Market Entry with Frictional Matching and Bargaining: An Experimental Study

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Abstract

This paper studies an experimental labor market that incorporates elements from the standard theory of equilibrium unemployment. Specifically, we test in a controlled lab setting a novel market entry game that includes matching frictions and wage bargaining. The model predicts that firms will enter up to the point at which stochastic rationing of workers equalizes the value of a vacancy with its costs. Between treatments, we vary productivity and bargaining strength. Consistent with theory, we find that increases in productivity increase job creation and thereby reduce unemployment. We also reproduce the expected outcomes associated with different forms of wage negotiation. When wages are determined by bargaining after match, firms face a hold-up problem. As a consequence, job creation collapses when workers have excessive bargaining power. In contrast, when wages are determined prior to entry, workers moderate their wage claims to induce vacancy creation. Although our findings tend to align with theory, we observe some deviations. In particular, there is a systematic bias in the aggregate level of entry: There is too much vacancy creation when productivity is low and too little vacancy creation when productivity is high. To explain this bias and to account for heterogeneity at the individual level, we estimate a quantal response equilibrium in which we allow for idiosyncratic preferences for entry.

Keywords: market entry, bargaining, search, labor economics, experiment

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1 Introduction

In this study, we investigate an experimental labor market that incorporates firm entry, frictional matching, and wage bargaining. The purpose of this study is to scrutinize in a controlled laboratory environment some of the main assumptions that underpin standard labor market search models.[1] In particular, we test components of the Diamond-Mortensen-Pissarides (DMP) model of equilibrium employment. Our experiment thus has a macroeconomic motivation.[2] Although the model we take to the lab is simple, it enables us to confront participants with an environment that closely matches theory. The principle research question we address is how vacancy creation varies in response to changes in productivity and the structure of wage bargaining. We also investigate a set of subsidiary research questions that relate to individual behavior when trade is mediated by a frictional process and negotiated via bargaining.

A key feature of trade in the labor market is that it is decentralized and uncoordinated. Because jobs and workers are heterogeneous, firms must invest resources to identify and recruit suitable candidates. A tractable way of representing these search frictions is via the use of a *matching function*. This modelling device is at the core of the Diamond-Mortensen-Pissarides model of equilibrium unemployment (Pissarides 2000). The matching function gives a number jobs formed as a function of the number of job vacancies and the number of unemployed workers. Matching is frictional because the jobs are allocated randomly among the searching agents. This may be thought of as an urn-ball process in which applications correspond to balls and vacancies as jobs. Agents of a given type thus impose congestion externalities on each other and labor market participants face risk due to stochastic rationing that depends on market tightness. In particular, when the number of firms increases relative to the number of workers, matching probabilities for firms decrease.

Another characteristic of trade in the labor market is the presence of employment contracting. For production to take place, employers and potential employees must negotiate a wage. Because it is time-consuming and costly to recruit workers, good matches will be associated with a productive surplus. Trade in the labor market can thus be conceptualized as a two-stage process in which jobs and workers are randomly matched together in the first stage and then make a wage agreement that divides a match surplus in the second stage.[3] Search equilibrium of this type will typically be inefficient as the costs of market participation are sunk prior to matching.[4]

We incorporate matching frictions and wage contracting into a market entry game that can be implemented in the lab. Market entry games are an established class of binary choice games that have received considerable attention in the theoretical, econometric, and experimental literature.[5] Our game extends this literature to the labor market context. Specifically, the model that we take to the lab has the following structure: In the first stage, firms make a decision about whether to invest in vacancy creation and thereby participate in the labor market. In the second stage of the game, vacancies are randomly matched with workers according to a constant returns to scale matching function.[6] And, in the the third stage, matched firm-worker pairs divide a match surplus via a wage agreement. This game captures the notion that when considering whether to open a job vacancy, firms must anticipate the ease with which workers can be recruited and at what wage costs.

The essential prediction of the model is that firms will enter up to the point at which stochastic rationing

[1] The use of the lab to study the labor market is well established. See Charness and Kuhn (2011) and Falk and Fehr (2003) for overviews of this approach.

[2] For discussion of how experimental economics can be used to understand macroeconomic markets see Noussair et al. (1995). Duffy (2008) provides a comprehensive review of the experimental macroeconomics literatures.

[3] Random matching should be contrasted with *directed* (or competitive) search in which firms commit to wages and and workers observe the wages prior to sending applications.

[4] Efficiency in random search models follows from the *Hosios condition*. Essentially, this condition relates bargaining power of firms to the sensitivity of the matching function to the presence of more firms. In contrast to models of random search, models of directed/competitive search tend to be efficient (Moen 1997).

[5] An early game-theoretic description of market entry is provided by Selten and Güth (1982). Rapoport and Seale (2008) summarize some of the main experimental tests of market entry games in a handbook chapter.

[6] Most of the experimental literature on labor market search focuses on directed search (See Helland et al. 2017, for a study that organizes the experimental results in this area).

of workers equalizes the value of a vacancy with its costs. Just as in the Diamond-Mortensen-Pissarides model, a zero-profit condition determines the degree of vacancy creation. In terms of comparative statics, the model predicts that when hiring becomes more valuable, more firms can profitably compete for workers. Other factors equal, job creation will increase when productivity increases or when wages are lower. Because of matching frictions, there will be unemployment in equilibrium even when the equilibrium is efficient.[7]

The tension in this game is the coordination problem associated with entry. Although the zero-profit condition pins down a level of vacancy creation, it does not identify which subset of firms should enter the labor market. Firms thus face strategic uncertainty that is not resolved by theory and beliefs are critical.[8] This highlights a crucial difference between the small market setting we investigate and the assumption of atomistic agents made in most macro models. In the large market setting, the decision of an individual firm will not matter for the matching probability.[9] Although matching is stochastic at the individual level, a fixed proportion of firms are matched. In contrast, in the small market setting there is a coordination problem. Because the small market setting is an empirically relevant case, we are interested to know if the zero-profit assumption still holds.

Our treatment variables are the size of the match surplus and the wage contracting institution. The design of the experiment aims to cleanly identify the effect of each. At the beginning of each session, subjects were assigned either the firm role or the worker role. Subjects remained in this role throughout the duration of the experiment. Every session consisted of 30 repetitions of the game. Between each play of the game, subjects were re-matched within a block into new markets comprised of 6 firm players and 4 worker players. The goal of re-matching was to represent in a lab setting an anonymous macro labor market. This contrasts with most experimental tests of market entry games in which tacit coordination and equilibrium selection is the primary interest.

Our first four treatments comprise a 2×2 design in which we vary the level of productivity and the presence or absence of wage bargaining after matching. In the absence of bargaining, the entry decision is a choice between a fixed payment and a binary lottery with a prize equal to half of a match surplus. In the presence of bargaining, firms are randomly matched with workers and participate in an ultimatum bargaining stage in which the proposer is determined by a fair coin. These four treatments enable us to identify the effect of productivity and bargaining on entry. In the fifth treatment, we examine ultimatum bargaining after matching but let the worker propose. This tests the sub-game structure of the model. The prediction for this treatment is that vacancy creation collapses because firms get expropriated whenever they negotiate with a worker.

In the sixth treatment, we make a substantial change to the bargaining institution. At the beginning of each round, a wage proposal is elicited from each worker and a group wage is computed as the average of these independent proposals. The group wage is then advertised to the firms prior to the entry decision. This treatment gives workers the opportunity to induce entry by moderating their wage demand. To make this treatment as clean as possible, the group wage binds for all wage negotiations.

We make contributions to three distinct literatures. The first is the literature on labor market search. Our study is the first to take elements of the Diamond-Mortensen-Pissarides model to the laboratory. This tests the behavioral assumptions of the model. This is difficult to achieve by other means. The second contribution is to the literature on market entry games. We test whether frictional matching and bargaining alter the basic findings in the literature. Our results tend to reinforce the existing stylized facts. The third contribution is to the experimental literature on bargaining. We are the first to test whether the presence of entry prior to bargaining affects bargaining outcomes. We also test a novel multilateral bargaining game.

Our foremost finding is that the aggregate outcomes respond to changes in the environment in the fashion

[7] There are only a handful of studies that produce unemployment in the lab. one example is Fehr, Kirchsteiger, et al. (1996). In this study, they test the shirking model of unemployment in which unemployment is a by-product of efficiency wages. A motivation for this study is the fact that the search and matching framework has supplanted the shirking model as the basic way to understand unemployment.

[8] Strategic uncertainty may be characterized as "uncertainty concerning the actions and beliefs (and beliefs about the beliefs) of others" (Morris and Shin 2002).

[9] Notice that if all firms enter with probability p then the standard deviation of the matching probability goes to 0 at a rate of $1/\sqrt{N}$ as the number of firms N increases to infinity.

anticipated by theory. When productivity increases, test subjects create more vacancies. This generates an inverse relationship between vacancies and unemployment—an experimental equivalent of the Beveridge curve. We also find that the allocation of bargaining power affects vacancy creation via its effect on the expected value of a hire. Notably, when workers have more bargaining power, it generates high unemployment because firms cannot recoup the resources they invest in vacancy creation.

Nevertheless, we do not reproduce the exact predictions of the model. There is too little entry when productivity is high and too much entry when productivity is low. This appears to be a systematic bias. As a consequence, the zero-profit condition does not hold—even on average—and persistent arbitrage opportunities exist. To give this a macroeconomic interpretation, the experimentally observed elasticity of unemployment with respect to productivity is smaller than anticipated. This is notable because it is contrary to the pattern observed in macroeconomic data but in line with results from other market entry games.[10]

Given the additional complications and dynamics that we introduce in our labor market entry game, the consistency of our results with the general findings in the market entry literature is remarkable. Although one might have expected the risk introduced by frictional matching and bargaining to reduce entry, this effect is small if it even exists. A possible explanation is that the reduction in the entry frequency of an individual player creates an opportunity for another player to profitably enter. Our findings support the conclusion from the literature that market entry games are a robust environment that create strong incentives for entry.

Our bargaining results also deliver new findings. In the treatments with ultimatum bargaining, we find that offers tend to be lower and much more tightly distributed than in most of the literature. Bargaining offers also do not vary (in absolute terms) across treatments despite changes in the level of productivity and bargaining strength. Contrary to our expectation, workers do not appear to reward firms for entry. The modal offer is just slightly in excess of the direct costs of vacancy creation. We also show in a dramatic fashion that the offers are consistent with individual payoff maximization. Because workers have no way of internalizing the negative effect of high wage claims, vacancy creation collapses when workers have proposal power.

When we provide an institution by which workers commit to a group wage claim, the results are starkly different. In this environment, workers moderate their wage demands to induce entry by firms. Efficiency is restored because workers internalize the effect that their wage claims have on entry. A fascinating finding is that the distribution of individual wage proposals is roughly tri-modal with peaks at zero, half, and the entire surplus. Individuals appear to make offers strategically to move the group wage claim in the direction they prefer. This treatment demonstrates that labor organizations and centralized bargaining can have an efficiency enhancing effect by creating the preconditions for job creation. This treatment also suggests that the low offers associated with bargaining after match are a by-product of individual incentives rather than the outcome of a heuristic sharing rule.

In an attempt to reconcile our data to a model of behavior, we estimate a quantal response equilibrium (QRE) for our entry game. This approach is motivated by the observation that in a symmetric QRE the entry probabilities are closer to 0.5 than the Nash prediction. This can help explain the bias in the entry frequencies. However, a symmetric QRE cannot account for the heterogeneity that we observe at the individual level. In particular, there are a substantial number of individuals who enter in all periods. To account for both the aggregate bias and the individual pattern of entry, we therefore estimate a heterogeneous QRE in which we allow idiosyncratic subject-level preferences for entry. This helps account for some—though not all—of the variation in the data. This exercise suggests that aggregate biases can survive in environments with noise. This may be important beyond the lab.

The paper is organized as follows. In the next section, we provide context for this study and situate this study in the literature. After this background, we present the model that we test in the lab. This section includes the equilibrium analysis of each treatment and the associated predictions. In the third section, we go through the design and review the procedures. The fourth section presents the results and analysis of the results. The last section concludes.

[10]This behavioral finding makes the Shimer critique perhaps even more puzzling.

2 Background and Related Literature

2.1 The Standard Search and Matching Model of the Labor Market

Our study is motivated by the Diamond-Mortensen-Pissarides (DMP) model (Pissarides 2000). The DMP model is the workhorse model of the aggregate labor market because it is theoretically appealing and useful in empirical applications. Crucially, the model accounts for how fluctuations in productivity affect vacancy creation and thereby determine the level of unemployment. The DMP thus predicts movements in labor market variables over the business cycle.

Despite its successes, the DMP model exhibits some limitations. In his famous critique, Shimer (2005) shows that the standard calibration of the DMP model under-predicts volatility in the vacancy-unemployment ratio by more than an order of magnitude. The DMP model also struggles to account for certain empirical patterns. For instance, observed shifts in the Beveridge curve seem to imply adverse developments in matching efficiency (Elsby et al. 2015).

These shortcomings have stimulated research in a number of directions. One response to the quantitative limitations of the DMP models has been to propose alternative calibrations (Hagedorn and Manovskii 2008). Another approach has been to reexamine the theory, including reassessment of the free entry condition, the nature of wage determination, and the microfoundations of the search process. See, for example, Moen and Rosen (2006) who show how private information can increase the response of unemployment to changes in productivity.

We make a modest contribution to this literature. Although the DMP model addresses market level outcomes, an understanding of individual decision-making can help explain patterns in the aggregate data. The lab enables us to perform a clear test of how individuals behave when faced with the incentives from the model.[11] Specifically, we expose test subjects to reduced form matching frictions and directly test the no-profit condition. Our study thus lends credibility to the behavioral premises of the model. Comparable evidence is difficult to collect by other means. One issue is the availability of relevant data.[12] Another issue is the difficulty associated with identification.[13]

2.2 Market Entry

The model that we take to the lab is a version of a market entry game. Market entry games are a class of N-player binary choice games in which symmetric players simultaneously decide to either "enter" or to "stay out" (Selten and Güth 1982; Gary-Bobo 1990).[14] In this class of games, the payoff $\pi(v)$ is non-increasing in the number of entrants v and the payoff X from staying out is fixed. This environment is animated by the assumption that there exists some *market capacity* C such that $\pi(C) - X \geq 0$ but $\pi(C+1) - X < 0$.[15] Because any configuration of C total entrants is an equilibrium, these games are characterized by a large number of pure strategy Nash. There is also a symmetric mixed strategy equilibrium.[16] This creates a coordination problem. In the absence of a coordinating institution, agents face strategic uncertainty: The decision to enter is predicated on beliefs about the entry behavior of other players.

Market entry games are well known from industrial organization. For example, $\pi(v)$ might represents profits associated with Cournot competition between v firms and X a sunk cost associated with operation. If few firms choose to operate, profits are above the competitive level. However, if many firms produce, the

[11] Given the model is only an approximation to reality, what we are ultimately interested in is how well the assumptions represent real outcomes. An assumption is that findings inherit credibility from consistency with how individuals actually behave.

[12] Even data on aggregates such as vacancies and unemployment pose challenges (Elsby et al. 2015).

[13] For a discussion of identification challenges and other issues in the econometric studies of market entry and market structure see Toivanen and Waterson (2000) and Berry and Reiss (2007).

[14] This literature is part of the broader literature on coordination games (Ochs 1990; Cooper et al. 1990; Van Huyck et al. 1991; Cooper 1999).

[15] Minimally, we require that $\pi(F) - X < 0 < \pi(1) - X$, where F is the total number of participants.

[16] Other, "asymmetric equilibria," are also possible.

market is oversupplied and *ex post* firms would have preferred to stay out.[17]

Market entry games have attracted substantial attention from experimental economists and been examined in many variations.[18] One variation has been with respect to the payoff structure. Another has been whether the market capacity is constant or fluctuating. A third variation has been with respect to the matching protocols.

The basic finding in this literature is that test subjects manage to coordinate in such a way that profits from entry are nearly equalized with the outside option (Ochs 1990; Rapoport, Seale, Erev, et al. 1998; Sundali et al. 1995; Morgan, Orzen, Sefton, and Sisak 2012). This is despite the absence of any organizing institution or possibility of communication.[19] The high degree of coordination has even been described as "magic" (Kahneman 1988; Erev and Rapoport 1998).

Although the stylized fact of a high degree of coordination is well-established, at least one systematic bias has been identified. When the market capacity is low, there tends to be excessive entry while the opposite tends to holds when market capacity is high (Rapoport, Seale, and Ordóñez 2002; Goeree and Holt 2000; Morgan, Orzen, and Sefton 2012). We find evidence of the same bias in our study.[20] In addition, individual behavior is heterogeneous and inconsistent with mixed strategy play at the individual level (Duffy and Hopkins 2005; Erev and Rapoport 1998). Zwick and Rapoport (2002) identify four "clusters" of subjects that employ distinct strategies. Of the four groups, the largest is a group of players exhibiting "sequential dependencies" (i.e. the experienced history of "successes" or "failures") that is inconsistent with any model of randomization. Our data also mirror this finding.

The study most closely aligned with the present work is Rapoport, Seale, and Ordóñez (2002). Rapoport, Seale, and Ordóñez (2002) also investigate market entry under uncertainty. In their study, players who enter the market participate in a lottery for which the probability of winning depends on the number of entrants. This is comparable to the matching stage in our game. Although our studies differ in most other respects, our study corroborates their main finding that coordination is good on the aggregate level but not necessarily at the individual level. In terms of theory, Anderson and Engers (2007) develop results that are useful for understanding strategic uncertainty in market entry games. Although they study a specific and extreme game—the "blonde game" in which payoffs are zero for all entrants if there is more than one—their results generalize in a natural way to our setting.

A second strand in the literature that is relevant to the present study is the set of studies in which participants participate in a second stage after market entry. Examples include Camerer and Lovallo (1999) and Morgan, Orzen, and Sefton (2012). In the study by Camerer and Lovallo (1999), there is a skill-based tournament after entry, while in Morgan, Orzen, and Sefton (2012) test subjects make an investment decision. This introduces a subgame dimension that is important for the entry decision. Players must anticipate outcomes in the second stage when considering an entry decision in the first stage. Notably, the findings in these studies are similar to our own. This includes the finding of an aggregate bias in the entry frequencies.

