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Possession is Nine-Tenths of the Law
Bourgeois behavior, property and inequality in an Hawk–Dove experiment*

Marco Fabbri[†] Matteo Rizzolli[‡] and Antonello Maruotti[§]

Abstract

In all legal systems, possession and property are inextricably linked. Game theory captures this relationship in the Hawk–Dove game. When two contenders compete to appropriate an asset, one of the two most efficient outcomes is achieved when both play the *bourgeois* strategy: they coordinate in such a way that the incumbent possessor plays Hawk and the intruder plays Dove. In our Hawk–Dove experiment, we test the role of possession with respect to the emergence of such a bourgeois convention. Our treatment variation concerns the way the initial claim to the asset is established. We manipulate the type of information provided and the process of acquisition. We show that i) the highest level of bourgeois coordination emerges whenever the information is based on possession but also when the process is meritorious; ii) possession, both arbitrary and meritorious, induces only bourgeois coordination and never antibourgeois (this is the equally efficient opposite strategy of playing Hawk when the player is the intruder and playing Dove when he is the possessor); and iii) without merit or possession, coordination on a "bullying" equilibrium emerges, generating very inequitable outcomes. Possession thus triggers the establishment of property, and this prevents inequality from arising.

Keywords: Possession, Property, Stealing, Bourgeois Strategy, Hawk–Dove, Inequality, Innate Sense of Property, Labour.

JEL codes: C91, D23, K11, P14, P26

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I observe, that it will be for my interest to leave another in the possession of his goods, provided he will act in the same manner with regard to me. He is sensible of a like interest in the regulation of his conduct. [...]. After this convention, concerning abstinence from the possessions of others, is enter'd into, and every one has acquir'd a stability in his possessions, there immediately arise the ideas of justice and injustice; as also those of property, right, and obligation.

David Hume (1738) *A Treatise of Human Nature - Part 2, Book III*

But modern bourgeois private property is the final and most complete expression of the system of producing and appropriating products, that is based on class antagonisms, on the exploitation of the many by the few.

Karl Marx (1848) *The Communist Manifesto*

1 Introduction

Possession is *nine points of the law, the root of title, the origin of property* (Krier, 2009).[1] In many circumstances, what begins as a relationship between an individual and an asset– we call this *possession*– is then recognized and institutionalized by a community and therefore becomes a relationship between individuals with respect to an asset. This is what we define as *property*. The connection between possession and property has been described through the Hawk–Dove game introduced by theoretical biologists (Maynard Smith & Parker, 1976) to explain the emergence of property-like behavior in animals. The game models animal conflicts for the appropriation of a scarce resource and stylizes two possible strategies to be followed: i) with the Hawk (H) strategy, the subject is always prepared to fight to retain or gain a contested asset and ii) with the Dove (D) strategy, the subject defers and retreats if its opponent escalates the fighting. The theoretical literature on the game highlights that the most efficient (fittest) strategy is in fact the so-called *bourgeois* strategy, which is *"defend aggressively when one is an owner and defer to the opponent when one is an intruder"* (Maynard Smith & Parker, 1976; Maynard Smith, 1982). The most successful contenders adopting the bourgeois strategy respect others' belongings and expect others to respect theirs. This evolutionary account of the emergence of property can be extended to humans as well (Sugden, 1989, 2004) and in fact closely resembles the David Hume's account of the emergence of the property convention (Waldron, 2013) cited above. In the evolutionary explanation of the institution of property, possession plays a crucial role, as it spurs contenders to coordinate on the bourgeois strategy. However, possession is not necessary for the evolutionary explanation of the emergence of the property convention to stand. In fact, any other uncorrelated asymmetry (UA) between subjects[2] could be exploited in the Hawk–Dove game to

[1] In one sentence, Krier mentions some of the most famous terms relating to the same concept: the old common law precept that *possession is nine points of the law,* (the modern variant being *possession is nine-tenths of the law*) (Erickson, 2007); *possession is the root of title (Epstein, 1978);* and *possession is the origin of property* (Rose, 1985).

[2] Possession is an uncorrelated asymmetry because it always tags one contender as the "possessor" and the other contender as the "intruder", and these tags are uncorrelated with the payoffs. However, from a game theory point of

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achieve efficient coordination. And even if possession is indeed the chosen UA, theoretically there may also be coordination on the antibourgeois strategy, in which the possessor plays D and the intruder plays H (Eshel, 2005; Sherratt & Mesterton-Gibbons, 2015). In other words, possession is neither a necessary (other UA could be used) nor sufficient (the antibourgeois convention is equally efficient and equally likely to emerge) condition for the bourgeois convention to emerge. While all property scholars agree that possession and property are inextricably linked, the evolutionary theory of property based on the bourgeois convention within the Hawk–Dove game still does not fully explain why possession is unequivocally and universally considered the precursor of property. It is within this gulf that our research agenda is situated.

