On the empirical validity of axioms in unconstrained bargaining

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Sur la validité empirique des axiomes dans la négociation sans contraintes

Résumé

Nous rendons compte des résultats expérimentaux et testons les modèles coopératifs de négociation non structurée en vérifiant la pertinence empirique des axiomes. Nos données sont cohérentes avec les axiomes d'efficacité forte, de symétrie, d'indépendance d'alternatives non-pertinentes et de monotonie et rejettent l'invariance d'échelle. L'axiome de rationalité individuelle n'est pas vérifié dans une fraction significative des ententes quand il rentre en conflit avec la solution égalitaire. Les trois solutions célèbres qui satisfont les propriétés confirmées expliquent raisonnablement bien les ententes observées. L'entente la plus fréquente dans notre échantillon est la solution égalitaire. En termes de distance Euclidienne moyenne, la solution théorique qui explique le mieux les données est la solution "deal-me-out" (de Binmore et al, 1989; Binmore et al, 1991), suivi de très près par la solution de gains égaux (Roth et Malouf, 1979). Les solutions populaires qui satisfont les axiomes d'invariance d'échelle et de rationalité individuelle, comme la célèbre solution de Nash ou la solution de Kalai-Smorodinsky, sont peu performantes dans le laboratoire.

Mots-clés : Négociation bilatérale, expériences, solution de Nash, solution égalitaire, solution "Deal-me-out", rationalité individuelle, invariance d'échelle

On the empirical validity of axioms in unconstrained bargaining

Abstract

We report experimental results and test cooperative models of unstructured bargaining by checking the empirical relevance of underlying axioms. Our data support strong efficiency, symmetry, independence of irrelevant alternatives and monotonicity, and reject scale invariance. Individual rationality is violated by a significant fraction of agreements when in conflict to implement the equal split. The three well-known bargaining solutions that satisfy the confirmed properties explain the observed agreements reasonably well. The most frequent agreement in our sample is the egalitarian solution. In terms of the average Euclidean distance, the theoretical solution that best explains the data is the deal-me-out solution (Binmore et al., 1989; Binmore et al., 1991), followed very closely by the equal-gains solution (Roth and Malouf, 1979). Popular solutions that satisfy scale invariance and individual rationality, as the well-known Nash or Kalai-Smorodinsky bargaining solutions, perform poorly in the laboratory.

Keywords: bilateral bargaining, experiments, Nash bargaining solution, egalitarian solution, deal-me-out solution, individual rationality, scale invariance

JEL: C78, C91, D63

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1. Introduction

Bargaining is ubiquitous and being good at bargaining is often considered the key to success in life. We bargain with prospective and current employers, with sellers and service providers, with editors, and even with our partners. Most of the time bargaining occurs in an unstructured (or complex) environment without pre-specified fixed rules.

Game theorists have been interested in bargaining problems since the early years (von Neumann and Morgenstern, 1944; Nash, 1950; Rubinstein, 1982). As economics has embraced the game-theoretical approach to analyzing human interaction, abstract models of bargaining have appeared embedded in more general models of industrial organization (e.g., in models of vertical integration, Church and Ware, 2000: ch.22), labor economics and macroeconomics (e.g., in models of search and matching, Cahuc and Zylberberg, 2004: ch.7), to name a few examples. The availability of formal models and testable predictions has then attracted experimental economists to studying bargaining and especially the empirical relevance of the proposed models. Bargaining has even received its own chapter in the first volume of *The Handbook of Experimental Economics* (Kagel and Roth, 1995: ch.4).

The main motivation for our study stems from the lack of consensus in the experimental literature concerning bargaining. After having received more than half a century of attention from the economics profession, bargaining remains a black box that fails to produce clear results in line with any of the reigning paradigms. Advocates of strategic thinking claim that the observed results are essentially in line with game-theoretical predictions (Binmore et al., 1985; Binmore, 2007), while at the same time, advocates of other-regarding preferences stress that social preferences organize the collected data better (Güth et al., 1982; Güth and Tietz, 1990). We believe that the experimental study of bargaining has put unjustifiably large emphasis on strategic models of sequential bargaining games and has ended up testing joint hypotheses that include the usual assumptions behind any model from non-cooperative game theory (e.g., optimization, stable preferences, clear understanding of the game) that typically remain untested. It is surprising how the handbook survey (Roth, 1995) ignores the early literature on unstructured bargaining and dedicates only two pages to it (to its shortcomings) as opposed to the structured models. In the end, it summarizes a literature that has tested and failed to find conclusive support to sequential models of bargaining.[1]

In this paper, we report experimental results on unstructured bargaining from laboratory sessions. We have designed a series of symmetric and asymmetric treatments (in terms of possible payoffs and disagreement outcomes) with a minimal set of restrictions in each of which a randomly selected pair of participants have 5 minutes to reach an agreement. Participants were allowed to interact with each other (through the computer): they could chat, send and decide over proposals in any moment during the 5-minutes frame.

This unstructured design creates an intuitive conflict situation for participants and allows us to explore bargaining behavior without having to impose and to explain a strategic environment whose successful implementation would rely on the usual payoff-bridging principle (Bardsley et al., 2009: ch.3) and participants' cognitive and strategic sophistication. One could also say that instead of relying and testing non-cooperative game-theoretical models of bargaining, we approach the bargaining problem through the axioms of cooperative models. The axiomatic approach has "a strong comparative advantage in analyzing behavior in environments whose structures cannot be observed or described precisely" (Crawford, 2003). We search for empirical support for six well-known axioms (or properties) and six of the widely-used bargaining

[1]Neelin et al. (1988), for instance, find strong regularity in observed behavior, but reject both the Stahl-Rubinstein theory (the non-cooperative workhorse model of bargaining) and the equal-split model (the simplest possible version of other-regarding behavior).

solution concepts in cooperative game theory.[2] We rely on 12 treatments that create a sequence of bargaining situations for which the analyzed solution concepts predict different sequences of bargaining outcomes.

Our approach complements the literature discussed below with data from a within-subject design (including answers to a detailed post-experimental questionnaire) that includes a variety of bargaining situations for a systematic analysis. Also, we collected our observations at Waseda University (Tokyo, Japan) and at Paris 1 University (Paris, France), in two metropoles far from each other. Surprisingly enough, our findings are robust to the underlying cultural differences.

Our experiment also aims at complementing the theoretical literature on bargaining. We wish to contribute to the so-called Nash program which consists of (i) defining a solution, (ii) identifying the properties (or axioms) of this solution, and verifying whether a set of properties uniquely identifies the solution (axiomatic characterization), and (iii) constructing a non-cooperative game that yields the proposed solution as the equilibrium outcome (strategic characterization). As "[t]heoretical analyses usually yield definite predictions only under strong assumptions, which are reasonable for some applications but unrealistic and potentially misleading for many others" (Crawford, 2003), we believe that identifying (in the experimental laboratory) the features of unstructured bargaining environments in which certain properties that characterize a theoretical solution arise more naturally is a reasonable way of extending the Nash program.[3]

Consistently with the early – and somewhat forgotten – works on symmetric, un-

[2]We consider the properties of strong efficiency, symmetry, scale invariance, individual rationality, independence of irrelevant alternatives, and monotonicity. In terms of solutions, analyze the Nash bargaining solution, the Kalai-Smorodinksy bargaining solution, agreements that are proportional to disagreement payoffs, the egalitarian solution, the equal gains solution, and the deal-me-out solution (refer to section 3 for details).

[3]The term *Nash program* was coined by Ken Binmore according to Trockel (1999). We wish to refer to its experimental extension as the *Binmore program*. Our work contributes to understanding which properties arise naturally in the lab in complex, unstructured environments, i.e., to understanding "natural justice" (Binmore, 2005).

structured bargaining environments (Nydegger and Owen 1975; Roth and Malouf 1979, 1982; Roth and Murnighan 1982; Roth et al., 1981), our data confirm strong efficiency, symmetry, independence of irrelevant alternatives and monotonicity, and rejects scale invariance. Subjects seem to have a preference for equal monetary payoffs when the opponent's payoffs are observable, and this creates conflict with scale invariance.[4]

Concerning individual rationality, we identify two tendencies in behavior in the experimental laboratory. On the one hand, consistently with previous works (Anbarci and Feltovitch 2013, 2015; Kroll et al. 2014), bargaining agreements in our sample are "under-responsive" to changes in disagreement outcomes. This possibly is due to the relatively high occurrence of equal-split agreements. Even in situations in which the equal-split agreement is not individually rational (in 5 out of our 12 treatments), a significant fraction of participants agree upon the egalitarian outcome. On the other hand, somewhat surprisingly, the equal-split agreement is rare in treatments where one of the participants would have to give away 67% or more of their disagreement payoff for an equal split. In the rest of treatments, subjects give away at most 44% of their disagreement payoff for the equal split.[5]

We conclude that bargaining solutions that satisfy strong efficiency, symmetry, independence of irrelevant alternatives and monotonicity explain reasonably well the agreements observed in the experimental laboratory. Three well-known solutions that satisfy all these properties are (i) the egalitarian solution, where both bargainers would obtain the same payoff, the (ii) deal-me-out (DMO) solution, which is the individually rational agreement that is closest to the egalitarian solution and hence coincides with the egalitarian solution when the latter is individually rational (Binmore et al., 1989;

[4]This preference for equality shows up as an equal number of tokens when participants do not know the value of those token to the opponent (Roth and Malouf, 1982).

[5]Our 12 treatments have been designed to test the overall importance of the above-mentioned six properties, and do not allow for a precise sensitivity test on individual rationality. Further research with a new design is needed to explore this cut-off value that seems to be the opportunity cost of equality or participants' willingness to pay for equality.

Binmore et al.,1991), and (iii) the equal-gains solution, that gives bargainers the same increase in payoffs compared to the disagreement payoffs (Myerson, 1977; Roth and Malouf, 1979).

The most frequent agreement in our sample is the egalitarian one, except in the treatment where one of the two parties has to give away 62% of their payoff at disagreement if they were to agree on an equal split. The egalitarian solution is followed very closely by the deal-me-out and the equal-gains solutions in terms of frequencies. When all observed agreements are taken into consideration, the theoretical solution that best explains the data (in terms of average Euclidean distance) is the deal-me-out solution, followed very closely by the equal-gains solution. Although the egalitarian solution is overall the most frequent agreement, in treatments where the egalitarian solution is not individually rational we observe that (i) the frequency of the egalitarian solution drops considerably, and (ii) the other successful agreements are mostly individually rational. These two tendencies seem to be responsible for the result that (average) Euclidean distance of successful agreements is smaller to the deal-me-out solution – which coincides with the egalitarian solution when the latter is individually rational, but is always individually rational.

In summary, the deal-me-out solution arises as a good predictor for outcomes in the unconstrained bargaining environment, just like in the much more structured and constrained setup of the alternating-offer bargaining game (Binmore et al., 1989; Binmore et al., 1991). The overall predictive success of deal-me-out depends on the opportunity cost of equality for the bargainers. When that opportunity cost is zero, deal-me-out coincides with the egalitarian solution, and when that is high enough (62% or more according to our observations), deal-me-out outperforms the egalitarian solution in terms of (average) Euclidean distance to observed agreements, while the egalitarian solution outperforms deal-me-out in terms of observed frequency.