2.3 Bargaining in the Lab

Wage negotiations are an important dimension of our experiment and our findings substantially extend the experimental literature on bargaining. To the best of our knowledge no previous study has embedded ultimatum bargaining in an entry context.[21] We also contribute results from a new multilateral bargaining game.

When wage bargaining occurs after matching, the environment we investigate has features that are reminiscent of the investment "trust" game with the firm in the sender role and the workers in the receiver

[17] There exist some econometric studies that attempt to structurally estimate discrete choice market entry games using field data (Bresnahan and Reiss 1990; Ciliberto and Tamer 2009).

[18] Section A.1 presents an example of the most common linear specification of payoffs.

[19] See Andersson and Holm (2010) for a study that incorporates communication.

[20] In appendix section , we present the findings from Sundali et al. (1995). This study illustrates in a clear way the main stylized facts frm the literature.

[21] This is surprising given that ultimatum bargaining has been examined in endless variations.

role.[22] The parallel is particularly strong in the treatment in which workers have all the bargaining power. When a firm invests in vacancy creation and is matched with a worker, the match surplus exceeds the firm's outside option—matching with a worker thus "scales up" the investment. On the other side of the market, workers do not earn anything in the absence of vacancy creation. In a similar fashion to the investment game, workers may therefore want to reward firms for vacancy creation by accepting low wages and this, in turn, may induce firms to create job openings.[23]

Despite the qualitative parallels to the trust game, however, our results do not align with the findings from that literature. Workers do not provide firms with any additional compensation. One reason may be the public good quality of the wage level. When a worker sets a low wage, the positive effect this has on vacancy creation is shared among all the workers. In an individual transaction, however, a worker receives all the benefits of a high wage. The temptation to set a high wage may be especially acute when matching is infrequent. Another reason that investments in vacancy creation are not strongly reciprocated may be because this is not viewed as an investment in a particular worker and therefore not the basis for gift-exchange.

Another aspect of our model that is not present in most other studies is that participants must take an active decision to participate in bargaining. The selection effect might explain why offers in our study tend to be lower than in most of the literature.

The study also contributes a new bargaining structure. The treatment in which workers negotiate a group wage claim prior to firm entry does not have a close analog in the literature. This intra-worker bargaining dramatically tests the ability of test participants to trade-off the benefit of a low wage with the benefit from a higher matching probability. An important aspect of this bargaining institution is that only a few sophisticated types are required to generate an optimal outcome. If naive workers propose super-optimally high wages, sophisticated workers can propose sub-optimal wages such that the average proposal maximizes expected earnings.

3 Model and Treatments

3.1 Model

In all treatments, the labor market entry game we investigate has the following basic structure:

0. Before the beginning of the game, players are assigned one of two roles, either *firm* or *worker*. Throughout, we refer to players in the firm role as firms and players in the worker role as workers. We refer to the set of players participating in the game as a *market*.

1. **Vacancy Creation**: In the first stage, F firms decide independently whether or not to participate in a frictional labor market. Firms that choose to participate pay a *search cost* X to open a vacancy. [24] We refer to this as a decision to *enter* the labor market and we refer to firms in the labor market as *entrants*. We denote the total number entrants by v. This indicates the number of job vacancies. Firms that do not participate in the labor market forgo the search cost and earn X.

   U unemployed workers participate in the labor market automatically and are passive at the entry stage.[25]

[22] The basic trust game was proposed by Berg et al. (1995). In this game, a "sender" invests some portion of an endowment with a "receiver." This investment is then scaled up by a factor larger than 1. In the last stage, the receiver can return some portion of the scaled-up investment to the sender. For a comprehensive overview of findings in such games see that meta-analysis by Johnson and Mislin (2011). Contrary to standard theory, the basic finding is a high level of investment by the sender and a high level of return by the receiver.

[23] The key differences with the trust game are, however, that the setting is multilateral and the investment decision is binary.

[24] The search cost can be thought of as including the direct costs as search as well as the opportunity cost of unused capital. For a discussion of a magnitude of these costs see Hagedorn and Manovskii (2008). In the absence of opening a job, the cost X could be invested in some other opportunity.

[25] To focus on the firm decision, we do not incorporate features such as an unemployment benefit.

2. **Matching**: In the second stage, vacancies and unemployed workers are matched into M pairs via a constants returns to scale matching technology. Constant returns to scale is the standard and empirically relevant specification of the matching function in the labor market context (Petrongolo and Pissarides 2001). This matching function takes as inputs the number of vacancies v and the number of unemployed U such that the expected number of matches M equals

$$M(U, v) = AU^{\alpha}v^{1-\alpha}. \tag{1}$$

Given the number of matches, the matching probabilities follow directly from the number of participants on each side of the market. This implies matching probabilities for firms of

$$\frac{M(U, v)}{v} = A\frac{U^{\alpha}v^{1-\alpha}}{v} = A(\theta)^{\alpha} = q(\theta)$$

where $\theta = \frac{v}{U}$ is the the number of vacancies per workers. We refer to θ as the *market tightness*. The matching probability for firms is declining in the number of entrants though convex.[26] This captures the notion that when additional firms compete for workers, the labor market becomes more congested.[27] Because workers do not make an entry decision, all matching uncertainty relates to the decisions of other firms.[28]

3. **Wage Bargaining**: After matching, matched firms and workers negotiate a wage w to divide a *production (match) surplus* Y. For shorthand, we refer to Y as the *productivity.* If a firm and worker reach an agreement, a job is created, the firm earns $Y - w$, and the worker earns w. If they fail to reach an agreement, both parties earn zero.

   Throughout, we let η denote the (expected) share of the surplus that the firm can appropriate if the firm hires. We interpret η as the bargaining strength of the firm. The expected wage payment is therefore $w = (1 - \eta)Y$. In the treatments with bargaining the η in practice will be endogenous.

With this notation, the *ex ante* expected payoff for firm f when $v - 1$ other create vacancies is therefore

$$\mathbb{E}[\pi_f] = \begin{cases} X & \text{if } f \text{ doesn't enter} \\ q(\theta)(Y - w) & \text{if } f \text{ and } v - 1 \text{ other firms enter.} \end{cases} \tag{2}$$

Even in the absence of uncertainty about the number of (other) entrants, firm f faces stochastic risk because of the matching function: With a probability $1 - q(\theta)$ the firm remains unmatched and earns zero. In addition, firms face bargaining risk in some treatments.

For a given level of Y and w, the *market capacity* C is the maximum number of firms such that

$$q\left(\frac{C}{U}\right)(Y - w) \geq X \quad \text{and } q\left(\frac{C+1}{U}\right)(Y - w) < X. \tag{3}$$

In the benchmark analysis of the game, we assume that firms maximize expected earnings and that bargaining outcomes are described by η such that $Y - w = \eta Y$. For these assumptions, the labor market entry game has a similar set of equilibria as the basic market entry game: A set of pure strategy Nash in which a subset of players choose to enter while the remaining choose to stay out; a set of mixed strategy Nash in which a subset of the players use pure strategies while the rest randomize; and a unique mixed strategy Nash in which all players randomize with the same probability p^*.[29] The pure strategy Nash equilibria are defined by the market capacity since any of the $\binom{N}{C}$ combinations of C entrants exhausts the expected profits in the market. However, we expect the symmetric mixed strategy to be the most relevant model of behavior

[26] Section B.1 in the appendix shows the shape of the matching function and the associated matching probabilities for firms.

[27] The equivalent probability for workers is computed in the analogous fashion and denoted by $\mu(\theta)$. This function increases in v, meaning that more entrants increase the matching probability for workers.

[28] It could be worthwhile in future work to extend the experiment to include an entry margin for workers.

[29] It may also be possible to construct genuinely asymmetric equilibria in which players randomize with different probabilities.

in our experiment because we randomly rematch players into markets in each period. We address this design choice further in the next section 4. The goal is to try to simulate a series of one-shot interactions. This means that individuals have no direct way of coordination and decisions are predicated on beliefs. If we think of this as an ϵ uncertainty about the decisions of other agents, then a purification argument suggests that symmetric randomization is the relevant equilibrium.

In this characterization of the market entry game, the mixing probability for the symmetric mixed strategy with homogenous firms must satisfy the *zero-profit* condition

$$\sum_{v=0}^{F-1} \binom{F-1}{v} (p^*)^v (1-p^*)^{F-v-1} q\left(\frac{U}{v}\right) \eta Y = X \tag{4}$$

This condition says that if $N-1$ players randomize their entry decision according to the probability p^* then the N^{th} player will be indifferent between entry and taking the outside option.[30] Condition 4 says that in the mixed strategy Nash any excess profits associated with entry will be dissipated by competition. While it is not possible to solve for p^* analytically due to the non-linearity introduced by the matching function, it is straightforward to solve equation 4 numerically.[31]

Condition 4 has obvious comparative statics. For a given p, an increase in Y or η increases the left-hand side of 4. p^* must increase correspondingly to maintain the equality in response to any such change.

3.2 Treatments

In all treatments, a market is comprised of $F = 6$ firms and $U = 4$ workers. Throughout, we fix the search cost $X = 95$ and use a simple parametrization of the matching function: $A = \frac{1}{2}$ and $\alpha = \frac{1}{2}$. Table 1 summarizes the matching outcomes associated with each level of entry for the specifications used in our study. With this specification of the matching function, an equal split of the production surplus is approximately efficient in the sense of maximizing total surplus in the market, $M(U, v)Y + (F - v)X$ (that is, the sum of payoffs for both firms and workers). The basic efficiency results are located in the appendix, subsection B.2.

Table 1: Matches and Matching Probabilities

v	U	$M(U,V)$	$q(\theta)$
0	4	0	·
1	4	1	1.00
2	4	1.41	0.71
3	4	1.73	0.58
4	4	2	0.50
5	4	2.24	0.44
6	4	2.45	0.41

In terms of the framework presented in the previous subsection 3.1, our treatments can be thought of as varying the productivity Y and the bargaining strength η. We conduct six treatments in total. We label the treatments by B^Y where $B = \{M, N, W, G\}$ denotes the form of wage determination and $Y = \{h, l\}$

[30] Existence and uniqueness (in the class of symmetric strategies) of the mixed strategy equilibrium, as well as efficiency results follow, with minor modifications, from Anderson and Engers 2007.

[31] In the study by Rapoport, Seale, and Ordóñez (2002) the probability of winning the lottery is linear in the number of entrants, $p = \frac{F-v}{F}$. This is tractable because the binomial sum can be manipulated in a straightforward fashion to get an analytic expression for p^*. However, this specification does not correspond with any reasonable matching function since the expected number of matches declines when the number of entrants gets sufficiently large. To see this, note that the expected number of firm matches is pv. This implies a number of matches $v - \frac{v^2}{F}$ for the linear matching case—a concave function of the number of entrants.

denotes the surplus, $Y = 400$ high (h) and $Y = 300$ low (l). The first two treatments M^h and M^l focus on matching (M) frictions. The second two treatments N^h and N^l add "neutral" (N) ultimatum bargaining into the frictional matching setting. In last two treatments we examine variations in the wage contracting institution. The workers get to propose in W^h and the workers as a group (G) commit to a group wage in G^h .

3.2.1 Treatments M^h and M^l : Matching Frictions (M)

M^h and M^l examine the impact of frictional matching on market entry in the absence of bargaining. This represents a situation in which wages are set prior to vacancy creation. It also be thought of as a way to exogenously enforce Nash bargaining with bargaining weight η. These two treatments provide a baseline to which the other treatments can be compared.

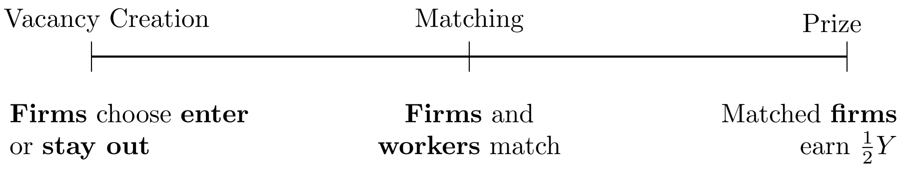


Figure 1: Treatments M^h and M^l

Figure 1 shows the structure of treatments M^h and M^l . In the first stage, firms choose to either take the outside payment X or to participate in a binary matching lottery. Firms that choose to participate in the lottery either win a prize ηY with probability $q(\theta)$ or earn zero with a complementary probability. This represents matching with a worker and paying wage $w = (1 - \eta)Y$. Although the prize is fixed, the probability of winning declines as additional firms enter because of matching frictions. Intuitively, this is because more vacancies compete for the same number of workers.

Firms in this treatment face strategic uncertainty associated with the entry of other firms but no risk associated with bargaining. These two treatments are comparable to the standard market entry game except the payoff from entry is a stochastic rather than deterministic function of the number of other entrants. The model examined in these treatments also can be thought of as a reexamination of the setting of Rapoport, Seale, and Ordóñez (2002) except the probability of winning is a non-linear rather than linear function of the number of entrants.

We fix $\eta = \frac{1}{2}$ in both treatments. Between treatments, we vary the level of the productive surplus. In M^h , $Y = 400$ such that the lottery prize is $\eta Y = 200$ and the market capacity is $C = 4$; in M^l , $Y = 300$ such that the lottery prize is $\eta Y = 150$ and the market capacity is $C = 2$. For these productivities, the symmetric Nash equilibrium identified by equation 4 predicts an entry frequency of $p^*_{T1} = 0.73$ in treatment M^h and $p^*_{T2} = 0.37$ in treatment M^l .

3.2.2 Treatments N^h and N^l : Neutral Bargaining after Match (N)

In treatments N^h and N^l , we extend the first two treatments by including a "neutral" bargaining stage. These treatments describe a situation in which firms open vacancies knowing that once a suitable worker is identified, a wage must be negotiated.

As in the first two treatments, firms in the first stage choose to either take the outside payment X or to participate in a binary lottery in which firms get matched with a worker ("win a prize") with probability $q(\theta)$. However, in contrast to the first two treatments, the prize is not a fixed payment but the opportunity to bargain over a production surplus Y. $Y = 400$ in N^h and $Y = 300$ in N^l . The timing is shown in figure 2.

We implement the bargaining stage as ultimatum bargaining in which the proposer is determined by a fair coin flip. This means that in half of instances, the firm gets to propose the wage and, in half of instances, the worker gets to propose the wage. We therefore refer to this as neutral bargaining. Because X is a sunk

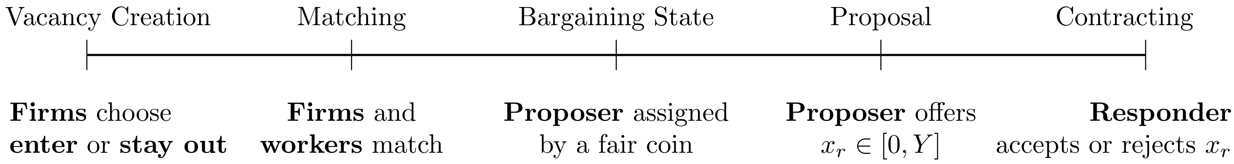


Figure 2: Treatments N^h and N^l

cost, the outside option of both firms and workers is 0. Firms and workers are therefore symmetric at the bargaining stage. This captures a situation in which the firm and the worker have roughly equal bargaining power. This protocol is an attempt to endogenously represent Nash Bargaining from the DMP model with bargaining weight η

Regardless of the proposer's type (firm or worker), let $x_r \in [0, Y]$ denote the offer extended to the responder. If the responder accepts the offer, the proposer earns $Y - x_r$ and the responder gets x_r.[32] If the responder rejects the offer, both the proposer and the responder earn zero.

The standard prediction from economic theory is that the proposer in an ultimatum games will extract all the surplus. That is, the proposer will offer $x_r = 0$ (or $x_r = \epsilon$) and keep Y. The expected payoff in the bargaining stage is therefore to appropriate the entire surplus half of the time and expect to earn $\frac{1}{2}Y$. This means $\eta = \frac{1}{2}$, just as in treatments M^h and M^l . Moreover, the conclusion that $\eta = 0.5$ holds as long as the sharing norm is consistent: If the proposer always gets a share $\gamma \in [0, 1]$ of the surplus and the responder always gets the complementary share $1 - \gamma$, the expected earnings will be $\frac{1}{2}\gamma Y + \frac{1}{2}(1 - \gamma)Y = \frac{1}{2}Y$. In terms of expected earnings, treatments N^h and N^l are therefore strategically equivalent in expected earnings to treatments M^h and M^l , with the same predictions for entry and entry probabilities.

Note that in these treatments, the bargaining stage is "decoupled" from the entry decision because the firm gets to propose half of the time. This initial test of a market entry game with post-match bargaining thus introduces post-match bargaining in a fashion that should have minimal consequences for entry.

3.2.3 Treatments W^h : Worker Wage Demand after Match (W)

Treatment W^h is identical to treatment N^h but with a single change to the bargaining stage. Instead of a random draw determining the proposer, workers always get to make the wage claim (see figure 3).

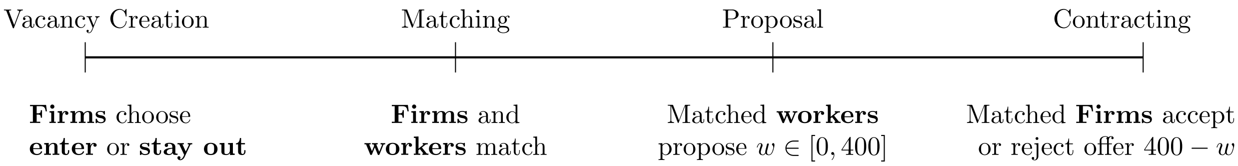


Figure 3: Treatment W^h

Taking the standard model as the baseline, the proposer appropriates all the surplus. Workers will therefore demand high wages whenever bargaining takes place. This means that the expected share of the productive surplus that accrues to the firm is $\eta = 0$. This yields a stark prediction. Because bargaining takes place after matching, firms face a hold-up problem: Firms can not recover their investment in vacancy creation at the bargaining stage. Anticipating this, firms will choose to not open vacancies. In contrast to N^h and N^l , in W^h the entry decision depends intimately on the bargaining outcome.