In our experiment, subjects interact in groups of six over thirty rounds. In each round, three pairs are randomly matched to interact in two distinct activities. In the first part of the round, a UA is introduced, while in the second part the two subjects of each pair play the Hawk–Dove game and contend an amount of experimental monetary units. This second part is always the same across rounds and treatments. It is in the first part that our manipulation takes place. Our treatment variation concerns the way the initial claim to the experimental monetary units is established, that is to say, the nature of the UA we provide. On the one hand, we manipulate the type of information provided (the UA is either "possessory" or "colored"), and on the other hand we manipulate the process of acquisition (the UA is either "arbitrary" or "meritorious").

In designing our possessory treatments, we have mimicked some well-known mechanisms of property acquisition that are also almost universally enforced in property law. Among all the possible ways property can be acquired (such as purchase, will, descent, confusion), we have focused for now on reproducing three paradigmatic ones–*Gift, Treasure Trove,* and *Labor.* In the *Gift* treatment, 50 tokens are initially given randomly to one subject as manna from heaven; the UA is therefore possessory and arbitrary. In the *Treasure Trove* treatment, the 50 tokens are found by one of the two subjects during an activity that resembles a treasure hunt; the UA is therefore possessory and meritorious. In the *Labor* treatment, the 50 tokens are assigned to the subject that performs better on a standard effort task during a tournament. Again, the UA is possessory and meritorious. For the non-possessory treatments, we have followed some previous designs that based the UA on an assigned "color": one subject enters the Hawk–Dove game being red and the other enters being blue. We thus have an arbitrary colored treatment (*Lucky Red*) where the color is assigned randomly and a meritorious colored treatment (*Master Red*) where the color is assigned to one of the two subjects through the same treasure hunt used in the Treasure Trove treatment.

With this design, we can address the following research questions. Does possession induce more coordination on the property convention than a theoretically equivalent UA based on color? Is merit important in establishing the property convention? What convention emerges, a *bourgeois* convention, an *antibourgeois* convention, or a mix of the two, as predicted by the theory? What are the welfare consequences of establishing the property convention?

The experimental evidence we provide informs some aspects of the longstanding debate on property

view, coordination would equally follow from any other tag that establishes an asymmetry among the subjects that is uncorrelated with their fighting ability. For instance, a convention could be established such that whoever faces the sun plays H and the other subject plays D. This convention is as efficient (fit) as the bourgeois convention (Eshel, 2005).

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that took place from the 17th to the 19th centuries among philosophical giants such as Hobbes, Locke, Hume, Rousseau, and Marx. At the beginning of the experiment, no property institution is in place, and subjects' positions are almost perfectly symmetrical. This resembles the state of nature or the original position idealized by many of those thinkers, and what happens next in the experiment puts some of the most famous philosophical predictions concerning the institutions of property to the empirical test. Does the absence of the Leviathan–or in other words, third-party enforced property rights–make *life short, brutish, and nasty,* measured by high levels of inefficient fighting, as Thomas Hobbes predicted? Or does the property convention emerge out of the spontaneous coordination of subjects, as David Hume theorized? What is the role of labor (John Locke) and first occupancy (Samuel von Pufendorf) in the spontaneous emergence of the property convention? And does the emergence of the bourgeois property convention lead to *the exploitation of the many by the few,* as Karl Marx predicted in the maxim cited at the beginning of the paper?

To our knowledge, we are the first to test whether the *bourgeois* strategy emerges in a lab setting once the possessor–intruder asymmetry is introduced; other UA have been used in previous Hawk–Dove experiments but never possession. By having both possessory and non-possessory treatments, we are able to prove that possession is indeed a superior coordinating asymmetry. However, we also highlight that meritoriousness plays an important part in fostering coordination over the bourgeois convention. We further show that possession, both when established arbitrarily or with merit, always leads to bourgeois coordination and never to antibourgeois coordination. Finally, we show that if subjects fail to establish the property convention then they still coordinate on an efficient equilibrium, but this equilibrium is highly inequitable because some aggressive subjects invariably play H and drive others into playing D and therefore into surrendering all the profits.

The remainder of the paper proceeds as follows. At the beginning of Section 2, we give a textbook introduction to the Hawk–Dove game, the bourgeois strategy, and some extensions of the game. Those scholars familiar with the game can skip this section entirely. In Section 3, we present the experimental design, and in Section 4 we present the results. We draw the conclusions in Section 5.