As for the poor predictors, our experimental results dethrone the Nash bargaining solution and the Kalai-Smorodinsky solution which – to the best of our knowledge – have been used by theorists disproportionately too often. Based on casual observations, Thomson (2009) reminds us that "[t]he Nash solution satisfying many invariance conditions, it is not much of a surprise that it should have come out [in theoretical research] often. On the other hand, the monotonicity axioms that have generally led to the Kalai-Smorodinsky and egalitarian solutions are readily understood and endorsed by the man on the street." The experimental results from our 12 treatments suggest that scale invariance is yet another invariance condition that lacks strong empirical support.

As for the inclusion of the bargaining solutions into high-level models of vertical integration, and search and matching, researchers seem to prefer solutions that have the property of scale invariance because it allows to write the bargaining problem in terms of an *object* and not in terms of *payoff*. For example, in search and matching models where wages are the result of bargaining between employers and workers, the agreement reached can be invariantly expressed in terms of the wage, in terms of utility and in terms of working hours as long as the applied solution concept is scale invariant –which is the case of the Nash bargaining solution and the Kalai-Smorodinsky solution. Results and agreements could, however, change drastically if one used a scale variant solution like the egalitarian one.

2. Experimental design

We ran three sessions at LEEP, Paris 1 University (Paris, France) and three at Waseda University (Tokyo, Japan). Participants were recruited with ORSEE in Paris and through online ads on the university website in Tokyo (Greiner, 2015). Both the main experiment and the post-experimental questionnaire were implemented with zTree (Fischbacher, 2007). Participants interacted anonymously in randomly matched pairs and played 10 (in one session in Tokyo) or 12 rounds (in all three sessions in Paris and in two sessions in Tokyo) of bargaining. Our observations stem from the *usual* convenience samples: subjects were volunteer undergraduate and graduate students (except for one unemployed participant in Paris) who received monetary performance-dependent compensations for participation.[6] Each round of bargaining occurred with a new randomly and anonymously assigned partner (stranger matching). Upon arrival the participants were randomly assigned to a booth with a computer terminal and could only interact with each other through zTree. Participants read the instructions individually, then played the bargaining games and answered the questions of a survey at the end of the session before receiving their earnings in cash. The experimental sessions lasted for about 90 minutes.[7]

In our experiment, participants were owners of virtual chicken farms and earned real money by selling virtual eggs (laid by virtual hens) at a fixed price (1 euro cent in Paris, 1 yen in Tokyo) under different conditions to the experimenter. We have used the intuitive framing story of chicken farms to create some context and to make the bargaining problem easier to imagine. Participants were paid their accumulative earnings in cash (plus the show-up fee) at the end of each experimental session.

In each round, each pair of matched participants could distribute 150 (virtual) hens by reaching an agreement. They had 5 minutes to do so, during which they were allowed to send numerical proposals and also text messages to each other without any further constraint. The computer interface allowed participants to send new or withdraw earlier proposals, to accept or reject previously received proposals, and to quit bargaining at any time during the round.

At the beginning of the round, participants were randomly assigned to a farm (a role) with a number of characteristics. Farms differed in terms of technology (the number of eggs laid by each hen), taxation (egg productions was heavily taxed on

[6] Paris: 60 subjects, age 18-49 (mean 21.9), 50% male, average earnings 10.59 euros + 7 euros as show-up fee. Tokyo: 60 subjects, age 18-28 (mean 20.5), 69% male, average earnings 1123 Japanese yen plus 700 Japanese yen as show-up fee.

[7] The English translation of the experimental instructions is in Appendix AppendixA. The French and the Japanese versions, the zTree files and the collected data are freely available from the authors upon request.

certain farms if production reached a pre-specified limit), and the hens allocated in case of disagreement. In our experimental design each round corresponds to a different bargaining situation and treatment. Participants in different sessions faced the same bargaining situations in the same order. At the beginning of each round, they were informed about the characteristics of their own farm and those of the opponent. In order to keep the changing characteristics of the farm under control, the computer screen contained a profit simulator that allowed subjects to check (privately, and at any time during the round) their own earnings and their opponent's for any hypothetical agreement. Table 1 provides a summary of our treatments.

TREATMENT	EGGS PER HEN		TAX (%)		UNTAXED		OUTSIDE OPT	
(ROLE)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
1	1	1	-	-	-	-	30	30
2	1	2	-	-	-	-	30	30
3	1	2	-	66	-	150	60	60
4	2	1	-	-	-	-	90	30
5	1	2	-	-	-	-	90	30
6	2	1	66	-	150	-	30	30
7	2	1	66	-	210	-	90	30
8	1	2	66	-	45	-	30	90
9	1	2	66	-	105	-	90	30
10	2	1	66	-	90	-	30	90
11	1	1	-	-	-	-	90	30
12	1	1	66	-	75	-	30	30

Table 1: Treatment summary. EGGS PER HEN: number of eggs laid by each hen; TAX (%): tax rate; UNTAXED: maximum number of monetary units untaxed; OUTSIDE OPT: number of hens in case of disagreement.

3. The bargaining problem: definitions and hypotheses

This section introduces the theoretical solutions to the bargaining problem that we consider and their properties.[8] The formal definitions are followed by a brief explanation of the method that we use to test their empirical relevance.

A two-person bargaining problem consists of a pair (a, S), where S is a closed

[8]The presentation follows the notation from Kalai and Smorodinsky (1975).

convex subset of $\Re^2_+$, $a = (a_1, a_2)$ is a vector in $\Re^2_+$, and the set

$$S \cap \{(x_1, x_2)|x_1 \geq a_1 \text{ and } x_2 \geq a_2\}$$

is nonempty and bounded. The set S represents the set of feasible *payoff* combinations. The vector a represents the pair of payoffs in case of disagreement, and we will refer to it as the outside option payoffs or the payoffs at disagreement. We denote by $f(a, S)$ the payoff vector representing the result of the negotiation or the agreement in the bargaining problem (a, S). In theory, this function f is called a solution. The axiomatic approach to solving bargaining problems consists of defining properties of the solution (called axioms) and analyse under which conditions the listed properties are compatible and if so, how. If a list of properties pins down a unique solution, then we say that the solution is axiomatically characterized by means of the corresponding list of axioms. Nash (1950) in his seminal work proposed four properties or axioms (that characterize the so-called Nash bargaining solution):

1. *Strong efficiency*: $f(a, S)$ is a payoff vector in S, and, for any x in S, if $x \geq f(a, S)$, then $x = f(a, S)$.
2. *Symmetry*: If $a_1 = a_2$ and $\{(x_2, x_1)|(x_1, x_2) \in S\} = S$, then $f_1(a, S) = f_2(a, S)$.
3. *Scale invariance*: For any real numbers c_1, c_2, d_1, and d_2 such that $c_1 > 0$ and $c_2 > 0$, if

$$S' = \{(c_1x_1 + d_1, c_2x_2 + d_2)|(x_1, x_2) \in S\}$$

and

$$a' = (c_1a_1 + d_1, c_2a_2 + d_2),$$

then

$$f(a', S') = (c_1f_1(a, S) + d_1, c_2f_2(a, S) + d_2).$$

4. *Individual rationality*: $f(a, S) \geq a$.
5. *Independence of irrelevant alternatives (IIA)*: For any closed convex set S, if $S' \subseteq S$ and $f(a, S) \in S'$, then $f(a, S') = f(a, S)$.

Kalai and Smorodinsky (1975) suggested a monotonicity axiom as an alternative of the controversial independence of irrelevant alternatives. Let $m_i(a, S)$ denote the maximal payoff that player i can get in any feasible individually rational allocation, so

$$m_i(a, S) = \max_{x \in S, x \geq a} x_i$$

For any number z_1 such that $a_1 \leq z_1 \leq m_1(a, S)$, let $h_2(z_1, S)$ denote the highest payoff that player 2 can get in a feasible payoff vector where player 1 gets z_1. That is,

$$h_2(z_1, S) = max\{x_2 | (z_1, x_2) \in S\}$$

We can similarly define $h_1(z_2, S)$.

6 *Individual monotonicity*. If $m_1(a, S') = m_1(a, S)$ and $h_2(z_1, S') \leq h_2(z_1, S)$ for every z_1 such that $a_1 \leq z_1 \leq m_1(S, d)$ then $f_2(a, S') \leq f_2(a, S)$. Similarly, if $m_2(a, S') = m_2(a, S)$ and $h_1(z_2, S') \leq h_1(z_2, S)$ for every z_2 such that $a_2 \leq z_2 \leq m_2(a, S)$ then $f_1(a, S') \leq f_1(a, S)$.

The axioms of strong efficiency, symmetry, scale invariance, individual rationality, and individual monotonicity characterize the Kalai-Smorodinsky bargaining solution.

Beside the Nash and the Kalai-Smorodinsky bargaining solutions, we consider four additional efficient solutions:[9]

[9]These solutions are weakly efficient in the sense of Pareto, as they lie in the upper-right frontier of S but they could belong to horizontal or vertical segments of the frontier. More formally, there cannot exist a vector of utility in S that provides strictly higher utility to both bargainers than any of the solutions proposed, although for some particular shapes of S there could exist the possibility of finding a vector of utilities in S where one of the bargainers' utilities is greater than at the solution. The Nash and the Kalai-Smorodinsky bargaining solutions also satisfy strong efficiency. That is, there cannot exist a vector of utilities in S where at least one of the bargainers' utilities is greater than at the solution.

- The efficient solution that is proportional to the distribution at disagreement point whenever $a \neq (0, 0)$.
- The efficient and egalitarian solution which gives the same payoff to the bargaining parties.
- The deal-me-out solution (Binmore et al., 1989; Binmore et al.,1991) which recommends individuals to distribute resources according to the egalitarian solution as long as it does not imply one of the agents to be worse off than in the disagreement point. In that case, the agent in questions receives her disagreement payoff and the partner keeps the rest.
- The equal gains (or egalitarian in differences) solution proposes that both agents gain the same in terms of the difference of final outcome minus the disagreement distribution. Put it differently, the difference in final payoffs is equal to the difference in the payoffs at disagreement. According to Roth and Malouf (1982), this is the proportional solution with equal weights proposed by Kalai (1977), Myerson (1977), Roth and Malouf (1979) and Roth (1979a, 1979b).[10]

Each of these solutions induces a payoff distribution and satisfies a number of the properties. Table B.13 in the appendix lists the suggested bargaining outcome by each of the considered solution concepts. Note that our study does not cover all the existing bargaining solutions, nor all the existing axiomatic characterizations. We have chosen the six most frequently used bargaining solutions and their "typical" axiomatic characterization (Table 2).

In terms of our experimental design, *weak Pareto efficiency* requires that participants in each pair agree upon a distribution of all the available 150 hens. Any agreement that involves less than 150 hens would be strictly Pareto-dominated by an agree-

[10] For the cases considered in this experiment, this egalitarian in differences or proportional solution with equal weights is equivalent to the maximin solution, because the payoffs obtained by players are not truncated from above as in Roth and Malouf (1982) experiment.

SOLUTION CONCEPT	PAR EFF	INDIV RAT	SCALE INVAR	IIR	SYMM	INDIV MON
Nash BS	◯	◯	◯	◯	◯	×
Kalai-Smorodinsky BS	◯	◯	◯	×	◯	◯
proportional wrt disagr.	◯	◯	×	◯	◯	◯
egalitarian	◯	×	×	◯	◯	◯
equal gains	◯	◯	×	◯	◯	◯
deal-me-out	◯	◯	×	◯	◯	◯

Table 2: Solutions and axioms. PAR EFF: weak Pareto efficiency; INDIV RAT: individual rationality; SCALE INVAR: scale invariance; IIR: independence of irrelevant alternatives; SYMM: symmetry; INDIV MON: individual monotonicity; ◯: the solution listed in the row satisfies the axiom listed in the column; ×: the solution listed in the row does not satisfy the axiom listed in the column.

ment where all the 150 hens are distributed. In particular, disagreements are also strictly Pareto-dominated.