When bargaining takes place after matching, allocating all the bargaining power to the workers generates complete unemployment. Relative to treatment N^h , many productive opportunities will not be exploited and efficiency will be low. The inefficiency in treatment W^h arises because workers have no mechanism by

[32] If the firm proposes, the wage is $w = x_r$ while if the worker proposes, the wage is $w = Y - x_r$.

which they can limit their individual demands. Individual-level bargaining does not include the effect that high wage demands place on the jobs available to other workers.

3.2.4 Treatments G^h : Group Wage Demand prior to Entry (G)

In contrast, in G^h we investigate an environment in which workers commit to a group wage prior to firm entry. This treatment incentives workers to set a wage that maximizes the expected *ex ante* payoffs and thereby creates the maximum surplus for workers. We can think of this as centralized wage formation with similarities to corporatism.[33] We assume that a labor organization negotiates a binding wage based on the negoatiation amongst the members.

In the first stage of G^h , each worker i makes a wage proposal w_i. These wages are then averaged into a group wage claim $\bar{w} = \frac{1}{U}\sum_{i=1}^{U} w_i$. Bargaining thus occurs among the workers. The group wage claim $\bar{w}$ is then advertised to firms prior to the entry decision. From the perspective of firms, G^h is comparable to M^h in the sense that the decision to open a vacancy amounts to the choice between a fixed payment and a lottery with price $Y - \bar{w}$. The structure of G^h is shown in figure 4.

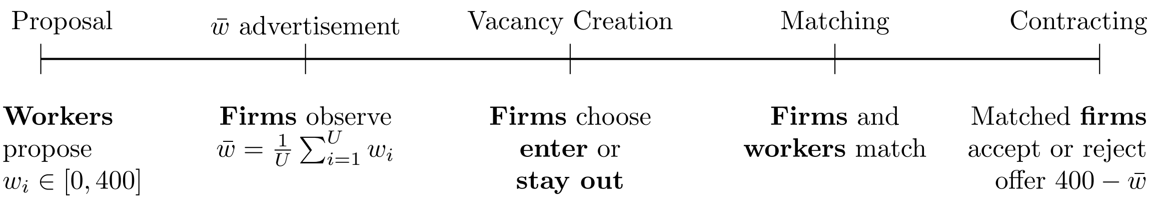


Figure 4: Treatment G^h

Because workers commit to a wage prior to vacancy creation, workers can influence the matching probability by moderating their wage claim. Specifically, we expect workers to set a wage $\bar{w}$ to induce the entry probability $\tilde{p}$ that maximizes the expected payoff

$$\sum_{v=0}^{F} \binom{F}{v} (\tilde{p})^v (1-\tilde{p})^{F-v} \mu(\theta)\bar{w} \tag{5}$$

where $\tilde{p}$ is determined from the no-profit condition (equation 4) and $\mu(\theta) = M(U, v)/U$ is the matching probability for workers. Workers set wages to induce vacancy creation up to the point at which the increase in the probability of getting hired is equalized with the cost of lower wages. Solving this problem exactly must be done numerically (we use MatLab). For $Y = 400$, the payoff maximizing group claim is $\bar{w} = 207$ with associated entry probability of $\tilde{p} = 0.78$. This means that $\eta = 0.52$. Of course, in practice, workers also must take into account the eagerness of firms to enter. The question is therefore whether workers are able to arrive at an optimal wages level via some process of experimentation and introspection. Because $\eta = 0.52$ is just slightly in excess of of η in M^h and N^h , we therefore similar results as in these treatments.

Although workers in G^h have all the bargaining power—just as in treatment W^h —treatment G^h predicts that wages will be lower, vacancy creation will be higher, and unemployment will be lower. This treatment anticipates that institutions such as unions can be efficiency enhancing because they enable workers to internalize the negative externalities associated with bargaining after match (See Layard et al. 2005, chapter 2).

4 Design

Our treatment variables are the size of the match surplus and wage contracting institution. The design of the experiment aims to cleanly assess the effect of each of these factors. We employ a conservative approach

[33]See Layard et al. (2005) for a more comprehensive discussion of the merits of centralized versus firm-level wage bargaining.

and the identification of the main treatment effects relies on non-parametric comparisons of independent block level outcomes. Credibility of our findings is enhanced because the tests are sufficiently powerful (List et al. 2011).[34]

In the framework of the previous section, the key parameters can be thought of as Y and η, where η is exogenous in M^h and M^l but is endogenous to the bargaining outcomes in treatments N^h –G^h .[35] Table 2 gathers the theoretical predictions for each treatment worked out in the previous section. The main comparisons are between the level of productivity (reading across table 2) and how wages are determined (reading down table 2).

Table 2: Treatments Summary

		$Y = 400$				$Y = 300$		
		C	p	η		C	p	η
Matching	M^h	4	0.73	0.50	M^l	2	0.38	0.50
Fair	N^h	4	0.73	0.50	N^l	2	0.38	0.50
Worker	W^h	0	0.00	0.00				
Group	G^h	4	0.78	0.52				

The predictions in table 2 are derived from the standard model in which agents maximize payoffs, do not make mistakes, hold correct beliefs etc. As we know from other existing evidence, many of these assumptions are questionable. The goal of the experiment is to investigate the extent to which the environment reproduces the equilibrium predictions even though reality does not coincide exactly with the model.

Our first four treatments, M^h -N^l , comprise a 2×2 design in which we examine productivity and post-match bargaining. The 2×2 format facilitates a comparative statics assessment of the effect of productivity and if there are effects of bargaining. There is also the possibility of interactions between these two factors.

Differences in the level of productivity translate into predictions for the distribution of entrants. Given symmetric randomization according to the mixed strategy Nash, the distribution of the total number of entrants should be binomially distributed as shown in figure 5. This plot in simple a mass function and may be interpreted in the following fashion: If players are playing according to the symmetric mixed strategy equilibrium then in any given period there is a some probability of $v = 0, \ldots, N = 6$ entrants. The probability of observing v entrants is equal to the height of the associated bar. Our choice of productivity levels predicts distinct distributions in which the low productivity treatment has a right skew and the high productivity treatment has a left skew. Moreover, the modal number of entrants is different by two entrants. This provides a benchmark to which we can compare our observations.

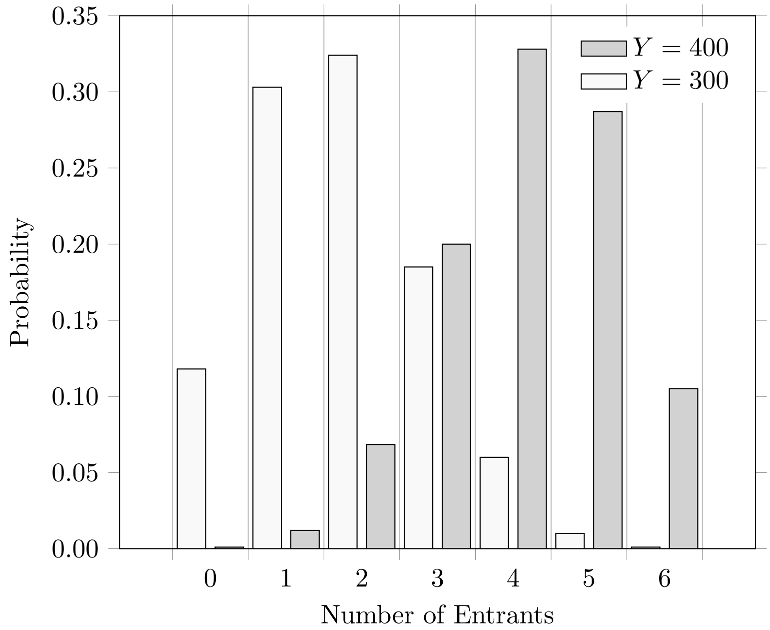
As discussed above, the ultimatum bargaining stage in N^h and N^l is specified in a neutral fashion such that all players can expect to earn half of the surplus given a symmetric sharing norm. We choose this bargaining protocol so that N^h and N^l are the mildest possible extension of M^h and M^l . This facilitates inference about the independent effect of bargaining.

There a number of reasons to expect bargaining to have an impact on entry. One reason is that bargaining exposes test subjects to an additional source of risk. This would predict lower entry. For example, risk averse subjects would prefer a guaranteed payment of half the surplus (as in M^h and M^l) rather than earning the entire surplus half of the the time (which is the prediction in N^h and N^l). Another way in which bargaining can be important is if η deviates from 0.5 due to behavioral factors. Average bargaining outcomes could vary depending on the identity of the proposer (firm or worker) or due to differences in the level of unemployment. For instance, workers may reciprocate entry by firms in similar fashion as in the trust game and allow firms to appropriate a large portion η of the surplus as a reward. High unemployment might also increase η

[34] We plan to do a final round of data collection in the spring of 2017 in which we add observations to strengthen our bargaining results.

[35] Y and η together determine the wage level.

Figure 5: Predicted Probability of Number of Entrants by Surplus



because matched workers have less leverage in bargaining. If workers endure a longer unemployment spell before again getting matched they may not be able to afford to reject low offers. This is a reason to expected differences between treatments N^h and N^l .

In treatments W^h and G^h , we introduce variations in how wages are determined. We compare these treatments with M^h and N^h which have the same level of surplus.

The first comparison, between N^h and W^h , accounts for how changes in bargaining power impact the expected payoff that firms can expect in the last stage. Specifically, we expect lower entry in W^h . Unless workers in W^h propose an equal 1/2 split of the productive surplus, the expected value of entry will be lower for firms in W^h than in N^h .[36] Anticipating this, firms will enter less frequently.

In comparison to W^h , G^h creates incentives for workers to moderate wage demands. If workers perceive how wage demands affect entry the outcomes should be dramatically than in W^h . In fact, theory predicts a "hyper fair" offer of more than 0.5. Although workers have all the bargaining power, the outcomes should be similar to N^h and M^h . The parallel with M^h is particularly strong because firms know prior to entry what they will earn if they get matched.

To try to discern the impact of bargaining outcomes, we compare the offers across types (firms compared with workers) and treatments. One clear hypothesis that can be checked is whether workers adjust their offers between N^h and W^h . Whereas in N^h firms get to propose half of the time, in W^h firms must be rewarded by workers. If there are trust game like effects, we would expect these to be larger in treatment W^h because the firms only enter if they are rewarded by workers. Treatment G^h illuminates the analysis of bargaining because workers have the chance to impact the degree of entry via the wages that they set. This tests the ability of workers to think through the incentives that they create via wages. Furthermore, wage formation in G^h is such that individual workers can affect the wage by setting extreme offers. This means that even a few sophisticated individuals can counteract inappropriately low or inappropriately high offers by making extreme wage proposals in the other direction. Difference in the wage proposals in W^h and G^h thus give some measure of how individuals response to the incentives created by bargaining after match.

Because of the entry margin, individuals who choose to participate in the bargaining stage may not be

[36]This conclusion is predicated on the plausible assumption that the sharing norm in N^h is such that the proposer is able to appropriate more of the surplus than the responder.

representative of the general population. This is a facet of our study that can result in differences relative to other studies of ultimatum bargaining.

4.1 Experimental Implementation

At the beginning of each session, subjects were assigned either the firm role or the worker role. Subjects remained in this role throughout the duration of the experiment. Each session implemented a single set of treatment parameters. For a discussion of the strengths and weaknesses of between-subject designs see Charness and Kuhn (2011). Given the novelty and complexity of our environment, we use a between-subject design to avoid confounds and establish a clear set of results. Moreover, between-subject comparisons are congruous with the realities of a marketplace in which different firms recruit different workers at different times.[37]

With respect to practical aspects of implementing the model in the laboratory, the use of matching in the lab requires that the matching technology generate an integer number of matches. This introduces a problem relative to the CRS matching function we employ which can yield fractional matches (see table 1). For instance, if five firms enter we expect 2.24 matches. This could be dealt with in various ways. We elect to enforce a "psuedo-law of large numbers": When there is a fractional match, an additional match is generated with a probability equal to the remainder. For example, if there are 2.24 matches, then there will be 2 matches in 76% of cases and 3 matches in 24% of cases. This means that given the number of entrants there be *at least* $\lfloor M(U,V) \rfloor$ matches but *no more than* $\lceil M(U,V) \rceil$ matches. This means that, on average, expected matching probabilities are correct.

A major distinction between our implementation of the market entry game and most previous work is our choice of matching protocol. Prior to each round, subjects were re-matched within a block into new markets of 6 firm players and 4 worker players. The goal of re-matching was to represent in a lab setting an anonymous macro labor market. This contrasts with most experimental tests of market entry games in which tacit coordination and equilibrium selection are the primary interest (Kahneman 1988; Sundali et al. 1995; Erev and Rapoport 1998; Rapoport, Seale, Erev, et al. 1998). Our aim is to simulate a series of independent market entry decisions and we therefore want to disrupt tacit collusion of the form that most studies hope to induce. Moreover, although we cannot induce play of a specific equilibrium, by re-matching we introduce strategic uncertainty such that test subjects must rely on beliefs about the likely level entry. In terms of implementation, the present study thus bears some similarity to studies in which the market capacity is varied from period to period. [38] Because re-matching circumscribes opportunities for coordination, we expect subjects to play as if the remaining players were randomizing symmetrically.[39] Furthermore, the only way for all players to be using best responses is for the distribution of entrants to adjust to the probability dictated by the unique mixed strategy equilibrium. If this were not the case, then an individual would have an incentive to either enter more often (arbitrage) or less often.

Given this set-up, the model and market parameters described in 4, and the levels of productivity denoted in table 2, our *ex ante* prediction is aggregate entry behavior consistent with the symmetric mixed strategy Nash equilibrium. This implies a binomial distribution over the number of entrants with a binomial

[37] If we instead interpret the model as one in which an individual firm repeatedly returns to the marketplace, a within-subject design could be appropriate to understand how firms adapt to changes in the environment over time. This could, however, introduce order effects that we wish to avoid at this initial stage.

[38] Although studies such as Sundali et al. 1995 (shown in appendix section A.1) use fixed groups, when the market capacity changes from period to period, equilibrium requires at least some players modify their strategies. This means that, by design, there is persistent strategic uncertainty. In contrast, in studies in which neither the market capacity nor the market composition are altered, the uncertainty is considerably reduced. In a notable contribution to the study of learning in games, Duffy and Hopkins 2005 show that in such an environment players should in the limit of many repetitions of the game converge to a pure strategy Nash equilibrium.

[39] If there are some players in the population who always enter while others never enter, and every period these individuals are selected randomly, then the experienced level of entry is consistent with individual randomization equal to the relative proportion of individuals who always enter. For example, if half of individuals always enter and the other half never enter, then a random draw of entrants implies that half will enter. This is equivalent to the case in which all players randomize with one half probability.

probability $p^* = 0.37$ for the low productivity treatments and $p^* = 0.73$ for the high productivity treatments. The expected distribution of entrants are shown in figure 5.

4.2 Procedures

All sessions were conducted in the research lab of the BI Norwegian Business school using participants recruited from the general student population at the BI Norwegian Business School and the University of Oslo, both located in Oslo, Norway. Recruitment and session management were handled via the *ORSEE* system (Greiner 2004). *z-Tree* was used to program and conduct the experiment (Fischbacher 2007). Anonymity of subjects was preserved throughout.

Table 3: Blocks per Treatment

Treatment	Blocks
M^h	5
M^l	4
N^h	2
N^l	2
W^h	2
G^h	2

We collected 17 block level observations, distributed among the treatments as shown in table 3. Each block consisted of 2-3 markets. In total 292 individuals participated in the experiment.

On arrival, subjects were randomly allocated to cubicles in the lab in order to break up social ties. After being seated, instructions were distributed and read aloud in order to achieve public knowledge of the rules. All instructions were phrased in neutral language. Although interested in capturing features of the labor market, we wished to avoid direct any direct connotation. For example, we did not wish to frame the bargaining portion of the experiment in such a way that it seemed important to pay a "fair" wage. We therefore referred to firms and workers players as A types and B types. For similar reasons, we described the labor market as simply a "matching market." This term conveys the essential information that A and B players will be randomly paired without implying anything about the relative status of the two types (such "boss" vs. "employee"). Another important detail of the language that we used was with respect to the description of the bargaining situation. Rather than ask the proposer to make an "offer" or to "divide the surplus," we instructed the proposer to state a *claim*: A claim was defined as an amount that the proposer gets if his or her claim is accepted. Our motivation for using this language was to avoid establishing a "property right" for the proposer. This is appropriate for the labor market context because the surplus is only realized after the firm and worker together produce.

Each session of the experiment began with two test periods in which players could get acquainted with the software. This was immediately followed by 30 periods in which the players earned payoffs. At the beginning of every round, subjects within a block were randomly matched into markets with the composition described above. Each round consisted of a single repetition of the market entry game.

Gameplay was formulated in the following fashion: In the first stage of the game, subjects in the firm role chose to either participate in the market or to take a guaranteed payment. A player who chose to take the guaranteed payment took no further actions in the game but did receive market level feedback at the same junctures as other players. After the entry stage, players received information on how many players of each type chose to enter, the number of realized matches, the matching probabilities, and whether or not they were matched. In the treatments without bargaining, players that matched earned the payoff ηY. In the other treatments, matched players were assigned either the proposer or responder role at this stage. In the ultimatum bargaining portion of the game, a screen was devoted to both the proposal decision and the responder decision. At the conclusion of the game, all players were provided with information on their own profits and a historical statistic describing previous decisions and market outcomes, along with accumulated profits.

The one exception to the basic structure was treatment G^h which featured two additional stages at the beginning of the experiment. In the first stage, wage proposals were collected from the worker types. The average of these proposals was then presented to all participants in a given market on a dedicated screen. Otherwise, the structure of the game was the same. In a similar way as the other treatments with bargaining, the proposer (workers) and responder (firms) were identified separately. In the final stage before payoffs and feedback, the responder had the right to reject the (group) wage offer. This stage was in some sense unnecessary but preserved as close as possible the experience in the treatments with ultimatum bargaining.

Subjects earned experimental currency units (ECU) based on the realized outcome in each period. After the final game, accumulated earnings in ECU were converted to Norwegian Kroner (NOK) using a fixed and publicly announced exchange rate. Subjects were paid in cash privately as they left the lab. On average subjects, earned between 220 and 250 NOK (about 36 USD at the time). A session typically lasted 60 minutes.