2 Possession, property, and the *Hawk–Dove* game

Possession and property are two different legal concepts, although this distinction is often ignored by economists and biologists who write on property (see Hare *et al.* 2016, for a noticeable exception). Possession describes a relationship between an individual and an asset. In many jurisdictions (but not all), possession deserves legal protection on its own (Rose, 1985; Chang, 2015). Property, however, describes a legal relationship between individuals with regard to an asset (Merrill & Smith, 2001; Merrill, 2015). While possession is often the precursor of property, the two can also conflict (Rose, 2015). Legal scholars and economists have only recently picked up the analysis of the relationship between possession and property, and several scholars (Gintis, 2007a; Waldron, 2013; Rose, 2014; Eswaran & Neary, 2014; Lewinsohn-Zamir, 2015) have put forward the hypothesis that property law values and protects possession for its key role in igniting the establishment of the property convention.

This mechanism has been modeled by the evolutionary biologist John Maynard Smith, who developed the Hawk–Dove game with animal behavior in mind. Population dynamics and biological fitness

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are two key concepts to understand evolution and equilibrium in such a game. However, as shown by Sugden (1989, 2004), if we substitute "utility" for "fitness" and "learning" for "natural selection", this approach can explain the property convention among humans as well. In the Hawk–Dove game[3], both subjects face a symmetric situation in which they can choose between two strategies: i) to play the hawk, which implies fighting aggressively for an asset of value v at cost c or ii) to play the dove, which means displaying aggression and, if faced with major escalation, retreating from the fight. If not faced with escalation, the dove shares the asset. In the variation of the game we implement, sharing the asset implies the costs a for the dove, reflecting the idea that non-exclusive control of the asset may imply transaction costs and diminished incentives for investment (see Rose, 2014). Figure 1 summarizes the payoff matrix of a Hawk–Dove.

Figure 1: The *Hawk–Dove* game

		Subject 2	
		Hawk	Dove
Subject 1	Hawk	$\frac{v-c}{2}$	v
	Dove	0	$\frac{v}{2} - a$

		Subject 2	
		Hawk	Dove
Subject 1	Hawk	−25	50
	Dove	0	15

Each matrix cell yields the payoff to its row strategy against its column strategy

If $c > v > a$, the Hawk–Dove game[4] has three Nash equilibria (NE). Assuming multiple repetitions with anonymous, randomly matched subjects, the Hawk–Dove game has two asymmetric NE in pure strategies (H-D and D-H) and an interior solution with a NE in mixed strategy, where subjects play H with probability p. The presence of a modest cost for asset sharing a in this variation of the game only affects the probability p with which the NE in mixed strategy is played. Furthermore, only the two NE in pure strategies are efficient (payoffs are maximal in H-D and D-H), as the mixed strategy equilibrium only achieves the efficient outcome with probability $2p(1 - p)$. Evolutionary game theory provides tools for equilibrium selection among these three NE. In the Hawk–Dove game with identical subjects, the evolutionary approach predicts that the unique evolutionary stable equilibrium is the mixed strategy NE one. In other words, evolution selects the inefficient equilibrium. This is true unless a UA between subjects is introduced. This UA implies that the two subjects engaging in a Hawk–Dove contest are identical except for a payoff-irrelevant characteristic that tells them apart and that can be observed by both. Subjects can be arbitrarily assigned different labels, such as "red" vs. "blue", or the labels can be determined by some characteristic of the subjects themselves[5], as long as the characteristic that determines the label is uncorrelated with subjects' fighting ability and thus with their payoffs. The UA is important because subjects can use it to select one of the two efficient NE in pure strategies over the inefficient one in mixed strategies; Sugden (1989) calls this equilibrium refinement a *convention*[6]. In the Hawk–Dove game subjects can coordinate on one of the two pure and efficient NE; if, for instance, subjects are randomly assigned either a blue label or a red label before

[3]Games with similar payoff structures are also known as the battle-of-the-sexes game or the chicken game.
[4]Notice that if $v > c$ and $a < 2c$ then this is a Prisoner's Dilemma instead.
[5]See also footnote 2.
[6]This solution concept is also known as a correlated equilibrium (Aumann, 1987). The equivalent concept in evolutionary game theory is called an evolutionary stable strategy (ESS).

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each fight, they could coordinate so that whoever happens to be blue plays H and the other plays D (or vice versa). Notice, however, that there is no criterion to consistently select one equilibrium among the two evolutionary stable NE[7].