Symmetry requires that in a perfectly symmetrical bargaining situation (treatment 1) participants agree upon receiving an equal number of hens (75,75).

Individual rationality requires that subjects agree upon a distribution of hens that yields each of them at least the same earnings as their outside option, which is the payoff they would get in case of disagreement.

Scale invariance means that an agreement in terms of hens does not depend on scale or technology (i.e., the number of eggs per hen) obtained by each participant. In particular, we would not observe significant differences between treatments 1 and 2, between treatments 4, 5, and 11, and between treatments 6 and 12. Previous studies (e.g., Nydeggen and Owen, 1975; and Roth and Malouf 1979, 1982; Roth and Murnighan 1982) found an equality bias in agreements in unstructured bargaining environments. Moreover, this equality bias seems to depend on the information about one's own and the opponent's payoffs. In our experimental design this bias would mean that participants whose hens lay more eggs agree upon receiving a smaller number of hens so that a more equal final distribution of payoffs is obtained. We will refer to this bias as *interpersonal comparisons of utility* (ICU).

Independence of irrelevant alternatives and *individual monotonicity* are related to how the agreement depends (or does not depend) on taxes in our design. (i) If the maximum untaxed income is higher or equal than the gains one could obtain in the case of a farm with the same characteristics but without the tax, then the tax is "irrelevant" in the sense of IIA. For that reason, IIA is supported by the data as long as taxes have no significant effect on agreements in the above-mentioned cases. (ii) If, however, the maximum untaxed income is smaller than the gains one could obtain in the case of a farm with the same characteristics but without the tax, then taxes are not irrelevant according to the definition of IIA, and hence this property does not apply in these cases. Nevertheless, the property of individual monotonicity applies. Individual monotonicity, in these cases, is then supported by the experimental data if taxes have a significant effect on agreements (negative on one's own gains and positive on the opponent's gains).[11]

Note that our experiment incorporates treatments in which the outside options are increased for both agents or to only one of them (as compared to treatment 1) to check whether IIA and/or monotonicity interact/s in any way with individual rationality (Table 1). Considering the most asymmetric (unequal) cases in terms of outside options, we have designed treatments where taxes are paid by the agent with the better technology (more eggs per hen) and treatments were taxes are paid by the agent with the worse technology (less eggs per hen). This will allow us to check whether IIA or monotonicity interact with interpersonal comparisons of utility.

4. Results

Tables B.10, B.11, and B.12 in the appendix offer a summary of the outcome of our experiment by listing all observed agreements (in terms of hens) and their frequency by round and city. Except for the initial and final rounds (rounds 1 and 12) in which

[11] In our experimental design, we have set the maximum untaxed income to coincide with the earnings from the Nash bargaining solution. We will discuss in the next section that the agreements reached during the equivalent treatments without taxes are below the maximum untaxed income level except in treatments 8 and 10. Hence, taxes are theoretically irrelevant in all treatments with taxes except in treatments 8 and 10.

the equal split dominates, we observe a lot of heterogeneity. In what follows, we organize the data with the help of the theoretical solutions to the unconstrained bargaining problem and the axioms behind those solutions. We present and analyze the data from Paris and Tokyo separately. It is remarkable that the observations and main results do not differ radically across the two cities.

4.1. Pareto Efficiency

Table 3 below shows the number of agreements as a percentage of the number of bargaining pairs (first bloc of three columns) and the number of efficient agreements as a percentage of total agreements (second bloc) by treatment and city. We observe that the vast majority of bargaining pairs were able to reach an agreement, with the lowest percentages being in Paris in treatment 8 and in Tokyo in treatment 3 (both 70%). These are situations in which a distribution of hens that would yield equal payoffs to the bargaining parties is not individually rational (for one of them). Practically all observed agreements are efficient (i.e., they distribute all the 150 hens): agreements are always efficient in Tokyo and 98% of the agreements are efficient in Paris.

	AGREEMENTS			EFFICIENT AGREEMENTS		
TREATMENT	PARIS	TOKYO	ALL	PARIS	TOKYO	ALL
1	100	90	95	90	100	94.74
2	86.67	96.67	91.67	96.15	100	98.18
3	76.67	70	73.33	100	100	100
4	73.33	76.67	75	100	100	100
5	76.67	93.33	85	100	100	100
6	86.67	96.67	91.67	100	100	100
7	83.33	73.33	78.33	96	100	97.87
8	70	80	75	100	100	100
9	86.67	76.67	81.67	100	100	100
10	90	93.33	91.67	100	100	100
11	80	91.67	83.33	100	100	100
12	100	100	100	100	100	100
ALL	84.17	85.49	84.8	98.35	100	99.14

Table 3: Observed number agreements as a percentage of all possible agreements, and efficient agreements as a percentage of observed agreements.

Given that most reached agreements are efficient, understanding how and why efficiency works goes through understanding why and how participants manage to reach an agreement. Table 4 shows the result from a logit regression for agreements (the dependent variable takes value 1 if agreement is reached, and 0 otherwise). The model includes four regressors. First, we consider the possibility that differences in productivity (number of eggs per hen) could make it harder to reach an agreement (treatments 1, 11, and 12). Second, we consider the possibility that agreements are more difficult to reach if the distribution of hens that guarantees equality in payoffs is not individually rational (treatments 3, 4, 7, 8, and 11). Third, we also consider the possibility that if the number of hens at disagreement is very unequal then it could be more difficult to reach an agreement. Finally, we follow Young (1995), who argued that bargainers have a coordination problem to solve that includes to correctly anticipate what the opponent is going to agree to. Expectations about what the others do, and signaling of what one is willing to agree to are important components of one's bargaining abilities.[12] We define FIRST-OFFER SIGNAL as

$$\frac{\text{first offer to opponent - opponent's outside option}}{\text{150 - sum of outside options}}$$

in order to measure the "signal" sent by one's first proposal in the bargaining process. A very low value of this variable means that the participant is willing to fight for a deal that favors her. Larger values correspond to more generous first offers.[13]

As can be seen from Table 4, all our regressors are significant. Agreements are significantly easier to reach in treatments where either there was equal number of eggs per hen, or where distributing according to equal payoffs did not enter in conflict with individual rationality. The size of these two effects is rather large and very similar: the

[12]This might explain that bargaining happens in two stages: 1) choose the starting offer, then 2) compromise.

[13]On average, it took 2.5 minutes, 3 offers, and 5 messages to reach and agreement both in Paris and in Tokyo. Given that communication is not our primary concern in this paper, we postpone the detailed analysis of participants' interaction and focus on bargaining outcomes here.

equal number of EGGS PER HEN	2.04^{***}
	(0.50)
EQUALITY in conflict with IR	0.49^{***}
	(0.09)
diff. in OUTSIDE OPTIONS	0.99^{***}
	(0.00)
FIRST-OFFER SIGNAL	1.95^{***}
	(0.24)
CONSTANT	6.12^{***}
	(0.95)
PSEUDO R-SQUARED	0.0699
NUM. OBS.	1129

Table 4: Reaching an agreement. Dependent variable: 1 if agreement is reached, 0 otherwise. Odds ratios from logit regression. Robust standard errors clustered around participants. Estimated coefficients significantly different from zero at $^{***}1\%$, $^{**}5\%$, and $^{*}10\%$.

odds of reaching an agreement roughly double when one or the other condition holds. It is significantly easier to reach an agreement when the difference in outside options is smaller and also for participants who were sending more tempered (first-offer) signals.

All our treatments have been designed to make sure that several mutually-beneficial agreements exist, that is bargaining parties could improve upon the disagreement payoffs by simultaneously accepting such an allocation of the 150 hens in the available five-minutes bargaining time. In the majority of pairs that were unable to reach an agreement, we find that the least favored party refuses to receive less than her partner, even when the partner offers a distribution of hens that yields more monetary payoff than the disagreement outcome. We conjecture that this might be a sort of "demonstration of power" bias in unstructured bargaining environments. People are willing to sacrifice part of their payoff to avoid losing relative stakes, and (wasteful) disagreements remind the opponent that each bargaining party has veto power although exercising it might have different opportunity cost (Navarro and Veszteg, 2011).

4.2. Symmetry

The only treatment with symmetric roles in our experiment is treatment 1. Both in Paris and in Tokyo, 27 of the 30 bargaining pairs agreed on the equal distribution of hens in that situation. In Tokyo all those agreements were efficient, while in Paris 25 of them. We do not have a more plausible explanation for the few unequal and inefficient agreements than the possible first-round confusion.[14]

4.3. Individual Rationality

A bargaining agreement is said to be individually rational if both bargaining parties obtain at least as much payoff as they would enjoy without reaching an agreement. In our experiment overall, most agreements were individually rational: 80% of them in Paris, and 88% of them in Tokyo. Nevertheless, the proportion of individually rational agreements fluctuates considerably from treatment to treatment. Individually-rational agreements are minority in treatments 3, 4 and 7 in Paris, and their proportion is below 75% in those treatments even in Tokyo (Table 5).

TREATMENT	PARIS	TOKYO	ALL
1	90	100	94.7
2	100	100	100
3	47.8	52.4	50
4	27.3	52.2	40
5	100	96.4	98
6	100	100	100
7	40	72.3	55.3
8	66.7	79.2	73.3
9	96.2	100	98
10	96.3	100	98.1
11	70.8	90.9	77.1
12	100	100	100
ALL	79.5	87.7	83.4

Table 5: Proportion of individually-rational agreements.

Recall that treatments 3, 4, 7, 8, and 11 have been designed such that an egalitarian solution would not be individually rational. In particular, individual rationality would imply that in treatment 3 one of the participants obtains *at least* 120 EMU while the other earns *at most* 90 EMU. In treatments 4 and 7, one of the participants would

[14]One subject in Paris was even able to get 130 hens by an agreement that left her partner with an outcome below the disagreement level. In spite of the stranger-matching protocol and the experimenters' explicit request to keep interaction in the chat box anonymous, the participant convinced her partner that they could "re-catch later on" and balance payoffs then.

obtain *at least* 180 EMU, while the other *at most* 60 EMU. Note that in treatment 7 the maximum untaxed income for the favored participant is 210 EMU and in all those three treatments the favored participant is the one obtaining two eggs per hen.

The classical references on the bargaining problem (Nash, 1950; Nash, 1953; Kalai and Smorodinsky, 1975; Kalai, 1977) consider the property or axiom of individual rationality as too obvious to be discussed. Nash (1950), for instance, restricts the bargaining problem to the subset where both bargainers obtain a higher payoff than in their disagreement point.[15] Similarly, Kalai and Smorondinsky (1975) consider feasible agreements where both agents obtain at least their utility at disagreement: "we can disregard all the points of S that fail to satisfy this condition because it is impossible that both players will agree into such a solution" (sic, p.514, Assumption 4).

As highlighted in the analysis of efficiency above, the treatments where disagreement payoffs are very unequal have a low frequency of agreements (or efficiency). It turns out that they also have a low frequency of individual rationality. From what we read in the recorded conversations during treatments 3 and 4, most of non-individually-rational agreements in Paris were reached by pairs where the less favored participant would start the bargaining by proposing the egalitarian solution and refusing to accept anything that would give her less. This behavior is consistent with the choice of the egalitarian solution as a threat point in line with Nash (1953).[16] What is more important, individual rationality is violated as a considerable number of the favored participants (in treatments 3 and 4) *accept* proposals that give them a smaller amount of money than what they would have obtained by quitting. This is an important evidence

[15]By scale invariance then the problem gets 0-normalized, so that both agents' utility in case of disagreement is equal to 0.