Sample instructions and screen shots are available upon request.[40]

5 Results

We present our findings as a series of *Results*. Unless otherwise noted, statistics and tabulations are based on data from the last half of periods. We focus on the last half of the data because there is a negative trend in the level of entry during the initial stages of some of the treatments. By comparison, behavior is more or less stable in the second half of the periods. With the exception of W^h , none of our conclusions depends in an important way on the exact selection of the data that we use.

The level of vacancy creation and the trends over time are shown in figure 6. The block level results are quite similar to the aggregated outcomes.[41] For each treatment, this plots show the average number of vacancies, a linear fit line, and the market capacity. Notice that the negative trend mostly disappears in the second half of the data.[42]

In table 4, we summarize the data on entry. The first row presents the relative frequency of entry by treatment. This is simply a relative frequency computed across all individuals. The second row shows the predicted entry frequencies associated with the symmetric mixed strategy equilibrium. The key observation is that all the observed entry frequencies are closer to 0.5 than predicted in theory. The third row presents the payoffs associated with entry. These payoffs are computed as the total earnings from entry divided by the total number of entry decisions.

Table 4: Aggregate Entry Frequencies and Associated Payoffs

Treatment	M^h	M^l	N^h	N^l	W^h	G^h
Observed	0.67	0.53	0.61	0.48	0.34	0.58
Predicted	0.73	0.37	0.73	0.37	0.00	0.78
Payoffs	99.5	81.1	107.7	82.6	69.5	92.4

Result 1 *Vacancy creation increases when the productivity of a job increases.*

The average number of vacancies varies in the expected fashion with productivity (see table 5). This pattern is evident in treatments without bargaining (3.99 in M^h and 3.17 in M^l) and those with bargaining (3.66

[40]Instructions and screen shots will made available when final data collection concludes.
[41]The same figure at the block level for the second half of periods is show in 20.
[42]This can be seen clearly in figure 21 in the appendix. This plot shows that only N^l displays any trend in the first four treatments for the last half of the data.

Figure 6: Average vacancy creation by period

in N^h and 2.88 in N^l). In addition, the maximum observation in the low surplus treatments tends to be close to the minimum observation in the high surplus treatment. This is indicative of observations that come from distinct distributions.

Table 5: Summary Statistics Vacancies

		$Y = 400$					$Y = 300$			
		Mean	Std.Dev.	Min.	Max.		Mean	Std.Dev.	Min.	Max.
Matching	M^h	4.00	0.33	3.64	4.33	M^l	3.23	0.29	2.98	3.60
Bargaining	N^h	3.66	0.20	3.51	3.80	N^l	3	0.35	2.63	3.13

To formally test the impact of productivity on vacancy creation, we employ a one-tailed Wilcoxon Rank-Sum (WSR) test at the block level.[43] These tests are carried out on the block level data presented in the appendix in table 6. The WSR test between treatments M^h and M^l yields a p-value of 0.014 with a power of 0.84.[44] The results become even stronger when we pool the high productivity treatments M^h and N^h and compare these with the low productivity treatments M^l and N^l . For this test, the p-values is 0.004 with a power of 0.99. These findings indicate that there is a systematically higher degree of entry in the high productivity treatments.

Result 2 *The presence of bargaining does not significantly reduce vacancy creation.*

[43]The Wilcoxon Rank-Sum test tests the hypothesis that two independent samples come from the same distribution.
[44]To compute power we use the Stata package developed by Bellemare et al. (2014).

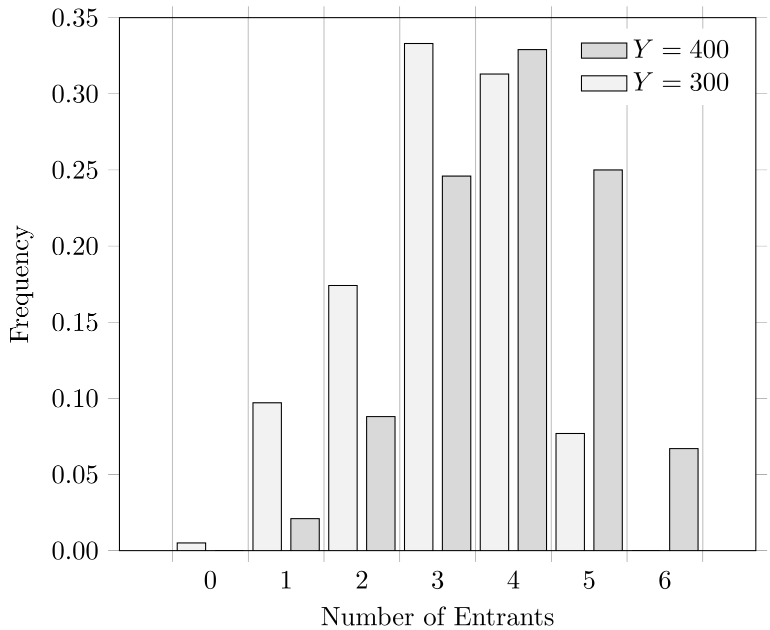
The difference between treatments M^h and N^h and between M^l and N^l is the presence of a bargaining stage. Casual inspection of the aggregate entry frequencies and the level of vacancy creation suggests that the presence of bargaining after matching may have some negative impact on firm entry. In each treatment with bargaining, the average entry is slightly depressed relative to the case without bargaining. We can not, however, substantiate this based on block-level comparisons. There is too much overlap between the distributions of observations. This can be seen in table 6 in the appendix. A Wilcoxon rank-sum test examining the impact of bargaining has a p-value 0.44. In addition, for the observed difference in entry between treatments with and without bargaining (-0.11), we would need more than a ten-fold increase in the number of observations to get sufficient power to detect an effect of this size. If the presence of bargaining has an impact on entry at the aggregate level, then we can conclude that this effect is small.

If we treat group level observations in each period as independent observations, we pass this threshold. However, this depends on the assumption that outcomes within the same block can be treated as independent observations.

Result 3 *Vacancy creation is less sensitive to productivity changes than predicted by theory.*

Although the number of vacancies created varies in the expected direction with changes to productivity, the degree of vacancy creation is too great when the productivity is low while the degree of vacancy creation is too weak when the productivity is high (see table 4). In the high productivity treatments M^l and N^l , the aggregate entry frequency is more than 10 percentage points higher than the equilibrium prediction (0.53 and 0.48 vs. 0.37). Conversely, in the low productivity treatments M^h and N^h , the aggregate entry frequency is lower than the equilibrium prediction by about the same amount (0.67 and 0.61 vs. 0.73). As a consequence the distribution of entrants is shifted right in the low surplus treatment and left in the high productivity treatments. This is evident from figure 7 which shows the relative frequency of each number of entrants in the high and low surplus cases. For example, in both the high and low surplus cases, a bit more than 30% of periods, four (out of six) firms decided to entry. For comparison, see figure 5 which predicts much less overlap between these distributions. The same figures are presented within the M and N treatments in appendix figure 22.

Figure 7: Average Number of Vacancies by Surplus



The pattern of over-entry in M^l and N^l but under-entry if M^h and N^h implies that the no-profit condition is not satisfied, even on average. Test subjects that enter in treatments M^l and N^l earn less than the outside option while test subjects that enter in treatments M^h and N^l earn more than the outside option. The quantitative effect on payoffs is shown in the bottom row of table 4. We see that in the high surplus treatments entrants earn rents from entry while in the low surplus treatments entrants earn more than 10 ECUs less than what they could have earned by taking the guaranteed payment.

The labor market interpretation of this result is that the response of vacancies to productivity is muted relative to theory. This is notable because it goes in the opposite direction of the stylized facts from the labor market but is consistent with the findings from other market entry games.

In light of the first three results, there does not seem to be a major impact of risk aversion on entry. It appears that bargaining may have a slight negative impact on entry and one can speculate that this is related to risk aversion. Mitigating our ability to draw this conclusion, a risk aversion measure collected from a Holt-Laury test conducted at the end of sessions N^h and N^l did not have any explanatory power.[45] The finding that entry is too high in the low surplus treatment also leads one to question the importance of risk aversion. While risk aversion may play some role in determining which individuals decide to enter, it does not seem to have a major explanatory power at the aggregate level. This is consistent with some previous studies in this area (Rapoport, Seale, and Ordóñez 2002).

Result 4 *Offers in ultimatum bargaining are lower and more tightly distributed than in other studies.*

1. *There is substantial coordination on a modal ultimatum bargaining offer and this offer does not vary between treatments.*

2. *The average ultimatum bargaining offer varies slightly with the level of productivity but does not depend on whether the proposer is a firm or a worker.*

3. *Workers offer slightly more generous shares to firms in W^h compared with N^h .*

In treatments N^h , N^l , and W^h there is ultimatum bargaining after matching. In N^h and N^l , the proposer is determined by a fair coin while in W^h the workers always get to propose. We present the bargaining results in terms of *offers*. An offer is the the amount that the proposer—who may be either a worker or a firm in treatments N^h and N^l —offers as a take-it-or-leave-it offer to the responder.

Figure 23 in the appendix shows the evolution of bargaining offers at the group level over time. Offers fall from a high level in the early periods but rapidly stabilize in the vicinity of 100. The initial high level of offers is likely due to a combination of learning the mechanics of bargaining—there may have been some confusion about whether a "claim" accrues to the proposer or responder—and due to the evolution of a sharing convention in which players discover that offers of 100 will be accepted but offers below this level are rejected with higher probability.

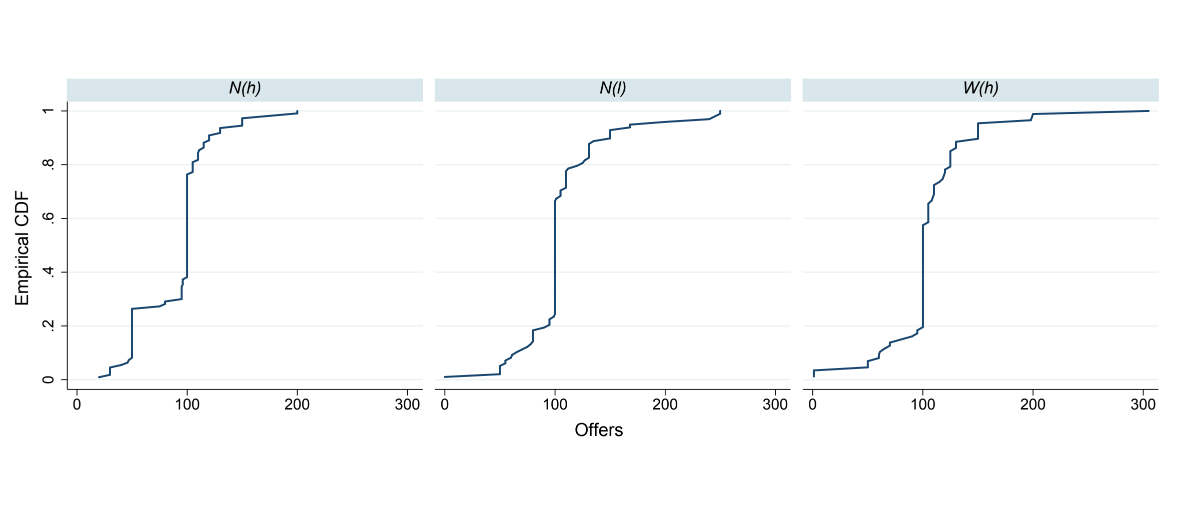
The empirical cumulative distribution functions for offers is presented in figure 8. This figure summarizes the main findings. The defining feature of these plots is the large fraction of offers at 100. This can be seen from the long vertical portion in each plot. This length of the vertical portion implies that an overwhelmingly fraction of offers were equal to 100. In N^h , 30% of offers were equal to 100 with 45% of offers 100 ± 10; in N^l the percentage was 38% with 50% $\pm$ 10; and in W^h the percentage was 32% with 39% $\pm$ 10.

In terms of the average offer, we identify a small differences between the two levels of productivity. The average offer is 98 in the high surplus treatment and 107 in the low surplus treatment. This difference is significant at the 5% level. This appears to be associated with the more common occurrence of offers of 50 in N^h which can be seen at the left hand side of the left panel in figure 8.

Whether using the modal offer or the mean offer as the main statistic, the level of offers is more or less constant in terms of absolute levels of ECUs. In terms of shares of the surplus, however, this implies that individuals in the high surplus treatment share about a quarter of the surplus while individuals in the low surplus treatment share a bit more than a third of the surplus. This contrasts with the findings from most

[45] We have reason to question the validity of our implementation of the Holt-Laury test. Only 60-70% of respondants demonstrated "reasonable" preferences.

Figure 8: Offers in Ultimatum Bargaining



studies of ultimatum bargaining. An initial hypotheses as to why bargaining shares might vary with the size of the surplus is that players are willing to accept smaller *shares* when the surplus is large. While Andersen et al. 2011 finds some support for this conjecture, it only holds for truly enormous sums. The stakes would therefore need to be much larger than those seen in this study. We therefore do not expect this to be a driving force in our results.

With respect to type, we do not find a significant difference between offers: Overall, 97 by firms compared with 104 by workers.

Consistent with the hypothesis that workers decrease their wage demands somewhat in W^h to induce entry by firms, we do find that workers offer significantly more generous shares in W^h compared with N^h (106 vs. 83 with a p-value of 0.007). This difference also does not appears to be driven by a universal sharing convention in N^h and W^h . Rather, the differences appear to be driven specifically by differences in worker behavior. This assertion follows from the observation that there is a statistical difference between firms and workers in treatment N^h : Offers of 111 by firms relative to 83 by workers, significant at the 1% level. However, even though workers moderate their wage demands slightly in W^h $\eta = 0.265$, this is only sufficient to warrant entry by a single firm.

With respect offers that get rejected, we find that the probability that offers get rejected increases steeply as the offers fall below 100.[46] Histograms showing the offers that were rejected are presented in figure 24 in the appendix. There do not appear to be any difference between types in terms of which offers were rejected.

Overall, we conclude that our findings are lower than in most studies of ultimatum bargaining but not implausible. The main difference seems to be the tight distribution of offers in the vicinity of offers of 100. Notably. this is close to 95, the direct search cost borne by firms. Worth commenting on is also the fact that the high degree of coordination on offers around 100 implies an average η close to 0.5 since a firm is equally likely to be in the proposer and responder position.

Standard results from studies of ultimatum bargaining are modal and median offers of 40-50 percent and mean offers of 30-40 percent (See Camerer 2003, Tables 2.2 and 2.3). The overall lower level of offers we find may be due to the presence of frictional matching. Individuals realize that they have limited opportunities for bargaining and therefore seek to earn as much as possible when they have the chance. We also speculate

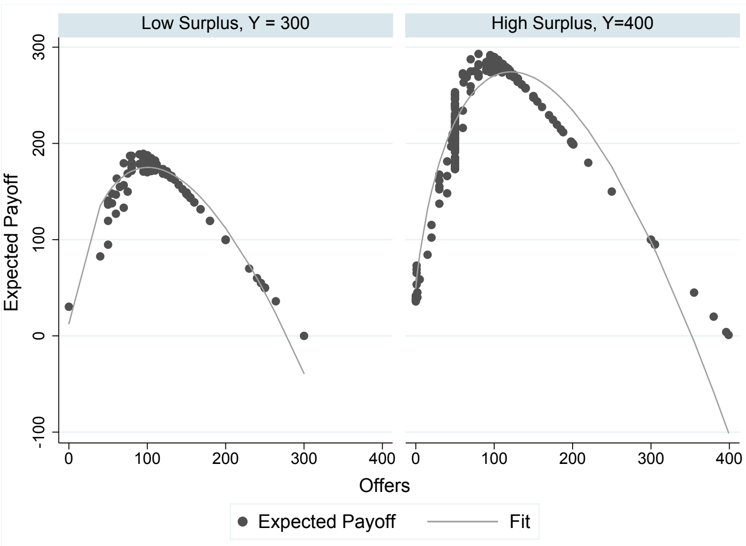
[46]The stylized facts from ultimatum bargaining is that there are few low offers and offers less than 20 percent are rejected about half the time (Camerer 2003). These outcomes are also surprisingly insensitive to the size of the stakes; the size of stakes must be increased dramatically before low offers are accepted (Andersen et al. 2011). Although generosity may result in part from fear of rejection, positive offers in dictator games suggest some role of altruism. A notable *caveat* is that combination of design features such as anonymity and earned endowments can reduce dictator offers close to zero (Cherry et al. 2002)

that the overall lower level of offers may in part be driven by the selection of firm players that choose to enter the bargaining portion of the game.

Result 5 *Wage offers in ultimatum bargaining maximize individual payoffs.*

A natural question to ask why there is coordination on offers near 100. From an empirical perspective, this question has a clear answer: Offers of 100 maximize expected payoffs. Although the standard model predicts that any non-negative offers should be accepted in ultimatum bargaining, in practice lower offers are rejected with a higher probability. The optimal bargaining offer therefore trades off the likelihood of being accepted with the value of agreement. To assess this formally, we estimate a logistic regression to yield the probability that an offer of a given size is accepted.[47] This exercise shows subjects almost never reject offers above 100 but reject offers with an increasing probability as offers fall below this level. When we weight the probability that an offer is accepted by the value that the offer is accepted, this gives the expected payoff from a given offer.

Figure 9: Expected Payoff by Offer



In figure 9, we present a plot of the expected payoff associated with each ultimatum offer along with a simple polynomial fit. This plot illustrates that expected payoffs are maximized in the vicinity of offers of 100. We conclude from this exercise that test subjects maximize their individual payoffs, taking into account what offers will be accepted.

Result 6 *Increases in the bargaining strength of workers in ultimatum bargaining increases unemployment.*

In treatment W^h , the workers always get to propose in the bargaining stage. In figure 6, we see that the average number of vacancies falls from around 4 in the first period to about 1.5 in the final period. This is due to the fact that the workers are not able to coordinate on a higher wage level and thereby induce entry. Given that the expected wage in W^h is only slightly greater than 100, the market capacity is only a single vacancy. It is in some sense remarkable that firms persist in entering as long as they do given that they sacrifice almost 25 ECUs per entry decision. Because of over-entry by firms, workers in W^h earn relatively high payoffs because workers exploit the firms who enter—higher payoffs than in N^h or N^l .

