and 31. Thus, the people with whom you are participating will change every ten periods and your type may also change.

In each period, you will decide between joining either one of two competing firms (labeled “firm %” and “firm #”). If you join firm #, you pay a subscription fee of 4 points and if you join the firm %, you pay a subscription fee of 2 points. The three other players in your market will also individually decide on which firm to join at the same time as you. On your screen, click on the firm (% or #) that you want to join. After you click “OK,” a new box will pop up to confirm that you are certain about your choice. If you want to stay with your choice, please click “yes” and click “no” otherwise. If you click “no,” you will go back to the initial box that allows you to choose one of the firms. When all the players in the market have made their decisions, you will learn your payoffs.

At the end of the period, for each firm, you will learn the number of players of each type that joined that firm in that period. Your net payoff depends on the numbers of players of each type in the firm that you join as well as that firm's subscription fee. Once you join a firm, before paying the subscription fee, in rounds 1-10, you will earn a gross payoff according to Table 1. The two columns present your gross payoffs when the number of players of your type (including yourself) in the firm you choose is 1 and 2 respectively. The three rows present your gross payoffs when the number of players of your opposite type in the firm you choose is 0, 1 or 2 respectively. You will be able to see the table on your screen during these periods.

Table 1. Gross payoffs before paying the subscription fee in periods 1-10 and 21-30

		Number of players of your own type (including yourself) in the firm you joined	
		1	2
Number of players of the opposite type in the firm you joined	0	5	5
	1	9	6
	2	12	11

The subscription fee is 2 points for firm % and 4 points for firm #. At the end of the period, you will see your net payoff (your gross payoff minus your firm's subscription fee) in points from that period. At the end of every 10 periods, you will see your net payoffs from all previous periods.

Differences between periods

At the start of period 11, your payoffs will change. Specifically, in rounds 11-20, you will earn gross payoffs (before paying the subscription fee) according to the following table:

Table 2. Gross payoffs before paying the subscription fee in periods 11-20 and 31-40

		Number of players of your own type (including yourself) in the firm you joined	
		1	2
Number of players of the opposite type in the firm you joined	0	5	5
	1	9	8
	2	12	11

Once again, you will be able to see the table on your screen during these periods. Also, remember that the subscription fee is 2 points for firm % and 4 points for firm #.

The payoffs in periods 21-30 are calculated in the same way as in periods 1-10 using Table 1. The payoffs in periods 31-40 are calculated in the same way as in periods 11-20 using Table 2.

Ending the session

At the end of period 40, you will see a screen displaying your total earnings for the experiment. Recall that, if you earn y points in total from the experiment, your total income from the experiment would be $\text{HKD } y/2$. You will be paid this amount in cash.

Payoff Matrices for Other Settings

For the remaining four settings, we present the gross payoffs for both **N** and **T** games using one table for conciseness. With differentiated platforms, the entry (u_A, u_B) lists the payoffs from platforms *A* and *B* respectively. For the outcomes where the gross payoffs are different for the two games, we present the **T** game payoffs inside parentheses.

Gross Payoffs for the *Homogeneous-Large* Treatment

The platform subscription fees were $p_A = 6$ and $p_B = 2$ in this treatment.

		Number of players of the player's own type			
		1	2	3	4
Number of players of the opposite type	0	7	7	7	7
	1	11	10	7 [9]	7 [8]
	2	13	12	7 [11]	7 [10]
	3	15	14	13	10 [12]
	4	17	16	15	14

Gross Payoffs for the *Differentiated* Treatment

The platform subscription fees were $p_A = 5$ and $p_B = 2$ in this treatment.

		Number of players of the player's own type	
		1	2
Number of players of the opposite type	0	(6, 3)	(6, 3)
	1	(10, 9)	(7 [9], 6 [8])
	2	(13, 12)	(12, 11)

Gross Payoffs for *Differentiated-Cheap* and *Differentiated-RD* Treatments

The platform subscription fees were $p_A = 3$ and $p_B = 2$ in these treatments.

		Number of players of the player's own type	
		1	2
Number of players of the opposite type	0	(4, 4)	(4, 4)
	1	(11, 8)	(8 [10], 6)
	2	(13, 11)	(12, 10)

For both **N** and **T** games, the gross payoff equals 22 for a player who is the only one of her type to choose platform *B* while both players of the other type choose platform *B* in the Differentiated-RD treatment instead of 11 as in the Differentiated-Cheap treatment.

Gross Payoffs for the *Cloned Platforms* Treatment

We used the same gross payoff matrices as in the *Homogeneous-Large* Treatment in this treatment. However, the platform subscription fees were $p_A = p_B = 2$.

Gross Payoffs for the *Horizontal Differentiation* Treatment

The platform subscription fees were: for one pair of square and triangle players, $p_A = 5$ and $p_B = 2$ and for the other pair of square and triangle players, $p_A = 3$ and $p_B = 4$.

		Number of players of the player's own type	
		1	2
Number of players of the opposite type	0	(6, 5)	(6, 5)
	1	(10[11], 9[10])	(7[8], 6[7])
	2	(16[13], 12)	(15[12], 11)

With the payoffs not inside the square brackets, the market tipping to platform A is the Pareto dominant equilibrium. With the payoffs inside the square brackets, none of the equilibria is Pareto dominant. Specifically, the coexisting equilibrium where a player goes to her preferred platform is not Pareto dominated by any other platform.