[16]Although it seems natural to consider individual rationality with respect to the monetary payoffs that bargaining parties would obtain in case of disagreement, participants in our experiment were free to choose their "threat points" as imagined by Nash (1953). Nash (1953) studies a non-cooperative bargaining game where players first choose a strategy that will be used if no agreement is reached (a threat) and afterwards inform each other of their chosen threats before the non-cooperative (demand) game starts. Individual rationality would then be defined with respect to the *threat strategies* chosen by the players. In our experimental design, we assigned a number of hens to each participant in case of disagreement and these numbers were known to both players.

of that interpersonal comparisons of utility (ICU) not only disrupts scale invariance (as discussed in the next subsection) but also individual rationality (although at a minor scale). In all treatments 3, 4, 7, 8, and 11, and in both cities, there was at least one participant proposing a distribution of hens that was not individually rational, but was more egalitarian than the outside-option payoffs. In other words, at least some participants seem to have *preferences* for equality or to display inequality aversion.

In order to illustrate the above claim statistically, we define the following inequality ratio for each pair of participants i and j who reached an agreement:

$$iq = \max\left\{\frac{u_i}{u_j}, \frac{u_j}{u_i}\right\},$$

where u_i and u_j are the monetary payoffs obtained by participants i and j, respectively, according to their agreement. If this inequality ratio tend to be smaller for agreements that are not individually rational than for agreements that are, then we can confirm that participants have a taste for equality and are willing to sacrifice some monetary gains for it. Figure 1 shows the box plot of the inequality ratios for individually rational (IR) and non-individually-rational (non IR) agreements by for treatments 3, 4, 7, 8, and 11 in which the egalitarian distribution is not individually rational.

Both in Tokyo and Paris, all three quartiles of the inequality-ratio distribution are statistically different across categories (p-values: 0.000), significantly smaller for non-individually-rational agreements. This confirms our claim that when individual rationality results in very unequal distributions of money, some participants choose alternative threats to trigger quitting or to block unequal proposals from their bargaining partners, and some participants end up accepting more equal payoffs even though they could have obtained a higher payoff in case of disagreement.

In summary, individual rationality is far less of an obvious or non-problematic axiom than assumed by the seminal theoretical solutions to bargaining. Although we have found evidence for individual rationality traded off for equality by many participants,

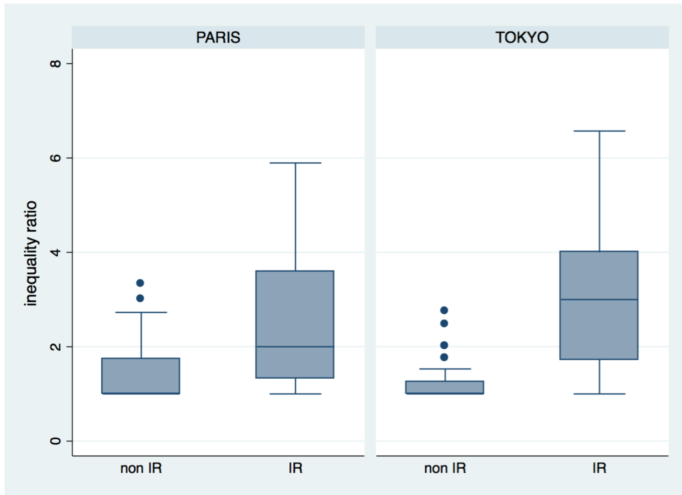

Figure 1: Equality vs. individual rationality. Box plot for agreements in treatments 3, 4, 7, 8, and 11. IR: individually rational agreements. INEQUALITY RATIO: $iq = \max\{\frac{u_i}{u_j}, \frac{u_j}{u_i}\}$.

our data also offer empirical support for individual rationality as a property because a significant number of bargaining pairs reach an individually-rational agreement even in the more asymmetric rounds. The OLS regression estimates shown in Table 6 – and discussed further in detail in the subsequent subsections – suggest that outside options have a significant effect on the final agreement and that effect has the expected sign: a higher outside option tends to increase one's number of hens at an agreement, and a higher outside option for the opponent tends to decrease it. This is in line with findings presented by Anbarci and Feltovich (2013, 2015). The coefficient that they estimate for one's own outside option is around 0.35, meaning that a higher outside option allows a subject to obtain a higher number of hens in an agreement, although the responsiveness of the outcome is considerably below 1. What our experimental findings add to these existing results is that outside options do have a significant impact on bargaining outcomes, but the size of the effect is typically rather small (0.09 of one's payoff, and -0.08 of the opponent's). It is in the most asymmetric and most extreme situations, when individual rationality would lead to a very unequal distribution of payoff, that effect size of the outside options increases to 0.34-0.35 in absolute value.[17]

4.4. Scale Invariance

In our experiment bargaining parties were required to decide how to distribute 150 hens, but it was eggs (laid by those hens) that led directly to monetary gains. The axiom of scale invariance requires the distribution of the 150 hens to be independent of changes in the the way participants derive value from hens, as long as those changes are positive affine transformation. In other words, if bargaining is about hens, for its outcome (in terms of hens) it should not matter how many eggs each of those hens lay.

We explore the effect of our treatment variables on bargaining outcomes with the help of a simple regression model. We regress the number of hens one receives in a specific bargaining round (that has ended in an agreement) on productivity (number of eggs per hen), on taxes (whether taxes are to be paid or not), and on outside options. Table 6 contains the coefficient estimates and it shows that productivity (number of eggs per hen) has a large significant negative effect on the bargaining outcome, and that the opponent's productivity has a significant positive effect of similar size. This finding is consistent with previous results that have identified a bias towards egalitarian distributions in unstructured bilateral bargaining environments (Nydegger and Owen, 1974; Roth and Malouf, 1979, 1982; Roth and Murnighan, 1982; Roth at al., 1981).

One can also make pairwise treatment-to-treatment comparisons to explore this effect.[18] For example, by comparing treatments 1 and 2, we see that in treatment 1 the large majority of participants agreed on an equal number of hens, 75, while in treatment 2 the majority settled on a distribution that gives 50 hens to the subject obtaining 2 eggs per hen (hence 100 eggs) and 100 hens to the subject obtaining 1 egg per hen (hence

[17]Note that in our treatments 3, 4, 7, 8, and 11, the effect of one's own outside option is exactly 0.35, while the effect of the opponent's is -0.34.

[18]For the pairwise comparisons, see Tables B.10, B.11 and B.12 in appendix where we report the bargaining outcomes from the laboratory by treatment and city.

also 100 eggs). If scale invariance held, we would have the majority of agreements in treatment 2 still assigning 75 hens to each bargaining party. Similarly, we see that in the majority of agreements in treatments 4, 5, and 6 the more productive (or favored) participant obtains 50 hens and the least productive subject obtains 100.

We have also compared the average agreement across treatments with the help of formal statistical tests: a parametric t-test and the non-parametric Wilcoxon rank-sum test. The pairwise comparisons between treatments 1 and 2, treatments 11 and 4, and treatments 12 and 6 show that the differences are statistically significant (p-values $<$ 0.03 for all tests and pairs). It is also true for treatments 11 and 5 (p-values < 0.05), but only in Paris. Interestingly, the average deal does not differ between treatments 11 and 5 in Tokyo (p-values > 0.70). This is probably due to the outside options which *favor* the participants with worse technology (1 egg per hen). The regression analysis reported in Table 6 controls for all our treatment variables simultaneously.[19]

EGGS PER HEN	-16.93^{***}
EGGS PER HEN opponent	18.21^{***}
TAXED	1.70
TAXED (TRTS 8&10)	-7.69^{***}
TAXED opponent	-0.66
TAXED opponent (TRTS 8&10)	7.08^{***}
OUT OPTION	0.09^{***}
OUT OPTION (TRTS IR VS. EQ)	0.26^{***}
OUT OPT opponent	-0.08^{***}
OUT OPT opponent (TRTS IR VS. EQ)	-0.26^{***}
CONSTANT	71.81^{***}
R-SQUARED	0.5860
NUM. OBS.	1160

Table 6: Explaining the final agreement. Dependent variable: number of hens obtained in the agreement. OLS coefficient estimates. Robust standard errors clustered around participants. Estimated coefficients significantly different from zero at $^{***}1\%$, $^{**}5\%$, and $^{*}10\%$.

[19]We have checked the robustness of our regression results with a subject-specific fixed-effects model, a subject-specific-random effects model, and a restricted Tobit model. As compared to the discussed OLS results, the changes in the estimated coefficients and their statistical significance are very small. Refer to Table B.17 in the appendix for further details.

4.5. Independence of Irrelevant Alternatives and Monotonicity

The coefficient estimates from the very same regression model (Table 6) indicate that taxes generally have no significant impact on bargaining outcomes except in treatments 8 and 10, where the effect is of a loss of almost 8 hens (when one is required to pay tax). In order to see why treatments 8 and 10 are special, recall that taxes in our experiment were calibrated for the Nash bargaining solution (which does not typically yield the same result as the egalitarian solution) in such a way that the (Nash) bargaining solution without tax remains a feasible option even after the introduction of the tax. As we have argued in the introduction, the bargaining outcomes observed in the laboratory are closer to the deal-me-out solution and to the egalitarian solution than to the Nash bargaining solution. Given that our treatments to test the property of independence of irrelevant alternatives have been calibrated for the Nash bargaining solution, it could be the case that the observed bargaining outcomes in treatments without tax are infeasible in the corresponding treatment with tax (and taxes are therefore not irrelevant). It turns out, however, that it is not the case, except for treatments 8 and 10, which we use to test monotonicity. Note, for example, that the egalitarian solution yields 100 eggs to each participant in the treatments where one of the participants can obtain two eggs per hen. Treatments 8 and 10 have a maximal untaxed number of eggs of 45 and 90, respectively, so that an agreement in which both participants obtain 100 eggs is simply impossible.

For these reasons, if independence of irrelevant alternatives is satisfied, the tax should have no impact on the bargaining outcomes, except again for treatments 8 and 10. If individual monotonicity holds, in those two treatments the participant who is required to pay tax has to receive less than in similar situations without the tax. The results of the regression analysis reported in Table 6 support both properties; our data are in line with the axiom of independence of irrelevant alternatives and the axiom of individual monotonicity.

A treatment-to-treatment comparison of the modal agreement leads to the very same conclusions (for more details refer to Tables B.10, B.11 and B.12 in Appendix AppendixB). For example, treatments 1 and 12 are identical except that in the latter one of the bargaining parties is required to pay a tax if she receives more than 75 hens (and eggs). We observe that, in these two treatments, the overwhelming majority of agreements in Paris and all the agreements in Tokyo were the equal share that in these cases coincides with the Nash bargaining solution. Similarly, by comparing treatment 2 to treatments 3 and 6, we observe that at least half of the pairs agree to obtain an equal number of eggs (and equal monetary earnings) in both cities in treatment 2, while at least a third (but less than half) of the pairs agree on such a distribution of hens in both cities in treatments 3 and 6. The egalitarian solution remains modal also in treatments 4 and 7 (except in Tokyo), and also in 5 and 9.