Result 7 *When workers can commit to a common wage offer, this restores efficiency.*

[47] See figure 25 in the appendix.

Treatment G^h changes the bargaining institution and allows workers as a group to commit to a wage level. In contrast to the ultimatum bargaining treatments in which offers were in the range of 100, in this treatment the average offer was 174. The expected share that workers could expect was therefore $\eta = 0.44$. This translates to a market capacity of about three firms. The substantial moderation of wage demands leads to a much higher level of entry than in the W^h . This increases earnings for workers substantially relative to N^h and somewhat relative to W^h (the with W^h is only a little more than 10 ECUs—this is due to the fact that workers in W^h have relatively high incomes.). Consistent with the analogy to M^h , no matched firms ever rejected the wage offer after choosing to enter.

Although the wage demands are substantially higher than the level that is predicted to maximize expected profits, workers in this treatment also do better than expected in theory because of moderately too much entry by firms.

Result 8 *When workers decide a group wage, there is considerable variation in beliefs about the appropriate level of the wage.*

Perhaps the most fascinating element of treatment G^h is the wage bargaining the occurs between workers. In this treatment, each worker submitted a wage proposal at the beginning of the stage. This was then advertised to the firms before the entry decision. Workers there have an incentive to set a wage that trades off increases in the probability of matching with the size of the wage.

Figure 10: Wage Proposals

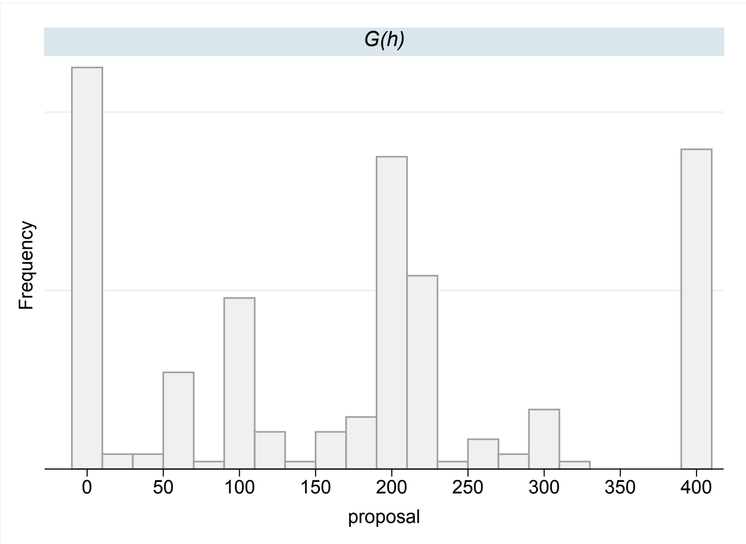


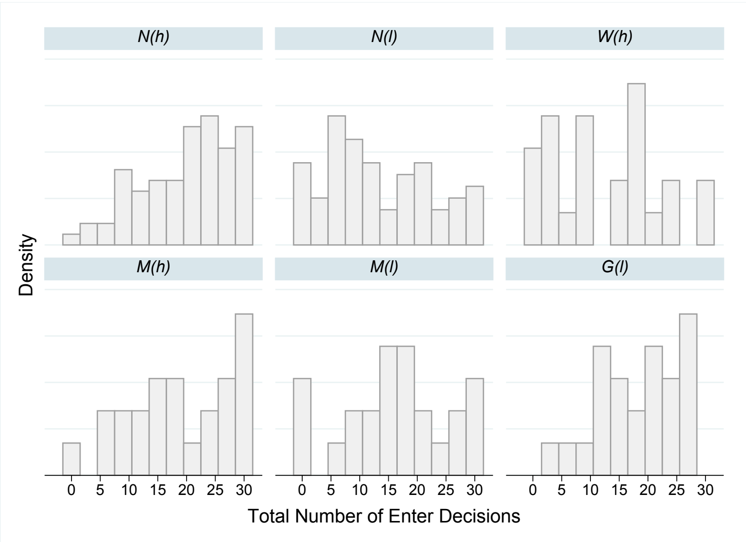
Figure 10 shows the wage proposals made by workers in G^h . In contrast to the offer distributions in the treatments with ultimatum bargaining which were tightly distributed around 100, in G^h we observe a tri-modal distribution. The distribution of wage offers has peaks at 0, 200, 400. These offers correspond to all, half, and none of the surplus. This testifies to substantial differences in beliefs about the optimal group wage level. The very extreme offers suggest that some individuals are strategically setting wage offers to try to influence the average wage proposal. It is evident from this finding that (at least some) test subjects understand the subgame structure of the experiment and understand that different wage levels translate into payoffs not just through their impact on the wage but also via the vacancy creation channel. The result that test subjects dramatically adjust their offers relative to the treatments with ultimatum bargaining after match—only a few make proposals of 100—shows that the environment has a strong impact on what offers can be sustained. In particular, workers are not able to restrain their wage demands in the absence of a centralized institution.

Result 9 *There is more heterogeneity at the individual level than can be accounted for by the symmetric mixed strategy Nash equilibrium*

The aggregate entry probabilities in the experiment are somewhat biased but reasonably close to the level predicted by symmetric randomization. However, a given aggregate level of entry is consistent with a wide range of patterns of entry at the individual level. In the simplest case, consider two test subjects. In terms of the expected number of entrants, the case when both randomize with a probability 0.5 and the case when one test subject always enters and one subject never enters is identical.

At the individual level, we find that there is substantial heterogeneity in excess of that predicted by symmetric randomization in how often subjects choose to enter. For each individual, we compute the proportion of the total number of periods in which an individual enters. Figure 11 shows this distribution of entry frequencies at the individual level. Some test subjects enter often and some rarely do. The strategy of always entering and nearly never entering are both relatively common.

Figure 11: Individual Entry Frequencies



In addition, consistent with expectations, in the treatments with higher productivity the distribution of entry frequencies stochastically dominates the equivalent treatment with lower productivity.[48]

If all test subjects in a given treatment randomize with the same probability p, this predicts a binomial distribution of entry frequencies across the 30 periods with mean $30p$ and variance $30p(1–p)$ and a probability of a given number of entry decisions k equal to $P(X = k) = \binom{30}{k} p^k(1 - p)^{30-k}$. This is the outcome we expect if we take the symmetric Nash equilibrium as the solution.

In figure 11, we present histograms showing the frequency of each level of entry. A first observation is that the distributions are much flatter than those predicted from the mixed strategy Nash prediction with larger standard deviations. A second crucial observation is that there is a substantial mass of test subjects in each treatment that choose to entry with high probability. In treatment T1, 8 individuals choose to enter in every period (about 10% of all participants).

The question is whether these data are consistent with randomization. If subjects randomized with a symmetric probability p we would expect a binomial distribution over the $N = 30$ trials. Relative to this benchmark, the observed distributions are too flat and wide (with, again, the caveat that the results are based on only 24 individuals in each treatment. The distributions might become more peaked with additional observations.). This suggests that entry can not be well accounted for by symmetric randomization.

[48]We present the CDF in figure 26 in the appendix.

To further investigate the role of randomization, we investigate the *pattern* of entry decisions. Specifically, we investigate how persistent subjects are in their decision to enter. In figure 27, we present the distribution of "streaks," where a streak is defined as consecutive decisions to enter. As is evident from the figure, most of the mass is concentrated on streaks of length less than four. In fact, for short streaks, the frequency falls close to geometrically. This implies that players switch fairly often between strategies.

Notably, the main differences across distributions is observed in the tails. For instance, the geometric pattern for short streaks is quite similar across treatments. In *both* high and low treatments, the geometric probability is close to 0.5. The main difference between treatments instead arises because in the high surplus treatment there are more players who enter very many times in a row. This implies that the aggregate differences between treatments can be attributed to a subset of players who use extended streaks.

From the individual analysis, we find arrive at a conclusion similar to that in Zwick and Rapoport (2002). There exists a subset of subjects who play as if randomizing—although not necessarily with symmetric probabilities and perhaps as consequence of sequential dependencies—as well as a population of subjects who do not adjust their strategies over time.

Result 10 *An equilibrium with noise and individual preferences for job creation can account for entry behavior in individual treatments.*

The environment we investigate is complex. Even the baseline treatments feature both strategic and stochastic uncertainty. It is reasonable to expect participants to make mistakes. The valuable question in this regard is how errors affect aggregate outcomes. In a naive framework, we would expect ideiosyncratic errors to cancel out on average. However, if players are sophisticated and recognize that other players may make errors, and that these other players also have beliefs about error (and beliefs about beliefs etc.), then mistakes in decision-making can have equilibrium consequences.

A rigorous way of modelling this is via the estimation of a quantal response equilibrium (QRE). In this framework, players decisions are perturbed by some random noise that is introduced into payoffs. In addition, this framework requires that beliefs be correct. That is, beliefs correspond to equilibrium choice probabilities.

As it turns out, the QRE provides an intuitive explanation for the bias we observe in aggregate entry (See Goeree, Holt, and Palfrey 2016, chapter 8, for a discussion of QRE in the context of participation games). In the market entry context, the expected payoff from entry depends negatively on the probability that other individuals enter. We denote this by $\mathbb{E}[\pi(p)]$ where p is the symmetric entry probability. Letting payoffs from entry and staying out be affected by some independently and identically distributed noise ϵ_e and ϵ_o respectively, then the choice to enter will be chosen in the case when $\mathbb{E}[\pi(p)] + \lambda\epsilon_e > X + \lambda\epsilon_o$, where λ is a parameter that can be interpreted as magnitude of noise in the environment. Notice that as noise increases behavior becomes more random, with choice probabilities going to $1/2$ as $\lambda \to \infty$. This characterization implies a choice probability $p = Pr\left(\epsilon_o - \epsilon_e < \frac{\mathbb{E}\pi_e(p)-X}{\mu}\right) = F(\mathbb{E}[\pi(p)]-X)$. Manipulating this further yields

$$\mu F^{-1}(p) = \mathbb{E}[\pi(p)] - X \tag{6}$$

The two sides of this equation are shown in figure 12.

Since the error terms are identically distributed, the distribution of their differences will be symmetric. The inverse of their distribution is illustrated by the upward sloping line. Moreover, because the outside option is fixed while the payoff from entering declines with the number of entrants, we know that $\mathbb{E}[\pi(p)]-x_o$ is downward sloping and crosses zero at the probability associated with the Nash equilibrium. We show on the plot the cases associated with a high ($Y = 400$) and low ($Y = 300$) surplus. However, the probability associated with the QRE must equalize the two sides of equation 6. We see from the figure that the intersection that there will be overentry in the low surplus case and overentry in the high surplus case. This is consistent the pattern we see in the data.

At the individual level, however, we observe substantially more heterogeneity in entry than predicted by a symmetric randomization. We observe a substantial number of individuals who always choose to enter, even when they persistently earn less than the fixed payment. In addition, in our low surplus treatment the

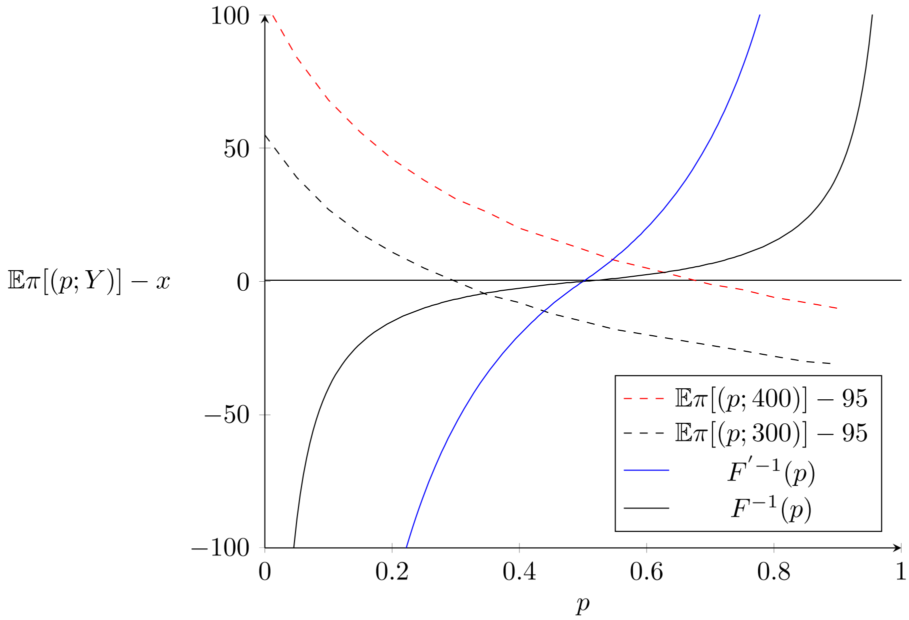


Figure 12: Quantal Response Equilibrium

entry frequency is close to 0.50.[49] This can only be reconciled to a symmetric QRE if behavior is totally random. Even though we can get a good fit for the aggregate entry frequency in the high surplus treatments, we cannot simultaneous fit both the low and high surplus treatments.

To try to reproduce our data in a model framework, we therefore estimate a heterogeneous QRE in which we allow idiosyncratic subject-level preferences for entry. We assume that every individual draws a preference parameter δ at the beginning of the experiment such that the payoff from entry is $\mathbb{E}[\pi(p)] + \delta$. Our approach is similar to that employed by Goeree, Holt, and Moore (2015). We model individuals as drawing a type δ_f from a discrete distribution $\tilde{\phi}(\mu, \sigma)$ that is generated from a truncated normal distribution. Specifically, we truncate a normal distribution to the region $\mu \pm \sigma$ and consider 11 points equal spaced in this interval $(\mu - \sigma, \mu - 0.8\sigma, \ldots, \mu + \sigma)$. To discrete-ize the distribution, the density at each point is divided by the sum of the densities at all points. Maintaining the assumption that each individual experiences some idiosyncratic extreme value distributed noise each period, the quantal response probabilities can still be written down in the logitistic form—for each individual f, δ_f is simply a constant that adjusts the expected payoff from entry.[50]

Formally, the estimation has two stages. In the first stage, a QRE is fit for a vector of parameters that include the level of noise λ and the parameters of the normal distribution μ and σ. This fitting was done by minimizing the difference between beliefs and the quantal response probabilities based on the logit specification. After estimating the theoretical QRE entry probabilities, we then compute the likelihood of observing data given the choice of parameters. The likelihood function is based on the observed number of entry decisions for each individual. For each individual f in each treatment T, we tabulate the number of

[49] In fact, if we consider all periods, the entry frequency is a few percentage points in excess of 0.50.

[50] We also estimated a simple model in which we estimated a simple additive constant for an estimated proportion of the population q. The idea was to try to account for the significant portion of players who always enter. However, this approach gave quite dramatic results. The difficult is that there is a left skew in entry in most the treatments. As a consequence, q must be relatively large. The outcome was therefore that a large proportion of individuals never entered while another large proportion always entered.

vacancy creation decisions $v(f,T)$ and then compute the likelihood function

$$\Pi_{f=1}^{F(T)}\left[\sum_{z=1}^{Z} p\left(\lambda,\mu,\sigma,T\right)^{v(f,T)}\left(1-p\left(\lambda,\mu,\sigma,T\right)\right)^{30-v(f,T)}\tilde{\phi}(z,\mu,\sigma)\right]. \tag{7}$$

Relative to a binary QRE without heterogeneity, the difference is the presence of the $\tilde{\phi}(z,\mu,\sigma)$ which accounts for the distribution of possible types.

Despite adding some explanatory power to our estimation, accounting for some additional heterogeneity at the individual level, it remains difficult to jointly fit both the high and low surplus treatments. One issues appears to be the data are skewed in a fashion that makes it difficult to fit with a symmetric distribution. We are therefore investigating the use of an asymmetric distribution such as the Gamma.

The HQRE helps account for some—though not all—of the variation in the data. This exercise suggests that aggregate biases can survive in environments with noise. This may be important beyond the lab.

5.1 Additional Analyses

In the entry portion of the experiment, we observe a pattern seen in a number of related studies: Over-entry when market capacity is low and under-entry with market capacity is high. In addition, we find that introduction of a post-entry bargaining stage only has marginal implications for entry behavior. The introduction of stochastic risk and bargaining thus does not alter the conclusions from the market entry literature. With respect to the bargaining portion of the experiment we find rapid and consistent coordination on a sharing norm. This sharing norm is the same in nominal (ECUs) terms across treatments. This implies that the share that the proposer keeps increases with the size of the pie. This last finding is is unusual.

In the subsections below, we consider two ways of explaining the entry and bargaining results: Fairness preferences for bargaining results and learning rules for entry. While both are appealing in certain respects, none provides an entirely satisfactory explanation for the results.

5.2 Fairness Preferences

A common way of explaining outcomes in ultimatum and dictator games is via the use of fairness preferences. In the conceptualization of Fehr and Schmidt (1999), other players' payoffs enter the utility function explicitly, with penalties associated with unequal payoffs. In the version proposed by Bolton and Ockenfels (2000), players are penalized when their earnings deviate from a sharing norm. Both approaches have been successful in reproducing a variety of stylized facts not well accounted for by basic rational behavior.

Because this study incorporates a standard ultimatum bargaining game, it is plausible that fairness preferences could help explain the results. Moreover, because fairness preferences concern *utility*, outcomes of the bargaining stage will also affect the entry decision. This means that fairness preferences have implications for both bargaining and entry.

However, theoretical consideration of these preferences suggests that neither the inequity preferences of Fehr and Schmidt (1999) nor the equality-reciprocity-competition preferences of Bolton and Ockenfels (2000) can explain the results from this experiment. Even under favorable assumptions on preference parameters, solving for an equilibrium with fairness preferences implies sharing of the surplus and a pattern of entry inconsistent with what we observe. For instance, beginning with the bargaining subgame, fairness preferences in this study predict substantially *lower* offers than what we observe. The reason is that unmatched players earn 0 and this actually loosens the constraint on the offers that proposers can make. Specifically, predicted offers tend to be in the range of 20-30 ECUs, that is, a third of what we find (allowing for some differences given various parametrization). Details of the computation are found in appendix C. It is also the case that bargaining outcomes predicted by these fairness preferences do not reproduce the pattern across treatments.