As for individual monotonicity, that is treatments 8 and 10, note that in treatment 4 the bargaining party who obtains one egg per hen gets more than 45 eggs in practically all agreements.[20] Recall, however, that the tax limit for the participant obtaining one egg per hen in treatment 8 is 45. This means that the tax is not irrelevant, it does remove relevant alternatives from the bargaining set. Similarly, note that in all the agreements in treatment 5 the participant obtaining two eggs per hen gets more than 90 eggs in the overwhelming majority of agreement, but the tax limit in round 10 is 90 for that participant.[21]

Pairwise comparisons confirm monotonicity by looking at the modal structure. In treatment 4, the egalitarian solution (where each participant obtains 100 eggs) is the most frequent one. In treatment 8, the taxpayer obtains at most about 70 eggs from 115 hens (close to the egalitarian solution for that treatment). In treatment 5 the egalitarian

[20]The exceptions are 1) one agreement in Paris giving exactly 45 eggs, and 2) another agreement also in Paris giving 40 eggs to the participant obtaining one egg per hen.

[21]The exceptions are 1) two agreements in Paris and 2) four agreements in Tokyo giving exactly 45, 3) one agreement in Paris and 4) one agreement in Tokyo giving 40, and 5) one agreement in Tokyo giving 41 to the participant obtaining two eggs per hen.

solution, where both participants obtain 100 eggs, is agreed upon in the vast majority of deals. In treatment 10, the taxpayer obtains at most about 97 eggs from 55 hens (the egalitarian solution for that treatment), except one agreement in Paris where the taxpayer obtained 127 eggs from 100 hens.

Just like in the subsection of scale invariance, we have also compared the average agreement across treatment with the help of formal statistical tests for each city separately: a parametric t-test and the non-parametric Wilcoxon rank-sum test. The pairwise comparisons show no statistically significant differences in the average agreements between treatments 1 and 12 (except for role A in Paris, where the p-values are 0.04 for the t-test and 0.18 for the Wilcoxon test), and treatments 2 and 3, 2 and 6, 4 and 7, and 5 and 9 (except for Tokyo, where the p-values are 0.10 for the t-test and 0.06 for the Wilcoxon test). As for individual monotonicity, the pairwise comparisons show statistically significant differences in the average agreements between treatments 4 and 8 (with p-values < 0.10 in both cities and tests), and 5 and 10 in Tokyo (p-values $<$ 0.03). In Paris, the latter two treatments produced statistically identical agreements on average (p-values > 0.40). As noted earlier, although these pairwise comparisons offer some informative insights into our database, it is the regression analysis reported above that controls for all our treatment variables simultaneously and that is able to offer a "clean" test for the empirical relevance of the studied axioms.

5. A solution to the bargaining problem?

Our data confirm the empirical relevance of the axioms of strong efficiency, symmetry, independence of irrelevant alternatives, and monotonicity. Scale invariance is invalidated. As for individual rationality, it is supported by the data in treatments where the disagreement payoffs are not asymmetric. However, treatments with very asymmetric disagreement payoffs produce a large heterogeneity in agreements, together with a low frequency of individually-rational agreements. These features of the data make it difficult to construct a model based on a “representative pair of agents” and a “universal solution” in line with the existing theoretical literature that typically explores and links its solution concepts to a certain combination of (characteristic) properties. What we can do is to identify a set of solutions that satisfy the empirically supported properties (i.e., strong efficiency, symmetry, independence of irrelevant alternatives, and monotonicity). This set includes the egalitarian solution, which is not individually rational, and the deal-me-out and the equal-gains solutions, which are both individually rational.

PARIS		TOKYO	
SOLUTION CONCEPT	DISTANCE	SOLUTION CONCEPT	DISTANCE
deal-me-out	13.16	deal-me-out	11.52
egalitarian	17.67	equal gains	14.57
equal gains	18.42	Kalai-Smorodinsky BS	16.75
Nash BS	20.66	Nash BS	17.14
Kalai-Smorodinsky BS	20.69	egalitarian	20.68
proportional wrt disagr.	26.51	proportional wrt disagr.	22.65

Table 7: Empirical explanatory power of theoretical solution concepts measured by the average Euclidean distance (from observed agreements). Solutions sorted from higher to lower explanatory power for each city.

Instead of looking at and testing the underlying properties, we now look at the empirical relevance of the theoretical bargaining solutions directly by computing their (average) Euclidean distance to observed agreements. Table 7 shows the ranking for the two cities separately. The deal-me-out solution outperforms all the other solutions that we have considered. The equal-gains solution comes overall second, while the egalitarian solution, although it is the second best in Paris, performs very poorly under this measure in Tokyo, and ranks overall third. If we focus on treatments 3, 4, 7, 8, and 11, the “difficult” ones in which equality and individual rationality are in conflict, the ranking is similar: deal-me-out leads, equal-gains follows outperforming the egalitarian solution (refer to Tables B.14 and B.15 in Appendix AppendixB for the Euclidean distances by treatment in Paris and Tokyo, respectively). Even if we consider the other seven, “less difficult” treatments, the deal-me-out solution wins the race tied with the egalitarian solution, followed by the equal-gains.

Although it is not the center of the empirical distribution of agreements (as measured by the Euclidean distance), the egalitarian solution is the modal outcome and hence constitutes an important focal point. Table 8 shows the ranking of solutions according to their frequency with which they coincide with observed agreements. Note that percentages add up to more than a hundred because in some treatments different solutions yield the same result.

PARIS		TOKYO	
SOLUTION CONCEPT	% FREQ.	SOLUTION CONCEPT	% FREQ.
egalitarian	52.32	egalitarian	43.68
deal-me-out	42.35	deal-me-out	41.88
equal gains	25.50	Nash BS	25.63
Nash BS	24.83	equal gains	23.47
proportional wrt disagr.	19.54	proportional wrt disagr.	18.05
Kalai-Smorodinsky BS	11.26	Kalai-Smorodinsky BS	13.00

Table 8: Empirical explanatory power of theoretical solution concepts measured by their observed frequency. Solutions sorted from higher to lower explanatory power for each city.

The three solutions that satisfy the properties supported by the data (egalitarian, deal-me-out, and equal-gains solutions) together account for almost 67% of all successful agreements in Paris (202 out of 302) and for almost 60% in Tokyo (165 out of 277). Given that the analyzed 12 treatments do not cover all possible cases that our treatment variables can generate, nor constitute a balanced collection, it is useful to look at what happens from treatment to treatment (refer to Table B.13 in Appendix AppendixB for more data). Note that the treatments in which at least half of the agreements can be identified by one of the considered solutions are treatments 1, 2, 3, 5, 6 (almost half), 9, and 12. In these situations, the egalitarian solution performs very well. In treatments 4, 7, 8, and 11, the considered solutions do not account for even half of the agreements. Recall that these are our "difficult" treatments. For example, treatment 11 creates a situation in which both participants obtain one egg per hen, and the number of hens at disagreement are 90 and 30. Treatments 4, 7, and 8 are such that the participants obtaining two eggs per hen has 90 hens at disagreement. Neither of the three solutions that have egalitarian flavor seem to perform well here (deal-me-out, equal gains, or egalitarian). More interestingly, treatments 3, 4, 7, 8, and 11 are the treatments were the deal me-out and the egalitarian solutions would yield different agreements. Except for treatment 8, egalitarian agreements are more frequent than deal-me-out agreements, and egalitarian agreements are the most frequent of the solutions considered. Table 9 below shows payoffs at disagreement, at the egalitarian solution, and at the deal-me-out solution for treatments 3, 4, 7, 8, and 11.

Treatment 8 yields the exact same inequality at disagreement as treatments 4 and 7. What makes treatment 8 different is that the participant who accepts to earn less payoff for the sake of equality sacrifices more monetary units than in any other treatments. In treatments 4 and 7 the favored participant at disagreement would give away 80 EMU in Paris and 80 EMU in Tokyo in order to accept an egalitarian solution, while in treatment 8 this amount would be of 122 EMU. In treatment 3, it would be only 20 EMU. In percentage terms, accepting the egalitarian solution in treatments 4 and 7 implies giving away 44% of the disagreement payoff, in treatment 8 it is 62%, and in treatment 3 it is 17%. The egalitarian solution in treatment 3 accounts for half of the successful agreements (the two cities together), for less than half in treatments 4 and 7 (31% and 21%, respectively), and finally for less than 10% in treatment 8 (no egalitarian agreement in Tokyo in treatment 8). We conjecture that individuals that have preferences for equality over individual rationality are willing to agree on an egalitarian deal as long as the amount that has to be given away (as compared to the disagreement payoff) is small.

TREATMENT	DISAGR	EGAL	DMO
3	60 - 120	100 - 100	90 - 120
4	180 - 30	100 - 100	180 - 60
7	180 - 30	100 - 100	180 - 60
8	30 - 180	68.67 - 68	50 - 180
11	90 - 30	75 - 75	90 - 30

Table 9: Payoffs at disagreement (DISAGR), at the egalitarian solution (EGAL), and at the deal-me-out solution (DMO) in the "difficult" treatments.

Additional axioms, like the property of strong individual rationality (Myerson 1977) could be helpful in differentiating among the three egalitarian solutions.[22] The equal gains solution satisfies both strong individual rationality and the (weak) individual rationality considered above. The deal-me-out solution does not satisfy strong individual rationality but satisfies individual rationality. And, finally, the egalitarian solution does not satisfy either type of individual rationality. In our database, 77% of all agreements is strongly individually rational, and only 7% is weakly individually rational without being strongly so as well (refer to Table B.16 in Appendix AppendixB). As discussed earlier, individual rationality varies considerably across treatments. Treatments 3, 4, 7, 8, and 11 which put individual rationality to a serious test, have a much larger (9-23%) proportion of agreements that are only weakly individually rational, but those agreements still remain a minority. Although this argument is not conclusive, it supports the equal gains solutions and the egalitarian solution based on the axiom of individual rationality.

For an alternative measure of the empirical success of the analyzed solution concepts, we have regressed the observed bargaining outcomes on the predicted ones.[23] Interestingly, when all six solution concepts are included in the analysis, the ones that contribute significantly to explaining the observed outcomes are the egalitarian solution, deal-me-out, and the Kalai-Smorodinsky solution (in decreasing order of explanatory power). We reach the same conclusion after the stepwise backward removal of insignificant regressors. When considering the solutions characterized by the previously confirmed axioms, we find that the ranking (in decreasing order) is: egalitarian solution, the equal-gains solutions, and finally deal-me-out. Combinations of the an-

[22]Intuitively, a solution satisfies strong individual rationality if both agents strictly gain from the agreement as compared to outside options whenever there are strict gains from agreeing. In other words, a solution satisfies strong individual rationality if it is individually rational and yields *strictly* higher payoffs than outside option payoffs to both agents whenever outside option payoffs are strictly Pareto dominated in S.

[23]Table B.18 in Appendix AppendixB reports the estimated coefficients and the results of the analysis of covariance.

alyzed solution concepts manage to explain roughly 56% of the observed variation in bargaining outcomes.

All the discussed solutions, except for the solution that is proportional to disagreement payoffs, have asymmetric versions where players have an exogenously determined weight (or some sort of bargaining power). For example, the egalitarian solution has an asymmetric version where bargainers obtain payoffs u_i and u_j on the Pareto frontier of the bargaining problem (i.e., an efficient agreement) and such that the ratio $\frac{u_i}{u_j}$ is equal to the ratio of the corresponding exogenously given weights. According to the asymmetric version of the equal-gains solution, bargainers obtain payoffs u_i and u_j on the Pareto frontier of the bargaining problem such that the ratio $\frac{u_i - a_i}{u_j - a_j}$, where a_i and a_j are the corresponding disagreement payoffs, is equal to the ratio of the corresponding weights. One's bargaining power or weight can, for example, be written as $p_i = \frac{u_i - a_i}{(u_i - a_i) + (u_j - a_j)}$ (Kalai, 1977). For this definition to make sense, we can only use observations with individually rational agreements. Given the observed frequency of egalitarian and equal-gains agreements, it is not surprising that the empirical distribution of Kalai's measure for bargaining power peaks at 50%. The distribution is symmetric (somebody's gain is somebody else's loss) and extreme values are rare (refer to the histogram in Figure B.2 in the appendix).

As opposed to economic or market power, bargaining power is typically defined with the help of bargaining outcomes (Bowles and Gintis, 2007). The danger of estimating the theoretical power indices from data is that ex post any efficient outcome can be rationalized. There is little value in fitting or calibrating a sufficiently flexible model to empirical observations if those estimates do not carry over across different (bargaining) situations.[24] Recall that we have observed our participants making decisions in a number of bargaining situations (with randomly assigned partners). We

[24]This is a serious problem that behavioral and experimental economics are reluctant to acknowledge. An illustration of the problem and a notable treatment, for example, is offered by Hargreaves Heap et al. (2014).

propose to measure bargaining power with the subject-specific fixed effects from a regression model that includes the same dependent and independent variables as the one reported in Table 6.[25] Apart from offering a robustness check for our statistical results, this approach considers all the observed agreements (including those that are not individually rational) when computing a proxy for bargaining power which essentially is an individual-specific fixed number (of hens) that can not be explained by our treatment variables (refer to the histogram in Figure B.3 in the appendix). With this approach the modal value for bargaining power remains 0, and an advantage or disadvantage of more than 5 hens (out of 150) is extremely rare. In summary, we do not find empirical support for the extensive use of asymmetric solution concepts for unconstrained bargaining problems.

Although our experimental design in unable to pin down a single best egalitarian solution (among the three considered), the empirical evidence that we report here suggests that the egalitarian solutions are more successful in organizing behavior in the laboratory than the frequently-used Nash and Kalai-Smorodinsky solutions. This finding has important implications for the conclusions and predictions of models that embed a bargaining problem (refer to the literature review in the introduction). Checking the extent of these implications is beyond the scope of this paper, but we have reconsidered the popular model by McDonald and Solow (1981) and recalculated its wage predictions which arise from bargaining between a firm and a trade union. Refer to appendix AppendixC for details.

6. Concluding Remarks

We have analyzed data from a series of experiments in Paris and Tokyo on unstructured bilateral bargaining with symmetric and asymmetric treatments. Our experimen-

[25]The Hausman test suggests the use of a fixed effects instead of a mixed effects at any usual significance level (p-value = 0.0000).

tal design allows us to check well-known properties proposed by Nash (1950, 1953) and Kalai and Smorodinsky (1975). In light of the observed agreements, we conclude that solutions that best explain the data are the ones that satisfy the axioms of strong efficiency, symmetry, independence of irrelevant alternatives, monotonicity, and that do not satisfy scale invariance. As for individual rationality, we have not found such a clear-cut conclusion. A significant proportion of our participants seem to display preferences for equality over individual rationality. From what is observed in the relevant treatments, where equality comes into conflict with individual rationality, these preferences for equality depend on the amount of money that the favored subject has to give away. According to our data, it seems that if equality does not impose an opportunity cost higher than (around) 45% of the disagreement payoff, then almost half of successful deals are not individually rational and are more egalitarian than the individually rational ones. In those treatments, the deal-me-out and the egalitarian solutions organize well the observations from the laboratory. Whether it is one or the other that explains the agreements depends on how strongly the favored participant cares for equality. If accepting equality implies that she has to give away more than 62% of her disagreement payoff (treatment 8), then individual rationality is a binding property. For those cases the agreement proposed by the deal-me-out solution seems to represent best how the bargaining problem is solved, followed closely by the equal-gains solution, which is also individually rational and satisfies the properties with empirical support listed above.

In summary, bargaining situations with very unequal disagreement payoffs pose a challenge to the involved parties who would be more or less willing to trade off individual rationality for equality. Given the modality of the egalitarian solution, we speculate that bargaining is often about in which direction and how far to deviate from the split that guarantees the same payoff to the involved parties. Highly asymmetric outside options could justify large deviations (in line with individual rationality), however the weaker bargaining party might fail to recognize or acknowledge that, and consequently bargaining could break down. Our experimental data show a significant increase in the number of disagreements in treatments where the disagreement payoffs are very unequal. Although rejection is wasteful, it might be a last resort unless one is willing to lose stake. This "demonstration of power" effect is similar to what we found in structured (ultimatum-style) bargaining environments (Navarro and Veszteg, 2011). A fine-tuned experimental design could confirm or refute this claim of ours, and could measure people's willingness to pay for equality.

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AppendixA. Instructions

This is the original set of instructions in English based upon which the Japanese and French translations were made. The screenshot included here is in French.

Welcome to our experiment!

You are about to participate in an experiment, which will help us to study decision-making and economic behavior. In this experiment, we will first ask you to read the instructions that explain the rules. Then you will be asked to make a series of decisions that will allow you to earn money. Your earnings will depend on the decisions you made and the decisions of others.

We will pay you at the end of the experiment in cash. Your identity, decisions and earnings will be kept strictly anonymous and confidential.

It is important that you remain silent and do not look at other people's work. If you have any questions or need assistance of any kind, please raise your hand, and an experimenter will come to you. If you talk, exclaim out loud, etc., you will be asked to leave and you will forfeit your earnings.

This experiment consists of 10 rounds and interaction will take place in randomly formed pairs. The computer will randomly assign you a partner in each round.

You are going to face similar decision-making scenarios in each round.

The general environment

You and your partner are asked to imagine that you each own a chicken farm. Your goal is to sell imaginary eggs to the experimenter produced by imaginary hens on your imaginary farm. You will receive 1 real Japanese yen for each imaginary egg that you produce and sell during the experiment.

Your earnings are going to depend on the number of hens you have on your farm, on the number of eggs each hen lays and on the amount of tax that you might be required to pay.

At the beginning of each round, the computer will randomly assign a farm with some particular characteristics (number of eggs each hen lays and the amount of tax) to you and to your partner. Note that your farm might have different characteristics from those of your partner. At the beginning of each round, you will be informed about the characteristics both of your farm and your opponent's.

Your decision task in each round is to reach an agreement with your partner on how to allocate 150 hens between your farm and your partner's farm. You are going to have at most 5 minutes in each round to reach an agreement.

If you are unable to reach an agreement, you and also your partner are going to be assigned a certain fixed number of hens. Note that the number of hens that your partner gets, if you do not reach an agreement, may be different from the number of hens that you get. Also, these numbers may change from round to round. At the beginning of each round, you will be informed about these numbers.

The details of your task

Let's imagine, for example, that each hen on your farm lays 2 eggs and that you are required to pay some tax to the government if the value of eggs that your farm produces exceeds a certain limit. Imagine that this limit for non-taxable income is 100 yen and that you are required to give 1/3 of the excess above 100 yen to the government.

Under these circumstances, if you had 50 hens, they would lay 2 * 50 = 100 eggs which is worth 100 yen. Given that this does not pass the limit of 100 yen, you would not have to pay tax to the government. So in the end, you would earn 100 yen.

If you had 110 hens, however, they would lay 2 * 110 = 220 eggs which is worth 220 yen. This does pass the limit of 100 yen, therefore you would be required to give (220 – 100) * 1/3 = 40 yen to the government. So in the end, you would earn 180 yen.

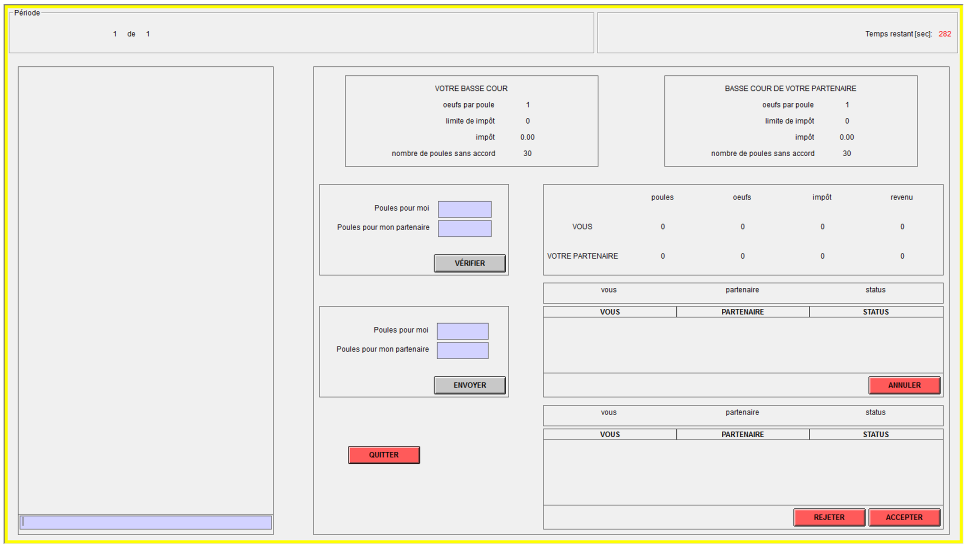
The details of the computer screen

The picture below shows an example of the computer screen that you and your partner will see in each round of this experiment. The two tables on the top specify the characteristics of your farm and your partner's. These characteristics are eggs per hen, limit of non-taxable income, tax rate, and the number of hens you get in case you do not reach an agreement. Remember that these characteristics may change from round to round, and that your partner is going to see the same information on her screen.

Remember that in each round you have 150 hens to assign between the two farms. If you would like to check the consequences of a specific split in terms of eggs, tax to be paid and final earnings, you can use the purple cells that appear in the center of the screen right above the CHECK button. Simply enter two numbers in the purple cells, click on the CHECK button and the numbers of the table on the right will automatically be updated. Note that this information is private. Your partner will not be informed about the splits that you check this way.

If you would like to send a proposal to your partner, enter two numbers in the purple cells above the SEND PROPOSAL button and click on the button. Your partner will immediately see your proposal on her screen and can decide whether to accept it or reject it. Your proposal will also appear in a table on your screen and you may cancel it as long as your partner has not yet accepted or rejected it. Proposals can be sent without any restriction at any moment in time, but remember that you have a limited 5 minutes to reach an agreement.

If your partner sends you a proposal, it will immediately appear in the table at the bottom of the screen. If you would like to accept or reject it, select it first and then click on the button of your choice.



Note that the round ends as soon as a proposal has been accepted or if you run out of time (the remaining time is displayed in seconds in the upper right corner of your screen). You can also abandon the screen (and the round) without any agreement before the time is over by clicking on the QUIT WITHOUT AGREEMENT button.

You are allowed to chat with your partner during the experiment. The left part of the screen is a chat box. You can type freely in the long purple cell at the bottom of this box and send your message by hitting ENTER on the keyboard. Please do not reveal your identity (your name, your e-mail address or phone number) while chatting. Do not forget that you will have to choose the correct keyboard setting when entering text in the chat box and when entering numbers for a proposal.