Although the two main varieties of fairness preferences do not explain the results, the notion that fairness concerns are important has appeal. An observation that is compatible with this intuition is that the modal offer of a 100 is close to the *average* earnings in the market. In tables 13 and 14, we show the average payoffs for the case of all subjects in a market ("All") and the case of just the players in the matching stage ("In").

Average Payoffs, Y High		
v	All	In
1	87.5	80.0
2	94.6	94.3
3	97.8	98.0
4	99.0	100.0
5	98.9	99.4
6	98.0	98.0

Figure 13: Average payoffs by comparison group, Y High

Average Payoffs, Y Low		
v	All	In
1	77.5	60.0
2	80.4	70.7
3	80.5	74.2
4	79.0	75.0
5	79.6	74.5
6	73.5	73.5

Figure 14: Average payoffs by comparison group, Y Low

Under this norm, an offer is accepted if it is at least as large the average earning. This explanation would be consistent with the observations from this study. Once offers fall below the market average, then begin to get rejected.

5.2.1 Learning Rules

To explain the entry decisions we estimate the predictive ability of two simple learning rules, *payoff reinforcement* and *fictitious play*. These two types of learning describe two distinct varieties of learning. The first, payoff reinforcement, is based on the notion that if an action had a positive outcome, then an agent becomes more likely to repeat the action (Roth and Erev 1995; Erev and Roth 1998). The second, fictitious play, is a type of belief learning in which the probability of an action increases if it *would have been* a best response.[51]

For both types of learning, we compute the propensities that a subject will choose to enter given their payoffs and observed behavior. Between each period, the entry propensities are updated given the realized payoffs. Although both rules require initialization of the initial propensities and the "stickiness" of initial propensities, the outcomes are relatively insensitive to these choices. After estimating the propensities, we use the estimated entry probabilities to predict actual entry[52]. In the regression based on payoff reinforcement probabilities, the estimated coefficient is highly significant and of a large size. In contrast, the same coefficient for fictitious play is insignificant.

To give a gross intuition for the predictive ability of these learning rules, we categorize the learning rule as predicting "enter" whenever the estimated propensity is greater than 0.5. Next, we cross-tabulate the prediction with the actual entry decision. Figure 15 shows the results for payoff reinforcement: In about 80%

[51]Note that players do not need to know their opponents' payoffs: Belief learning is simply about expectations about other players' actions.

[52]We estimate a logistic regression with fixed/random subject and time effects

Payoff Reinforcement		
$\mathbb{P}$	Enter	Stay Out
Enter	76.2	23.8
Stay Out	18.8	81.2

Figure 15: $\mathbb{P}_{\text{Enter}}$ reinforcement learning predictions

Fictitious Play		
$\mathbb{P}$	Enter	Stay Out
Enter	52.5	48.5
Stay Out	38.7	61.3

Figure 16: $\mathbb{P}_{\text{Enter}}$ belief learning predictions

of cases, the prediction is correct. In contrast, results for reinforcement learning, shown in 16, demonstrate that this learning rule has almost not predictive ability.

6 Conclusion

This study examines entry in a market entry game with labor market features. We find a high degree of coordination even though the level of entry is less sensitive to changes in productivity than predicted by the Nash equilibrium. This mirrors the results in the existing literature. The coordination success of agents in the model, though not perfect, does not seem to be perturbed by the additional complications we introduce. With respect to the market entry literature, we conclude that the complications that we introduce do not strongly alter aggregate outcomes. Indeed, the main bias that we observe is a general finding in the literature and not a peculiar aspect of our environment.[53] The finding that individual behavior is chaotic also is repeated in our findings. Overall, the "magic" of coordination appears to be a robust phenomenon even if some puzzles remain.

With respect to the bargaining results, we find that that offers are "optimal" but vary with the size of the surplus. This latter finding can not be accounted for by standard formulations of fairness preferences. We believe that the overwhelming reason for modal sharing of 100 relates to the direct cost of vacancy creation. Although it is fair to compensate firms for this cost, workers do not reward firms for the matching risk they bear. This leads to negative consequences for efficiency in treatment W^h . This illustrates why bargaining after matching is often inefficient. Notably, however, when we create an institution in which workers can coordinate their wage setting, they are able to rectify the situation and improve market outcomes. This suggests that in certain instances, workers should be willing to engage an organization to negotiate on their behalf. This result provides a new finding that explains the value of labor organizations.

Relative to the patterns observed in actual labor markets (and, indeed, our *ex ante* expectation, especially given the matching technology), we would perhaps have expected the opposite of our results: More volatility in entry and employment than in productivity. Despite the deviations from predictions, the results should still be interpreted as good news for the validity of the market entry assumption and for the basic assumptions that underpin labor search models. In the average across treatments, the level of entry is about correct. This is due to the fact the aggregate biases cancel out across high and low productivity settings. In the absence of more specific information about a market—and when considering industries aggregated across an entire economy—neither over nor under entry is more likely. In addition, our study examines an extremely small market yet subjects are still relatively close to satisfying the zero-profit condition. Even though the assumption of a continuum of agents and free-entry in macrolabor models is strong, the assumptions still hold—more or less—in the small market setting. That the assumptions holds both in small markets as well

[53] It is, however, difficult to tell if this effect is more or less strong in our environment, given that we make a number of alternate design decisions.

as large markets, for which it seems likely that the effects of strategic uncertainty are smaller, is good news for the DMP model. The one caveat to the positive conclusion for the model is that the presence of noise may lead to persistent over or under entry. This could help explain patterns of entry in new industries in which the potential profits are less certain.

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Appendices

A Background

A.1 Market Entry Games

In the version of the market entry game that has attracted the most attention, payoffs decline linearly in the number of entrants while the opportunity cost is constant (Kahneman 1988; Rapoport, Seale, Erev, et al. 1998; Sundali et al. 1995). In this set-up, the payoff for player i when $v-1$ other players enter is

$$\pi_i = \begin{cases} X & \text{if } i \text{ doesn't enter} \\ X + \beta(C - v) & \text{if } i \text{ enters} \end{cases} \tag{8}$$

where β is a scaling factor that dictates how sensitive payoffs are to entry and C is the market capacity.

The basic result in the literature on market entry games is that there is a high degree of coordination. Consider the study by Sundali et al. (1995). In this study, players in groups of 20 played a market entry game in which the market capacity, C, was varied between each period. The payoffs are a linear function of entrants such that in equilibrium the marginal entrant is indifferent between entering and staying out. Both C and $C-1$ entrants are therefore equilibria. In one treatment, players were only provided information on market capacity ("no info") while in another treatment players were also given feedback on payoffs ("info"). Figure 17 presents results. In this figure, the market capacity is given on the horizontal axis and the number of entrants is shown on the vertical axis. This figure illustrates the remarkable degree of coordination, even in the treatment with limited information.The close to linear relationship between C and v indicates that the Nash concept predicts outcomes.

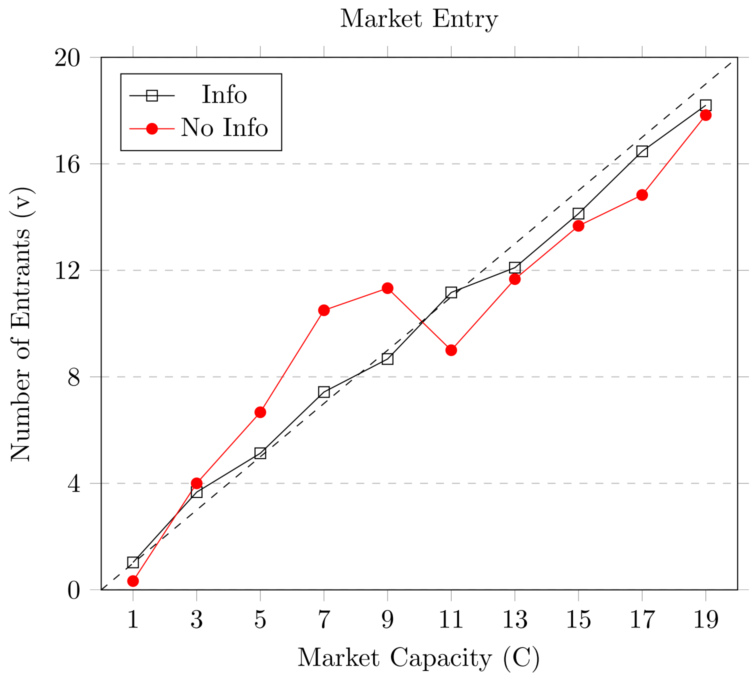


Figure 17: Entry in Sundali et al. (1995)

The second stylized fact on market entry games that is relevant to our study is the observation that there is more moderate entry—in the sense that participants enter with closer to a 0.5 probability—than predicted by the Nash equilibrium. The study by Sundali et al. (1995) also illustrates this bias. They find too much entry when the capacity is low and too little entry when the capacity is high. This can be seen in figure 17. When the market capacity exceeds 50% there is a switch from over to underentry. This feature is especially prominent in the "no info" treatment.

B Model

B.1 Matching Function

The matching technology is shown in figure 18. The total number of matches is a function of the number of firm entrants and has the shape shown for the specification of the matching function used in this study. This function increases monotonically in the number of entrants.

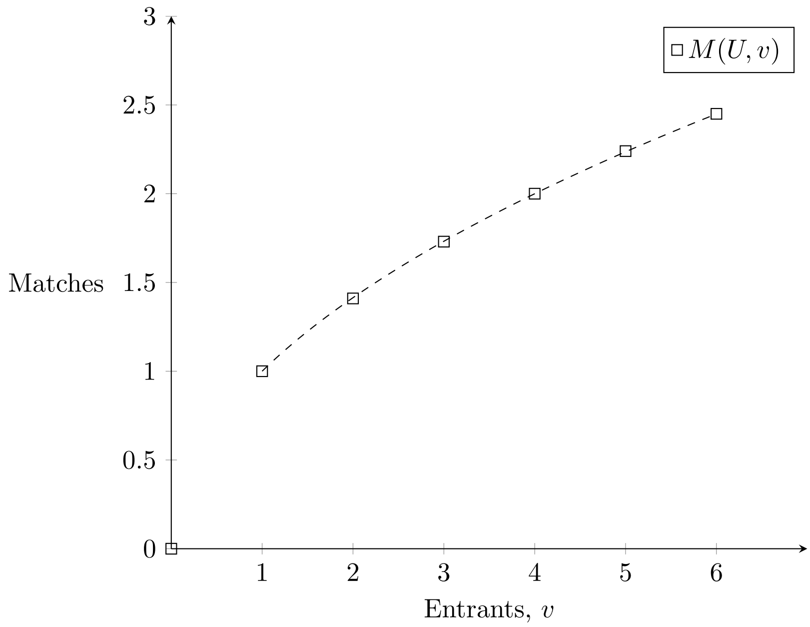


Figure 18: Total number of matches, given entry v

Although the number of matches increases with the number of firm entrants, the matching probabilities decline. Figure 19 is a plot of the associated matching probabilities for firms, $q(\theta)$. The effect of an additional entrant is to reduce the matching probability for all other players. Moreover, the negative externality imposed on other firms is most severe when entry is low: For instance, if a single firm enters, then that firm is guaranteed to match. However, if a second firm were to enter the matching probability drops to 71%.

B.2 Efficiency

We define expected total *social surplus* as the sum of payoffs to firms and workers:

$$\Sigma = M(U, v)Y + (F - v)X \tag{9}$$

The first component is the expected payoff from production. Each match M produces Y. The second component is the value of (avoided) search costs. A risk-neutral social planner who maximizes social surplus should therefore increase vacancy creation up to the point at which stochastic rationing of workers drives down the expected productivity of a match to equal the vacancy creation cost X. We see this from the first-order condition:

$$\begin{aligned} \frac{d\Sigma}{dv} &= \frac{dM}{dv}Y - X \\ &\Rightarrow \frac{dM}{dv}Y = X \end{aligned}$$

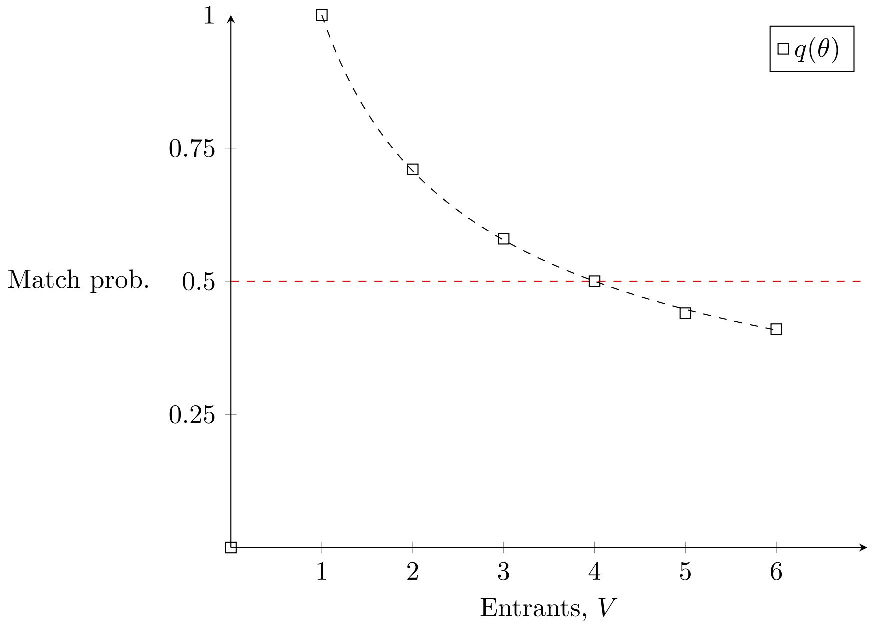


Figure 19: Matching probabilities for firms

Efficiency requires the number of vacancies to satisfy $\frac{dM}{dv} = \frac{X}{Y}$.

Given our parametrization of the matching function:

$$v^{\Sigma} = \left(\frac{95}{Y/2}\right)^2.$$

When $Y = 400$, efficiency requires $v^{\Sigma} = 4.4$. When $Y = 300$, efficiency requires $v^{\Sigma} = 2.5$. Hence, if the planner were able to perfectly coordinate entry, the planner would choose 4 entrants and 2 entrants respectively. If the planner must choose a symmetric entry probability, the problem is somewhat more complex. In such a case, the planner chooses a p^{Σ} to maximize

$$\mathbb{E}\left[\Sigma\right] = \sum_{v=0}^{F} \binom{F}{v} \left(p^{\Sigma}\right)^{v} \left(1 - p^{\Sigma}\right)^{F-v} \left[M(U,v)Y - (F-v)X\right].$$

This probability can be computed from the first order condition

$$\sum_{v=0}^{F} \binom{F}{v} \left(p^{\Sigma}\right)^{v} \left(1 - p^{\Sigma}\right)^{F-v} \left(\frac{v - p^{\Sigma}F}{p^{\Sigma}(1-p^{\Sigma})}\right) \left[M(U,v)Y - (F-v)X\right] = 0.$$

Closely related to the expected social surplus is the expected total profits of firms. If firms could collude, they would like to restrict entry relative to the non-cooperative Nash equilibrium. The reason is that entry imposes a congestion externality on other firms. Given our parametrization of the matching function, the level of vacancy creation that maximizes joint firm payoffs is reduced by a factor of η^2 relative to the socially efficient level of entry. For $\eta = 0.5$ this implies that if the efficiency level of entry is 4 firms, then the joint payoffs for firms are maximized if only a single firm (out of 6) enters.

C Results

The analogous results to those presented in the main text in figure 6 for vacancy creation at the block level are presented in figure 20. Each block consisted of 2-3 markets so the data are already somewhat aggregated at the level of a block observation. Although there is some heterogeneity at the block level, the overall level of vacancy creation is quite similar to the results at the higher level of aggregation. Notably, there is no perceivable time trend in most of the blocks.