AppendixB. Additional tables and figures

TREATMENT 1				TREATMENT 2			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
75 - 75	25 / 30	75 - 75	27 / 30	50 - 100	15 / 30	50 - 100	20 / 30
50 - 100	1 / 30	N/A	3 / 30	60 - 90	3 / 30	75 - 75	3 / 30
20 - 130	1 / 30			75 - 75	2 / 30	60 - 90	1 / 30
35 - 35	1 / 30			70 - 80	1 / 30	64 - 86	1 / 30
15 - 15	1 / 30			80 - 70	1 / 30	63 - 87	1 / 30
60 - 0	1 / 30			74 - 76	1 / 30	70 - 80	1 / 30
				65 - 85	1 / 30	80 - 70	1 / 30
				51 - 99	1 / 30	100 - 50	1 / 30
				50 - 50	1 / 30	N/A	1 / 30
				N/A	4 / 30		
TREATMENT 3				TREATMENT 4			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
100 - 50	12 / 30	100 - 50	10 / 30	50 - 100	8 / 30	50 - 100	6 / 30
90 - 60	5 / 30	90 - 60	5 / 30	60 - 90	2 / 30	100 - 50	5 / 30
75 - 75	3 / 30	75 - 75	3 / 30	90 - 60	2 / 30	90 - 60	4 / 30
80 - 70	2 / 30	85 - 65	2 / 30	100 - 50	2 / 30	65 - 85	1 / 30
76 - 74	1 / 30	80 - 70	1 / 30	75 - 75	2 / 30	95 - 55	1 / 30
N/A	7 / 30	N/A	9 / 30	110 - 40	1 / 30	75 - 75	1 / 30
				105 - 45	1 / 30	92 - 58	1 / 30
				65 - 85	1 / 30	60 - 90	1 / 30
				58 - 92	1 / 30	93 - 57	1 / 30
				80 - 70	1 / 30	58 - 92	1 / 30
				70 - 80	1 / 30	87 - 63	1 / 30
				N/A	8 / 30	N/A	7 / 30

Table B.10: Bargaining outcomes from treatments 1 to 4. N/A indicates that no agreement was reached.

TREATMENT 5				TREATMENT 6			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
100 - 50	19 / 30	100 - 50	14 / 30	50 - 100	14 / 30	50 - 100	12 / 30
105 - 45	2 / 30	105 - 45	4 / 30	60 - 90	4 / 30	75 - 75	5 / 30
110 - 40	1 / 30	90 - 60	2 / 30	90 - 60	2 / 30	65 - 85	3 / 30
101 - 49	1 / 30	95 - 55	2 / 30	65 - 85	2 / 30	60 - 90	3 / 30
N/A	7 / 30	110 - 40	1 / 30	85 - 65	1 / 30	55 - 95	2 / 30
		98 - 52	1 / 30	53 - 97	1 / 30	59 - 91	1 / 30
		99 - 51	1 / 30	70 - 80	1 / 30	70 - 80	1 / 30
		104 - 46	1 / 30	55 - 95	1 / 30	40 - 110	1 / 30
		109 - 41	1 / 30	N/A	4 / 30	51 - 99	1 / 30
		75 - 75	1 / 30			N/A	1 / 30
		N/A	2 / 30				

TREATMENT 7				TREATMENT 8			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
50 - 100	6 / 30	90 - 60	5 / 30	60 - 90	6 / 30	45 - 105	4 / 30
75 - 75	5 / 30	100 - 50	4 / 30	50 - 100	3 / 30	50 - 100	3 / 30
100 - 50	4 / 30	50 - 100	4 / 30	115 - 35	2 / 30	110 - 40	2 / 30
90 - 60	3 / 30	95 - 55	3 / 30	45 - 105	2 / 30	60 - 90	2 / 30
95 - 55	2 / 30	70 - 80	2 / 30	40 - 110	1 / 30	40 - 110	2 / 30
60 - 90	2 / 30	97 - 53	1 / 30	105 - 45	1 / 30	55 - 95	2 / 30
80 - 60	1 / 30	91 - 59	1 / 30	90 - 60	1 / 30	47 - 103	2 / 30
80 - 70	1 / 30	110 - 40	1 / 30	38 - 112	1 / 30	35 - 115	1 / 30
97 - 53	1 / 30	105 - 45	1 / 30	100 - 50	1 / 30	50 - 100	1 / 30
N/A	5 / 30	N/A	8 / 30	70 - 80	1 / 30	112 - 38	1 / 30
				75 - 75	1 / 30	90 - 60	1 / 30
				53 - 97	1 / 30	80 - 70	1 / 30
				N/A	9 / 30	57 - 93	1 / 30
						54 - 96	1 / 30
						N/A	6 / 30

Table B.11: Bargaining outcomes from treatments 5 to 8. N/A indicates that no agreement was reached.

TREATMENT 9				TREATMENT 10			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
100 - 50	18 / 30	100 - 50	11 / 30	50 - 100	10 / 30	45 - 105	8 / 30
95 - 55	2 / 30	105 - 45	6 / 30	45 - 105	6 / 30	40 - 110	6 / 30
105 - 45	2 / 30	110 - 40	2 / 30	54 - 96	5 / 30	54 - 96	4 / 30
90 - 60	1 / 30	90 - 60	1 / 30	40 - 110	2 / 30	50 - 100	4 / 30
103 - 47	1 / 30	106 - 44	1 / 30	55 - 95	1 / 30	55 - 95	1 / 30
102 - 48	1 / 30	103 - 47	1 / 30	47 - 103	1 / 30	53 - 97	1 / 30
0 - 150	1 / 30	50 - 100	1 / 30	53 - 97	1 / 30	52 - 98	1 / 30
N/A	4 / 30	N/A	7 / 30	100 - 50	1 / 30	48 - 102	1 / 30
				N/A	3 / 30	39 - 101	1 / 30
						31 - 109	1 / 30
						N/A	2 / 30

TREATMENT 11				TREATMENT 12			
PARIS		TOKYO		PARIS		TOKYO	
DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.	DEAL	FREQ.
75 - 75	6 / 30	100 - 50	3 / 12	75 - 75	28 / 30	75 - 75	12 / 12
105 - 45	4 / 30	105 - 45	2 / 12	70 - 80	2 / 30		
100 - 50	4 / 30	95 - 55	2 / 12				
90 - 60	3 / 30	96 - 54	1 / 12				
110 - 40	2 / 30	110 - 40	1 / 12				
95 - 55	2 / 30	103 - 47	1 / 12				
93 - 57	1 / 30	75 - 75	1 / 12				
102 - 48	1 / 30	N/A	1 / 12				
87 - 63	1 / 30						
N/A	6 / 30						

Table B.12: Bargaining outcomes from treatments 9 to 12. N/A indicates that no agreement was reached.

treatment 1			
solution		Paris	Tokyo
all	75 - 75	25 / 30	27 / 27

treatment 2			
solution		Paris	Tokyo
Nash, KS, prop	75 - 75	2 / 26	3 / 29
egal, DMO	50 - 100	15 / 26	20 / 29
EQG	60 - 90	3 / 26	1 / 29

treatment 3			
solution		Paris	Tokyo
Nash, prop	75 - 75	3 / 23	3 / 21
egal	100 - 50	12 / 23	10 / 21
DMO	90 - 60	5 / 23	5 / 21
EQG	80 - 70	2 / 23	1 / 21
KS	78 - 72	0 / 23	0 / 21

treatment 4			
solution		Paris	Tokyo
Nash, KS	105 - 45	1 / 22	0 / 23
egal	50 - 100	8 / 22	6 / 23
DMO	90 - 60	2 / 22	4 / 23
EQG	100 - 50	2 / 22	5 / 23
prop	113 - 38	0 / 22	0 / 23

treatment 5			
solution		Paris	Tokyo
Nash, KS	105 - 45	2 / 23	4 / 28
egal, DMO	100 - 50	19 / 23	14 / 28
EQG	110 - 40	1 / 23	1 / 28
prop	113 - 38	0 / 23	0 / 28

treatment 6			
solution		Paris	Tokyo
Nash, prop	75 - 75	0 / 26	5 / 29
egal, DMO	50 - 100	14 / 26	12 / 29
EQG	60 - 90	4 / 26	3 / 29
KS	66 - 84	0 / 26	0 / 29

treatment 7			
solution		Paris	Tokyo
Nash	105 - 45	0 / 25	1 / 22
egal	50 - 100	6 / 25	4 / 22
DMO	90 - 60	3 / 25	5 / 22
EQG	100 - 50	4 / 25	4 / 22
KS	102 - 48	0 / 25	0 / 22
prop	114 - 36	0 / 25	0 / 22

treatment 8			
solution		Paris	Tokyo
Nash	45 - 105	2 / 21	4 / 24
prop	38 - 112	1 / 21	0 / 24
egal	116 - 34	0 / 21	0 / 24
[egal]	[115 - 35]	[2 / 21]	[0 / 24]
DMO	60 - 90	6 / 21	2 / 24
EQG	51 - 99	0 / 21	0 / 24
[EQG]	[50 - 100]	[3 / 21]	[3 / 24]
KS	108 - 42	0 / 21	0 / 24

treatment 9			
solution		Paris	Tokyo
Nash	105 - 45	2 / 26	6 / 23
KS	102 - 48	1 / 26	0 / 23
egal, DMO	100 - 50	18 / 26	11 / 23
EQG	111 - 39	0 / 26	0 / 23
[EQG]	[110 - 40]	[0 / 26]	[2 / 23]
prop	114 - 36	0 / 26	0 / 23

treatment 10			
solution		Paris	Tokyo
Nash	45 - 105	6 / 27	4 / 28
prop	38 - 112	0 / 27	0 / 28
[prop]	[30 - 101]	[0 / 27]	[1 / 28]
egal,DMO	54 - 96	5 / 27	4 / 28
EQG	40 - 110	2 / 27	6 / 28
KS	42 - 108	0 / 27	0 / 28

treatment 11			
solution		Paris	Tokyo
Nash, KS, EQG	105 - 45	4 / 24	2 / 11
egal	75 - 75	6 / 24	1 / 11
DMO	90 - 60	3 / 24	0 / 11
prop	113 - 38	0 / 24	0 / 11

treatment 12			
solution		Paris	Tokyo
Nash, prop, egal, DMO, EQG	75 - 75	28 / 30	12 / 12
KS	66 - 84	0 / 30	0 / 12

Table B.13: Agreements recommended by well-known theoretical solutions and their frequencies by treatment and city. Nash: Nash bargaining solution, KS: Kalai-Smorodinsky bargaining solution, prop: proportional with respect to disagreement, egal: egalitarian (in eggs), EQG: equal gains, DMO: deal-me-out. []: approximate solutions and their frequencies.

TREATMENT	NASH	KS	PROP	EGAL	EQG	DMO
1	11.03	11.03	11.03	11.03	11.03	11.03
2	26.65	26.65	26.65	11.17	14.53	11.17
3	23.73	21.21	23.73	14.70	19.61	14.08
4	50.27	50.27	60.23	28.16	44.48	35.48
5	6.39	6.39	16.39	1.29	12.85	1.29
6	28.12	17.79	28.12	9.95	12.35	9.95
7	39.63	35.74	52.35	38.20	33.14	25.86
8	32.32	35.76	41.32	69.70	27.48	24.18
9	12.78	9.30	25.51	7.34	21.27	7.34
10	9.43	13.04	18.99	9.27	15.45	9.27
11	18.15	18.15	27.58	25.46	18.15	15.20
12	0.47	12.26	0.47	0.47	0.47	0.47
ALL	20.66	20.69	26.51	17.67	18.42	13.16

Table B.14: Average Euclidean distance from observed agreements to each of the solution considered in Paris. NASH: Nash bargaining solution, KS: Kalai-Smorodinsky bargaining solution, PROP: proportional with respect to disagreement, EGAL: egalitarian (in eggs), EQG: equal gains, DMO: deal-me-out.

TREATMENT	NASH	KS	PROP	EGAL	EQG	DMO
1	0.00	0.00	0.00	0.00	0.00	0.00
2	27.94	27.94	27.94	10.34	15.70	10.34
3	23.57	20.54	23.57	11.79	18.52	11.11
4	38.74	38.74	49.34	39.04	31.67	24.90
5	8.74	8.74	18.44	5.10	14.90	5.10
6	24.14	16.19	24.14	12.19	12.68	12.19
7	28.41	24.94	40.50	50.01	22.63	19.16
8	23.10	26.28	31.64	79.67	20.98	24.28
9	5.41	4.61	16.79	4.24	12.54	4.24
10	6.77	8.59	12.98	11.11	9.80	11.11
11	10.41	10.41	19.73	33.30	10.41	15.94
12	0.00	12.73	0.00	0.00	0.00	0.00
ALL	17.14	16.75	22.65	20.68	14.57	11.52

Table B.15: Average Euclidean distance from observed agreements to each of the solution considered in Tokyo. NASH: Nash bargaining solution, KS: Kalai-Smorodinsky bargaining solution, PROP: proportional with respect to disagreement, EGAL: egalitarian (in eggs), EQG: equal gains, DMO: deal-me-out.

TREATMENT	PARIS			TOKYO			ALL		
	S	W	I	S	W	I	S	W	I
1	90	0	10	100	0	0	95	0	5
2	100	0	0	100	0	0	100	0	0
3	26	22	52	29	24	48	27	23	50
4	18	9	73	35	17	48	27	13	60
5	100	0	0	89	7	4	94	4	2
6	100	0	0	100	0	0	100	0	0
7	28	12	60	50	23	27	38	17	45
8	38	29	33	71	8	21	56	18	27
9	92	4	4	96	4	0	94	4	2
10	96	0	4	100	0	0	98	0	2
11	58	13	29	91	0	9	69	9	23
12	100	0	0	100	0	0	100	0	0
ALL	73	7	20	81	7	12	77	7	17

Table B.16: Proportion of individually-rational agreements. S: strongly individually-rational agreements; W: weakly individually-rational agreements that are not strongly individually-rational; I: agreements that are not individually rational.

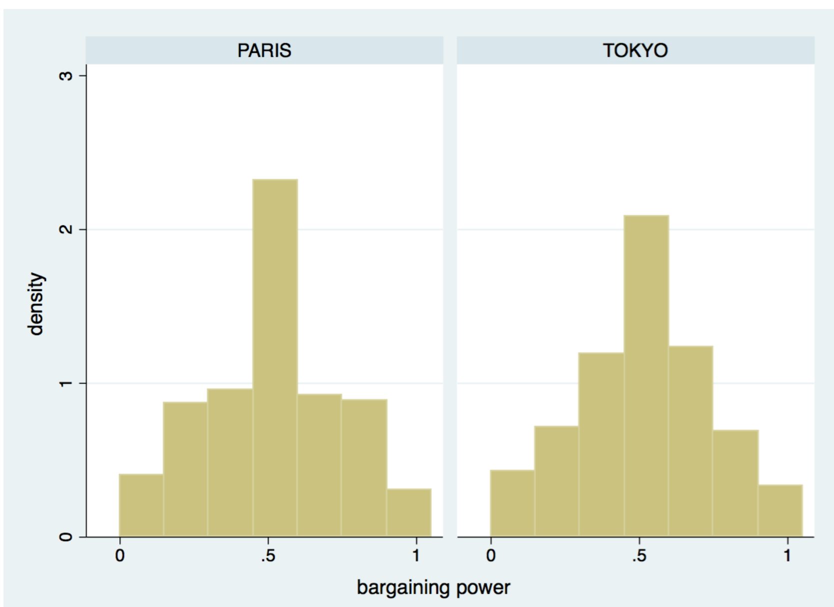


Figure B.2: Distribution of bargaining power measured through Kalai's weights.

	FE	RE	TOBIT
EGGS PER HEN	-17.08^{***}	-16.98^{***}	-16.91^{***}
EGGS PER HEN opponent	18.50^{***}	18.32^{***}	18.22^{***}
TAXED	2.27^{**}	1.90^{*}	1.70
TAXED (TRTS 8&10)	-9.13^{***}	-8.19^{***}	-7.69^{***}
TAXED opponent	-0.57	-0.66	-0.65
TAXED opponent (TRTS 8&10)	6.64^{***}	7.01^{***}	7.08^{***}
OUT OPTION	0.09^{***}	0.09^{***}	0.09^{***}
OUT OPTION (TRTS IR VS. EQ)	0.26^{***}	0.26^{***}	0.26^{***}
OUT OPTION opponent	-0.06^{**}	-0.07^{***}	-0.08^{***}
OUT OPTION opponent (TRTS IR VS. EQ)	-0.26^{***}	-0.26^{***}	-0.26^{***}
CONSTANT	71.31^{***}	71.62^{***}	71.78^{***}
(OVERALL) R-SQUARED	0.5857	0.5996	0.0974
NUM. OBS.	1160	1160	1160
$sigma_u$	6.31	3.57	–
$sigma_e$	13.66	13.66	–
rho	0.18	0.06	–

Table B.17: Explaining the final agreement. Dependent variable: number of hens obtained in the agreement. Coefficient estimates from regressions with subject-specific fixed effects (FE), subject-specific random effects (RE), and censored tobit between 0 and 150 (TOBIT). Robust standard errors clustered around participants. Estimated coefficients significantly different from zero at $^{***}1\%$, $^{**}5\%$, and $^{*}10\%$.

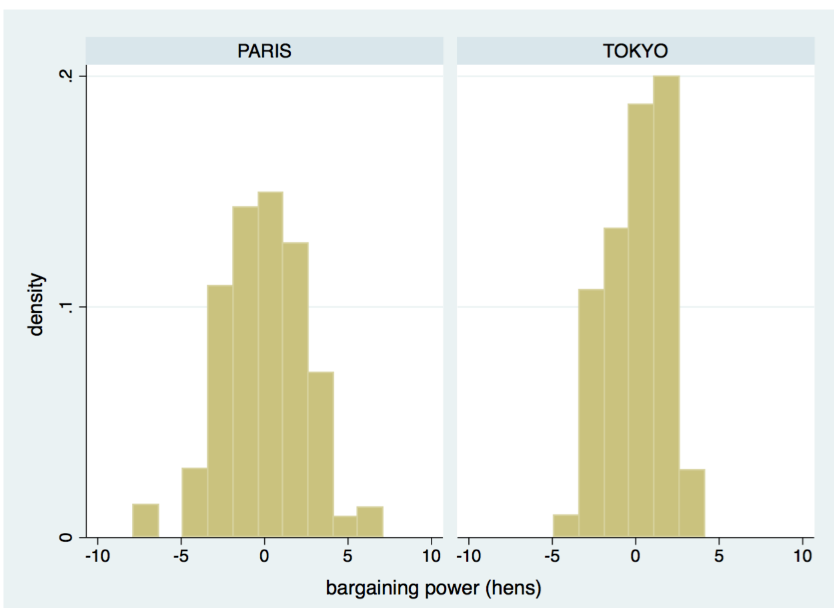


Figure B.3: Distribution of bargaining power measured through subject-specific fixed effects.

	(1)		(2)		(3)	
	COEFF.	SS	COEFF.	SS	COEFF.	SS
NASH	1.69	382	-	-	-	-
KS	0.23^{***}	662	0.32^{***}	12363	-	-
PROP	-1.42	501	-	-	-	-
EGAL	0.25^{***}	6844	0.28^{***}	22568	0.23^{***}	19647
EQG	0.25	160	-	-	0.37^{***}	11075
DMO	0.29^{***}	903	0.38^{***}	9384	0.28^{***}	3382
CONSTANT	-21.71	-	1.38	-	8.63^{***}	-
R-SQUARED	0.5645		0.5632		0.5609	
TOTAL SS	556710		556710		556710	
NUM. OBS.	1160		1160		1160	

Table B.18: Explaining the final agreement with the help of theoretical solutions. Dependent variable: number of hens obtained in the agreement. (1): OLS estimates and ANOVA results, (2): OLS estimates and ANOVA results with backward removal of insignificant regressors, (3): OLS estimates and ANOVA results based on supported axioms. NASH: Nash bargaining solution, KS: Kalai-Smorodinsky bargaining solution, PROP: proportional with respect to disagreement, EGAL: egalitarian (in eggs), EQG: equal gains, DMO: deal-me-out. Robust standard errors clustered around participants. Estimated coefficients significantly different from zero at $^{***}1\%$, $^{**}5\%$, and $^{*}10\%$. SS: partial sum of squares.

AppendixC. The McDonald-Solow model with different bargaining solutions

Consider a firm and a trade union bargaining over wage w and employment L.[26] The firm's profit is given by its revenues minus costs: $R(L) - w \cdot L$. For simplicity, only labor costs are considered. The trade union's payoff function is given by $L \cdot v(w)$, where $v(w)$ is the representative worker's utility function on money. To keep the computations simple, the labor-economics literature often assumes that workers are risk-neutral, therefore $v(w) = A \cdot w$ for some $A > 0$. Outside options are equal to 0 for the firm and to $L \cdot v(\bar{w}) = L \cdot A \cdot \bar{w}$ for the union, where $\bar{w}$ denotes the unemployment benefits.

The Pareto frontier of the bargaining problem, S, is the solution to the following maximization problem.

$$\begin{aligned} \max_{w \geq 0, L \geq 0} \quad & R(L) - w \cdot L \\ \text{such that} \quad & L \cdot A \cdot w \geq v \end{aligned}$$

[26]The notation follows chapter 7 in Cahuc and Zylberberg (2004). For more details on the maximization problem, refer to Danthine and Navarro (2013).

where $v \in \Re$. Note that the above problem is equivalent to $\max_{L \geq 0} R(L) - \frac{v}{A}$, because $L \cdot A \cdot w$ is monotonically increasing in w. Pareto efficiency then requires that the employment level L maximizes $R(L)$. Let L^* denote the optimal employment level.

The bargaining set S is then given by $\{(u, v) \in \Re^2$ such that $u \leq R(L^*) - \frac{v}{A}\}$, and the Pareto frontier by $\{(u, v) \in \Re^2$ such that $u = R(L^*) - \frac{v}{A}\}$. Recall that outside options are 0 for the firm and $L^* \cdot A \cdot \bar{w}$ for the union.

With the bargaining problem defined, we can consider now the wage level that different bargaining solutions yield.

- The Nash and the Kalai-Smorodinsky bargaining solutions both yield

$$w^N = w^{KS} = \frac{1}{2}\frac{R(L^*)}{L^*} + \frac{1}{2}\bar{w};$$

- the egalitarian solution yields

$$w^{EG} = \frac{R(L^*)}{(1 + A) \cdot L^*};$$

- the equal gains solution yields

$$w^{EQG} = \frac{R(L^*)}{(1 + A) \cdot L^*} + \frac{A}{1 + A} \cdot \bar{w};$$

- and, finally, the deal-me-out solution yields

$$w^{DMO} = \begin{cases} w^{EG} & \text{if } \bar{w} \leq w^{EG} \\ \bar{w} & \text{otherwise} \end{cases}.$$

Note that the Nash and the Kalai-Smorodinsky bargaining solutions do not depend on A, which is the multiplier in the worker's utility function, because of the scale-invariance property. At the same time, the three egalitarian solutions considered here critically do depend on A. Moreover, A also has an impact on the difference between the bargaining outcomes delivered by the egalitarian solutions.

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