Figure 20: Average Vacancy Creation M^h –N^l

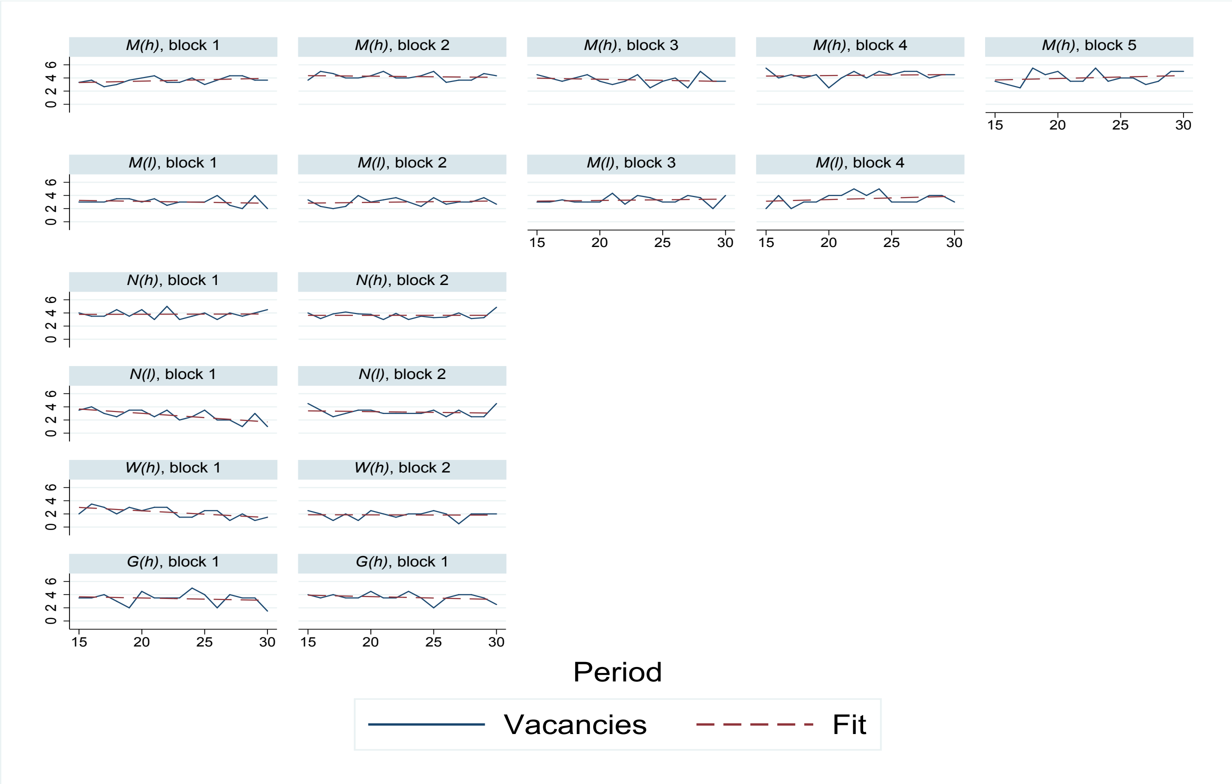
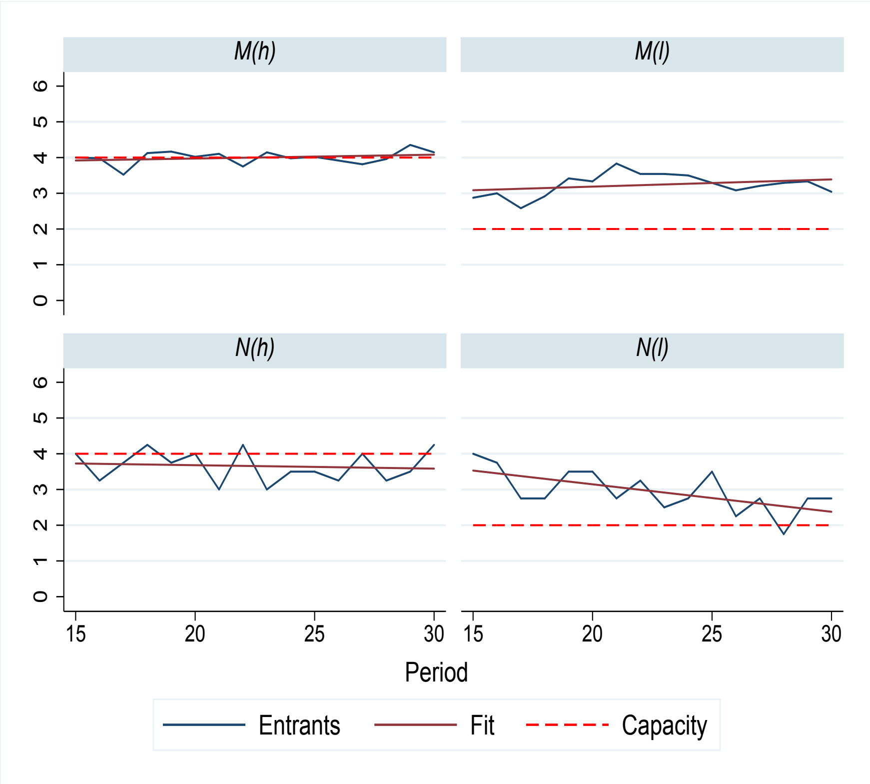


Figure 21 presents the entry in the second half of periods for the M and N treatments. For this portion of the data, only N^l exhibits any trend in the degree of entry. We conclude that it takes some time for behavior to converge to a stable level but that once it reaches that level it tends to stay there. This is perhaps surprising given that there continues to be considerable randomization at the individual level throughout the duration of the experiment.

Figure 21: Average Vacancy Creation M^h $-N^l$



Result 1

Table 6 presents the block level averages for number of vacacnies. These are the data used in the WSR tests presented in the main text.

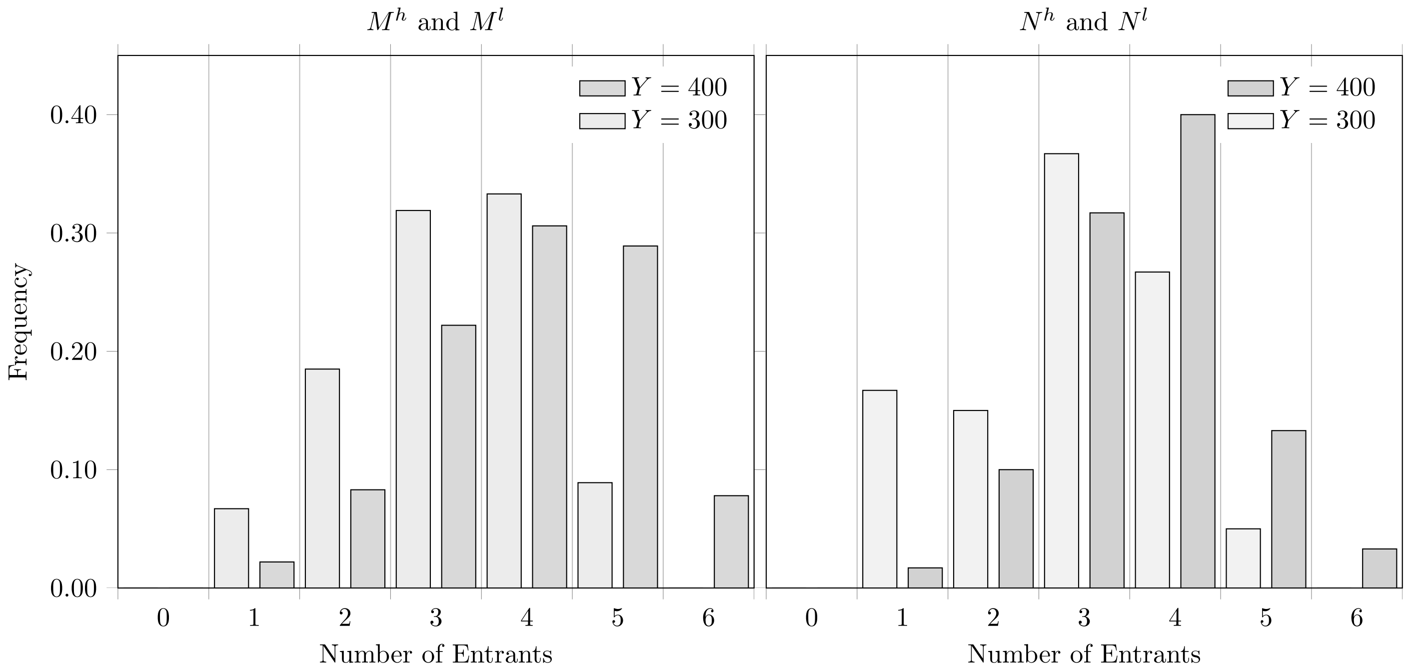
Table 6: Block Level Averages

		$Y = 400$						$Y = 300$			
Blocks		1	2	3	4	5		1	2	3	4
Matching	M^h	3.64	4.27	3.67	4.33	4.07	M^l	3.03	2.98	3.31	3.6
Neutral	N^h	3.80	3.51				N^l	2.63	3.13		
Worker	W^h	2.23	1.80								
Group	G^h	3.40	3.57								

Result 3

In 22 we show the distributions for entry for treatments M^h and M^l together (just matching) and treatments N^h and N^l together (neutral bargaining). In both case we see much more overlap than is expected from the Nash randomization probabilities.

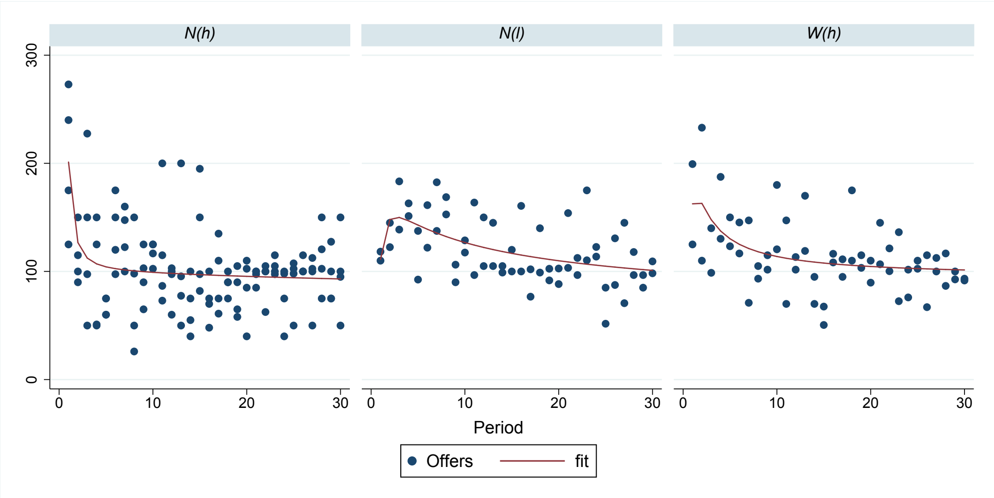
Figure 22: Distribution of Entrants N and M treatments



Result 4

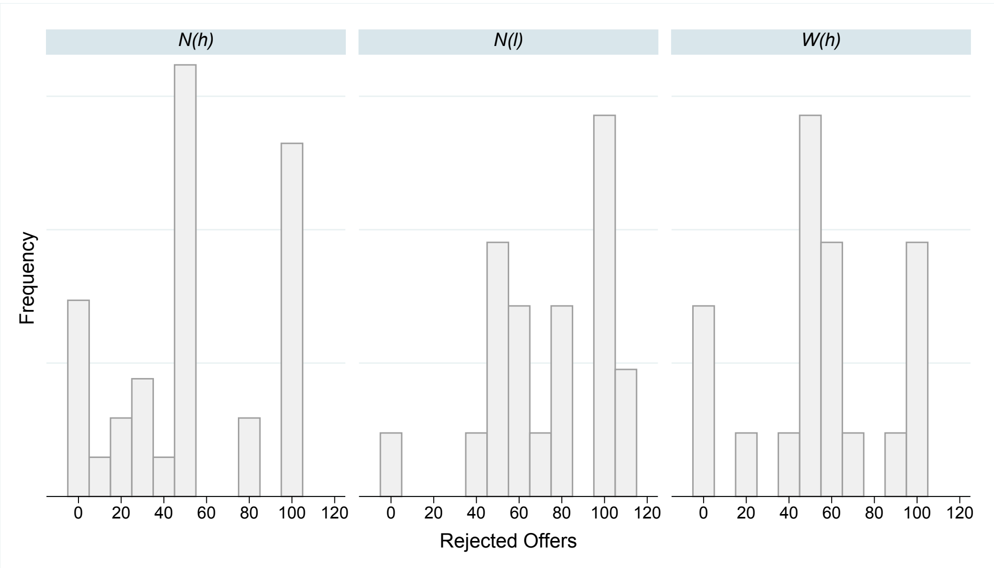
Figure 23 shows the bargaining offers over time. The offers are stable during most of the sessions with, perhaps, a slight downward trend:

Figure 23: Rejected Offers, N^h , N^l , and W^h



In figure 24, we show histograms showing all of the rejected offers in the treatments with ultimatum bargaining. The remarkable finding shown in this plot is that no offers in excess of 100 were rejected (in the second half of the data). This gives intuition as to why the offers cluster near 100. Below this level (that is, to the left of 100), the offers are rejected relatively often but offers above this level were never rejected.

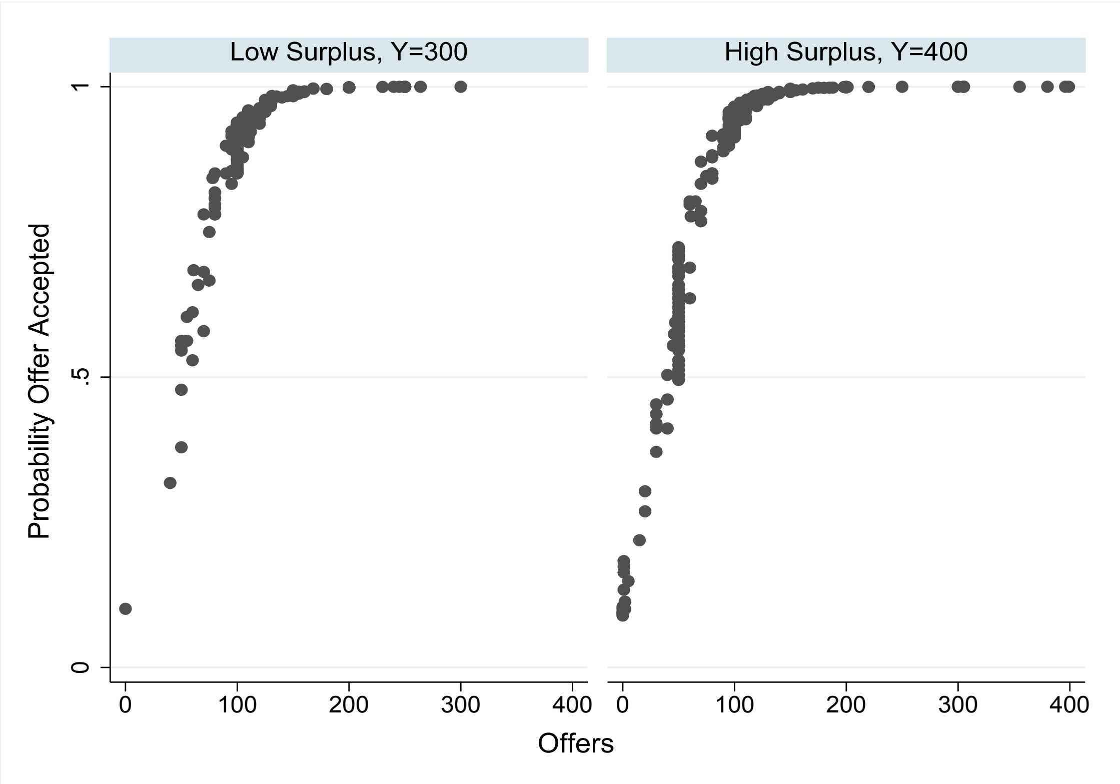
Figure 24: Rejected Offers, N^h , N^l , and W^h



Result 5

A revealing analysis is based on a logistic regression in which we estimate the probability that a given offer will be accepted. These estimated acceptance probabilities are shown in figure 25. As is apparent, the probabilities fall steeply below the modal offer. Moreover, using these probabilities, we can compute expected payoffs from the offers: That is, the surplus net of the offer, weighted by the acceptance probability. This is shown in figure 9. We see that the expected payoffs are maximized in the vicinity of the modal offer and, indeed, fall steeply on either side of this offer. This seems to imply consistency of beliefs about sharing among players.

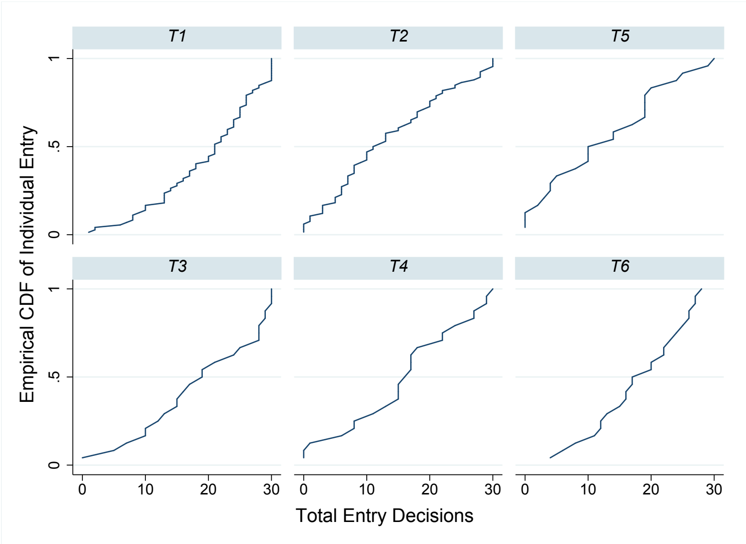
Figure 25: Probability of Acceptance



Result 9

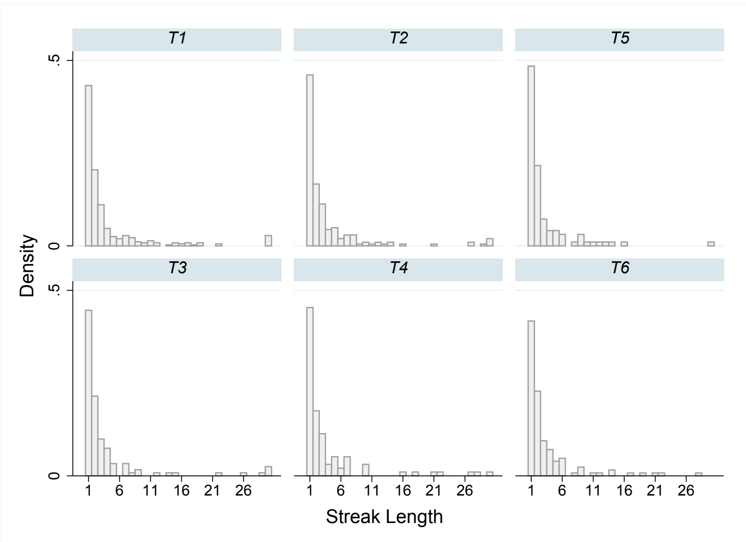
In figure 26, we present the empirical distributions showing the proportion of entrants that enter a given number of times or less. That is, if we randomly sampled an individual, these graphs show how likely it is that they enter x times or less. The main result here is that the high productivity treatments stochastically dominate the low productivity treatments.

Figure 26: Empirical Distributions of the Number of Enter Decisions



The distribution of streaks—that is, consecutive enter decisions—is shown in figure 27. Compared with the theoretical (geometric) distribution associated with symmetric randomization, there are many streaks in which the same individual enters many times in a row. This suggests that some individuals persistently enter.

Figure 27: Distribution of entry streaks (number of consecutive decision to enter



Additional Analyses

Inequity Aversion

We begin by considering inequity preferences as proposed by Fehr and Schmidt (1999) with unfavorable inequity parameter α and favorable inequity parameter β:

$$U_i(x_i, x_j) = x_i - \alpha \max\{0, x_j - x_i\} - \beta \max\{0, x_i - x_j\}. \tag{10}$$

Inequity Preferences with Match Reference

We first consider the case when only payoffs to a player and their match in bilateral bargaining enter the utility function. We will refer to this as inequity preference with match reference. Such preferences have been extensively explored and predict offers of a constant share of the surplus, independent of the size of the surplus. This is inconsistent with the empirical results which predict a negative relationship between the size of the surplus and the offer. We show this below.

Let p denote the proposer state and r denote the responder state. We denote material payoffs by x with the relevant subscript. In the bargaining stage, it does not matter whether a player is a firm or worker type. By subgame perfection, we first solve for the minimal acceptable offer of the responder and then back out the remaining outcomes. Utility for the responder is

$$\begin{aligned} U_r(x_p, x_r) &= x_r - \alpha (x_p - x_r) \\ U_r(x_p, x_r) &= x_r - \alpha (S - 2x_r). \end{aligned}$$

and the the utility for the proposer is

$$\begin{aligned} U_p(x_p, x_r) &= x_p - \beta (x_p - x_r) \\ U_p(x_p, x_r) &= x_p - \beta (2x_p - S) \end{aligned}$$

where we use the fact that when bargaining over a fixed surplus $x_r = S - x_p$. Given this specification, the responder will accept any offers that yield positive utility because rejection gives zero utility to both players. That is, offers satisfying $x_r \geq \frac{\alpha}{1+2\alpha} S$. Next, given the value of β, the proposer will either propose an offer of half the surplus or the lowest offer acceptable to the responder, depending on whether $\beta \lesseqgtr \frac{1}{2}$. Only the case with $\beta < 1/2$ is empirically relevant since proposers nearly always make offers that are much smaller than 1/2 of the surplus. As an example, consider that $\beta < 1/2$ and $\alpha = 1$. Then the proposer will offer 1/3 of the surplus and this is the minimum that the responder will accept. We conclude that shares offered in bilateral bargaining are independent of the size of the surplus. To explain our observations, α (or, more generally, the distribution of α) would need to be substantially different between treatments.

Inequity Preferences with Market Reference

Next we consider the case when payoffs to all other agents in the game also enter the utility function, that is a specification of equation 10 for all agents in the game. We refer to this as inequity preference with market reference. We assume initially that agents share the same values for α and β and that this is common knowledge. Again, we denote material payoffs by x with a subscript. x_o is a constant and $x_\varnothing = 0$. We denote the *states* that players can be in by o, p, r, and $\varnothing$. r and p denote the same types as above, o denotes firms that take the outside option, and $\varnothing$ denotes players in the bargaining stage who do not get matched. There is, in addition, a fifth type of agent that we denote by X. These are players who got matched but for whom bargaining ended with a rejection. This type of agent determines which offers are accepted, but should not be observed in the (common knowledge) equilibrium.

We begin by writing down the utilities for players in the bargaining stage of the game. These are *ex post* utilities that depend on final realizations in the game. When v players enter and M matches are *realized*, then there are $N - v$ firm players who do not enter, M proposers and M responders, and $U + v - 2M$ agents in the matching market who end up unmatched.[54] Next, we show that for plausible values of β proposers would like to maximize their own payoffs. Thereafter, we solve for the minimal acceptable offer for the responder. Finally, we back out v.

We show that proposers maximize their utility by maximizing their payoffs. We *assume* that proposers offer responders the minimal amount that will not be rejected. Then we derive a condition that ensures that this is an optimal decision. Moreover, given complete information, all proposers will offer this amount. This justifies the assumption.

The proposer's utility is:

$$\begin{aligned} U_p(x_p, \mathbf{x_r}, \mathbf{x_o}, \mathbf{x_\varnothing}) = x_p &+ \frac{\beta}{N+U-1} M\left(x_r - x_p\right) + \frac{\beta}{N+U-1}\left[(v-M)+(U-M)\right]\left(x_\varnothing - x_p\right) \\ &+ \frac{\beta}{N+U-1}(N-v)(x_o - x_p) \end{aligned}$$

The second term results from the M matches for which the proposer earns more than the responder, the third term results from a comparison of earnings with the $v+N-2M$ agents who did not get matched, and the last term results from the $N-v$ firm players who chose to stay out of the market. Simplifying further:

$$\begin{aligned} U_p(x_p, \mathbf{x_r}, \mathbf{x_o}, \mathbf{x_\varnothing}) &= x_p + \frac{\beta}{N+U-1} M\left(S - 2x_p\right) + \frac{\beta}{N+U-1}\left[(v-M)+(U-M)\right]\left(x_\varnothing - x_p\right) \\ &\quad + \frac{\beta}{N+U-1}(N-v)\left(x_o - x_p\right) \\ &= x_p - \frac{\beta}{N+U-1}(U+N)x_p + \frac{\beta}{N+U-1}(MS + (N-v)x_o) \end{aligned}$$

From the last line, we see that when $\beta < \frac{N+U-1}{N+U}$ the proposer's utility increases with x_p since own payoff increases at a faster rate than the penalty from favorable inequity.[55] It is very likely that this requirement is satisfied [56] If so, the proposer will offer a responder the minimal offer that the responder will accept. Moreover, it must be so that $x_p \geq x_r$.[57] In the empirical results, the relevant ranking is $x_p > x_r > x_o > x_\varnothing$. However, theoretically, nothing guarantees that $x_r > x_o$.

Next we compare the utility for a responder who accepts an offer with the utility for a responder who rejects an offer. On the equilibrium path, proposers will make offers that responders will accept. This means that a decision to reject leads to $M-1$ matches in which the offer is accepted, given that the other responders accept the equilibrium offer. For the responder, write the utility for the case when $x_r > x_o$:

$$\begin{aligned} U_r(x_r, \mathbf{x_p}, \mathbf{x_o}, \mathbf{x_\varnothing}) &= x_r - \frac{\alpha}{N+U-1} M(x_p - x_r) + \frac{\beta}{N+U-1}\left[v+U-2M\right]\left(x_\varnothing - x_r\right) \\ &\quad + \frac{\beta}{N+U-1}(N-v)(x_o - x_r) \\ &= x_r + \left[\frac{\alpha}{N+U-1}2M - \frac{\beta}{N+U-1}(N+U-2M)\right] x_r \\ &\quad - \left[\frac{\alpha}{N+U-1}MS - \frac{\beta}{N+U-1}(N-v)x_o\right]. \end{aligned}$$

[54]We refer to *realized* matches because v does not map deterministically to a number of matches: There is a probability $q = (M(v,U) - \lfloor M(V,U) \rfloor)$ that $M = \lceil M(V,U) \rceil$ and a complimentary probability that $M = \lfloor M(V,U) \rfloor$.

[55]If proposers happen to offer different amounts, this condition will be more complicated and could be either more or less strict. However, a similar intuition will hold.

[56]In their original study Fehr and Schmidt (1999) suggest an upperbound on β of 0.6 (See Fehr and Schmidt 1999, table III).

[57]It is a dominant strategy to accept offers of half the surplus (that is $x_p = x_r$) whenever $\beta < \frac{N+U-1}{N+U-2M}$, a condition that is slack (to solve for this condition, set $x_p = x_r$, and solve for a condition on β such that U_r is positive. The condition derived here is for the case when $x_r > x_o$). Moreover, a proposer would like to maximize their payoffs which are increasing inx_p . Hence, proposers will only make offers equal to less than half the surplus. An analogous computation can be carried out for the case when $x_r < x_o$.

and for the case when $x_r < x_o$:

$$\begin{aligned}
U_r(x_r, \mathbf{x_p}, \mathbf{x_o}, \mathbf{x_\varnothing}) = x_r &- \frac{\alpha}{N+U-1} M(x_p - x_r) - \frac{\alpha}{N+U-1}(N-v)(x_o - x_r) \\
&+ \frac{\beta}{N+U-1}(v+U-2M)(x_\varnothing - x_r) \\
= x_r &+ \left[\frac{\alpha}{N+U-1}(2M+N-v) - \frac{\beta}{N+U-1}(v+U-2M)\right] x_r \\
&- \frac{\alpha}{N+U-1}(MS + (N-v)x_o)
\end{aligned}$$

Utility for a responder who rejects an offer such that payoffs are $x_p = x_r = 0$ is:

$$\begin{aligned}
U_X(x_X, \mathbf{x_r}, \mathbf{x_p}, \mathbf{x_o}, \mathbf{x_\varnothing}) = x_x &- \frac{\alpha}{N+U-1}(M-1)(x_p - x_x) - \frac{\alpha}{N+U-1}(M-1)(x_r - x_x) \\
&- \frac{\alpha}{N+U-1}\left[v+U-2M\right](x_\varnothing - x_x) - \frac{\alpha}{N+U-1}(N-v)(x_o - x_x) \\
= &- \frac{\alpha}{N+U-1}\left[(M-1)S + (N-v)x_o\right]
\end{aligned}$$

Then we solve for the minimum x_r such that $U_r \geq U_x$. In the case when $x_r > x_o$,

$$x_r > \frac{\frac{\alpha}{N+U-1}S - \frac{\alpha+\beta}{N+U-1}(N-v)x_o}{1 + \frac{\alpha}{N+U-1}2M - \frac{\beta}{N+U-1}(N+U-2M)} \tag{11}$$

and in the case when $x_r < x_o$:

$$x_r > \frac{\frac{\alpha}{N+U-1}S}{1 + \frac{\alpha}{N+U-1}(2M+N-v) - \frac{\beta}{N+U-1}(v+U-2M)} \tag{12}$$

Let us denote these minimal acceptable offers by $\underline{x_r}$.

To assess whether $x_r \lesseqgtr x_o$ we compare $\underline{x}$ with x_o and derive conditions on α and β. For $\underline{x_r} > x_o$ we consider equation 11 relative to x_o:

$$\begin{aligned}
\frac{\alpha S - (\alpha+\beta)(N-v)x_o}{N+U-1+\alpha 2M - \beta(N+U-2M)} &> x_o \\
\alpha S - \alpha(N-v)x_o - \beta(N-v)x_o &> (N+U-1)x_o + \alpha 2M x_o - \beta(N+U-2M)x_o \\
\alpha\left[S/x_o - (N-v) - 2M\right] &> (N+U-1) - \beta\left[v+U-2M\right]
\end{aligned}$$

Conclude that $\underline{x_r} > x_o$ only for the case when

$$\beta > \frac{(N+U-1) - \alpha\left[S/x_o - (N-v) - 2M\right]}{v+U-2M} \tag{13}$$

The numerator on the right hand side will be larger than the denominator. For our parameter values, $S/x_o < (N-v) - 2M$. The numerator will therefore be *larger* than $N+U-1$ while the denominator is smaller.[58] But we concluded above that $\beta < \frac{N+U-1}{N+U}$. So inequity preferences predict the opposite ranking $(x_r < x_o)$ of what is observed empirically.

[58]The numerator is a quantity larger than the total number of players while the denominator is equal to the number of unmatched players.

Similarly, beginning from equation 12 for the case when $x_r < x_o$, we derive the complimentary condition:

$$\begin{aligned}\frac{\alpha S}{N+U-1+\alpha(2M+N-v)-\beta(v+U-2M)} &< x_o \\ \alpha\frac{S}{x_o} &< N+U-1+\alpha(2M+N-v)-\beta(v+U-2M) \\ \alpha\left[\frac{S}{x_o}-(N-v)-2M\right]-(N+U-1) &< -\beta(v+U-2M)\end{aligned}$$

And conclude again that $x_r < x_o$ when:

$$\beta < \frac{(N+U-1)-\alpha\left[S/x_o-(N-v)-2M\right]}{v+U-2M} \tag{14}$$

which, as argued above, will always be satisfied for this study.

This result predicts the incorrect ordering relative to our findings. In addition, not only is the ranking wrong, but the predicted difference between x_o and x_r is substantial. for reasonable values of α and β, offers are around 30 in the high surplus case and somewhat larger than 20 for the low surplus case. This is strongly counterfactual. Given these small shares, both less than a share of 0.1, the pattern across treatments is also unclear.

The details of this computation are included below. Note that we must consider the *expectation* because up to two different values of M can be realized for each level of entry v. To solve for the optimal entry v^*, we solve

$$U_o(v^*) = \mu(\theta)\left[\frac{1}{2}\mathbb{E}U_p(v^*)+\frac{1}{2}\mathbb{E}U_r(v^*)\right]+(1-\mu(\theta))\mathbb{E}U_\varnothing \tag{15}$$

$$\text{s.t } U_r(v^*) \geq U_X(v^*). \tag{16}$$

The utility for players who take the outside option is

$$\begin{aligned}U_o(x_o,\mathbf{x_r},\mathbf{x_p},\mathbf{x_o},\mathbf{x_\varnothing}) &= x_o-\frac{\alpha}{N+U-1}M(x_p-x_o)+\frac{\beta}{N+U-1}M(x_r-x_o)+\frac{\beta}{N+U-1}(v+U-2M)(x_\varnothing-x_o) \\ &= x_o\left(1+\frac{\alpha-\beta}{N+U-1}M-\frac{\beta}{N+U-1}(v+U-2M)\right)-\frac{\alpha}{N+U-1}Mx_p+\frac{\beta}{N+U-1}Mx_r\end{aligned}$$

given that $x_r < x_o$.[59] And the utility for players that do not get matched is

$$\begin{aligned}U_\varnothing(x_\varnothing,\mathbf{x_p},\mathbf{x_r},\mathbf{x_o}) &= -\frac{\alpha}{N+U-1}M\left(x_p-x_\varnothing\right)-\frac{\alpha}{N+U-1}M\left(x_r-x_\varnothing\right)-\frac{\alpha}{N+U-1}(N-\nu)\left(x_o-x_\varnothing\right) \\ &= -\frac{\alpha}{N+U-1}\left(MS+(N-v)x_o\right).\end{aligned}$$

Using our result on the offer $\underline{x_r}$, we can back out values of v^*.

Given that the theoretically predicted offers to responders are much lower than observed in the data, it may not be surprising that theoretically predicted entry also does not conform to the data. Moreover, the qualitative pattern of entry across treatments is ambiguous: It need not be the case that higher entry is predicted in the treatment with higher surplus. Finally, we note that the degree of entry is quite sensitive to changes in α and β.

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[59] Although only the case where $x_r < x_o$ is empirically relevant, the opposite case gives utility

$$\begin{aligned}U_o(x_o,\mathbf{x_r},\mathbf{x_p},\mathbf{x_o},\mathbf{x_\varnothing}) &= x_o-\frac{\alpha}{N+U-1}M(x_p-x_o)-\frac{\alpha}{N+U-1}M(x_r-x_o)+\frac{\beta}{N+U-1}(N+U-2M)(x_\varnothing-x_o) \\ &= x_o\left(1+\frac{\alpha}{N+U-1}2M-\frac{\beta}{N+U-1}(v+U-2M)\right)-\frac{\alpha}{N+U-1}MS\end{aligned}$$

.

ERC Model

Next consider *equity, reciprocity, and competition* (ERC) preferences (Bolton and Ockenfels 2000). ERC preferences specify a motivation function $U_i(y_i, \sigma_i)$ where y_i is the payoff to player i, σ is the share of the surplus i receives, and c is the total size of the surplus. The motivation function is continuous and differentiable in both arguments, increasing and concave in own payoff, and—for a given level of y_i—maximized by an equal division of c. De Bruyn and Bolton (2008) suggest a formulation similar to

$$U_i = \begin{cases} c\left(\sigma_i - \frac{b}{2}\left(\sigma_i - \frac{1}{2}\right)^2\right) & \text{if } \sigma \leq 1/2 \\ c\sigma_i & \text{if } \sigma > 1/2 \end{cases}$$

Narrow ERC Preferences

Specifying this for narrow preferences including just the proposer and the responder, the responder gets share $\sigma_r = (c - \sigma_p c)/c$, and has preferences

$$U_i = c\left(\sigma_r - \frac{b}{2}\left(\sigma_i - \frac{1}{2}\right)^2\right) \tag{17}$$

The responder will therefore accept offers satisfying $\sigma_r > \frac{b}{2}\left(\sigma_i - \frac{1}{2}\right)^2$. Minimal offers therefore lie to the left of 1/2 and, moreover, be described by a *share* of the surplus independent of the size of the pie. This can not be reconciled to our results.

Broad ERC Preferences

To attempt to generate sensitivity to the size of the pie, we consider broad preferences for which c is the *sum of all payoffs* in the market and σ_i individual i's share of this total. Moreover, we also adjust 1/2 to $1/(N+U)$ (that is, equal division among all agents in the game is the social fairness benchmark): $U_i = c\left(\sigma_i - \frac{b}{2}\left(\sigma_i - \frac{1}{N+U}\right)^2\right)$. The share for player i will then be relative to total payoffs

$$\sigma_i = \frac{x_i}{MS + (N-v)x_o} \tag{18}$$

where the denominator is the total payoff from matches plus the value of payoffs to agents who do not enter the market. Although again the preference structure implies a constant *share*, this is of *overall* payoffs. Offers x_r will therefore vary depending on S (and v).

However, given this specification of the preferences, minimal acceptable offer for responders will be below $1/(N+U)$ (imagine the intersection between the linear component of the preferences and the quadratic portion: Minimal offers must lie to the left of $1/(N+U)$). Indeed, offers much be substantially below the social fairness level if b is specified to yield reasonable values of x_p. This specification can therefore not fit the data. More complicated ERC preferences can be engineered, but this requires additional parameters or assumptions of functional form. Another possibility is that the preferences include a stochastic element.

As an exercise, consider an empirically relevant value of σ_r in the treatment with $S = 400$. Since we expect 4 firms to enter, there will be 2 matches and 2 firms that take the outside option. Given offers of about 100 in this treatment, $\sigma_{S=400} \sim 0.1$. Similar computations for the low surplus treatment translate to $\sigma_{S=300} \sim 0.125$. Using a value of $\sigma = 0.11$ we can solve for the offers x_r using equation 18: In this case, offers of share size $1/(N+U)$ are *never rejected* and, perhaps, agents do not offer less than this in order to avoid rejections.

Empirically consistent minimal acceptable offers		
v	$S = 300$	$S = 400$
1	85.3 (0.284)	96.3 (0.241)
2	88.5 (0.295)	104.0 (0.260)
3	88.5 (0.295)	107.6 (0.269)
4	86.9 (0.290)	108.9 (0.272)
5	84.2 (0.281)	108.8 (0.272)
6	80.8 (0.269)	107.8 (0.269)

Figure 28: Minimal offers by surplus Y

Instructions and Screenshots

Instructions and screenshots can be provided upon request.