Figure 2: **The *Hawk–Dove* Game with property as uncorrelated asymmetry**

		Subject 2			
		Hawk	Bourgeois	Anti-bourg.	Dove
Subject 1	Hawk	$\frac{v-c}{2}$	$\frac{3}{4}v - \frac{1}{4}c$	$\frac{3}{4}v - \frac{1}{4}c$	v
	Bourgeois	$\frac{v-c}{4}$	$\frac{1}{2}v$	$\frac{1}{2}v - \frac{1}{4}c$	$\frac{3}{4}v$
	Anti-bourg.	$\frac{v-c}{4}$	$\frac{1}{2}v - \frac{1}{4}c$	$\frac{1}{2}v$	$\frac{3}{4}v$
	Dove	0	$\frac{1}{4}v - \frac{1}{2}a$	$\frac{1}{4}v - \frac{1}{2}a$	$\frac{v}{2} - a$

Each matrix cell yields the payoff to its row strategy against its column strategy, calculated on the assumption that all subjects are randomly assigned to the role of possessor or intruder.

Both the original work of Maynard Smith & Price (1973) and Sugden (1989) explicitly refers to possession (of land or things) as a salient UA. Being first to possess the asset to be contested introduces a payoff-irrelevant piece of information that can be used to develop two alternative conventions:the *bourgeois* convention, where the possessor plays H and the intruder plays D, or the *antibourgeois* convention, where the possessor plays D and the intruder plays H.[8] Even if both conventions are equally likely to be selected in theory, only one is consistent with our understanding of property; Maynard Smith & Parker (1976) distinguished the "commonsense" bourgeois convention from the "paradoxical" antibourgeois one. It is no surprise that the empirical evidence from animal studies points at the absolute predominance of the commonsense bourgeois strategy. We know that many animal species display hawkish behavior when they possess a territory; among these are baboons (Kummer *et al.* , 1974), damselflies (Waage, 1988), desert ants (Wenseleers *et al.* , 2002), Ozark zigzag salamanders (Mathis *et al.* , 2000), some colonial spiders (Hodge & Uetz, 1995), and many species of birds (Krebs, 1982; Beletsky & Orians, 1987). Kokko *et al.* (2006, online appendix) survey 100 papers on animal behavior in resource contests and find that 84 species adopted the bourgeois convention while only one adopted the antibourgeois convention. Rigorous empirical evidence concerning the emergence of the bourgeois convention among human populations is more scant, but this is rather obvious given the fact that in human societies, the existence of laws and norms governing the protection of private property prevents researchers from observing the emergence of bourgeois conventions in purely lawless environments (Kandori, 1992; Posner, 2000; Zasu, 2007). However, humans also display a great deal of territoriality. Pape (2003) reports empirical evidence that suicide attacks are most likely carried out by people who are trying to displace occupying invaders, and Johnson & Toft (2014a,b) show how territory is central to some of today's most vexing conflicts and wars. More intriguingly, there is also ample evidence of both humans and animals displaying dovish behavior when they are the intruders. Potential intruders retreat in front of simple signals, such as occupancy, scent marking, or song, that

[7]In one group a convention could evolve such that blue plays H and red plays D while in another group the convention could be such that red plays H while blue plays D.

[8]Grafen (1987) points out that if bourgeois coordination creates consistent losers, then after a while intruders have no incentive to respect the convention. He calls this the "desperado effect".

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the asset or territory is "owned" (Parker, 1974; Davies, 1978). In lab experiments on the dictator game with takings, there is ample evidence that dictators playing the role of potential intruders respect property to some extent, even if the potential reaction of the owner is ruled out by design (Faillo *et al.* , 2018).

Similarly, experimental psychologists report evidence that young children–who are arguably not aware of the institutional environment they live in–already develop bourgeois conventions, as they are both willing to fight hard to maintain control of an asset they possess and at the same time recognize and respect others' possession of an asset (Fasig, 2000; Rochat *et al.* , 2014; Rossano *et al.* , 2011; Goulding & Friedman, 2018). Against the difficulty of disentangling the bottom-up emergence of a bourgeois convention from the top-down deterrence effect of property law enforcement, the controlled environment of a laboratory makes it possible to recreate an ad-hoc pre-institutionalized setting that allows researchers to isolate the effects of these factors.

2.1 The puzzling preponderance of the Bourgeois convention

As stated, the simple Hawk–Dove model cannot explain why subjects preponderantly choose the bourgeois strategy over the antiborgeois strategy. Kokko *et al.* (2006) and Sherratt & Mesterton-Gibbons (2015) survey several extensions of the Hawk–Dove game that could possibly explain the preponderance of the bourgeois strategy. One set of extensions is based on the idea that the asymmetry between possessor and intruder is, after all, correlated with the payoffs in the game; in other words, being the possessor gives some advantage in fighting. Another set of extensions maintains that the asymmetry between possessor and intruder is uncorrelated, but certain mechanisms ensure that the commonsense strategy prevails. The best known of these explanations is *infinite regress* (Mesterton-Gibbons, 1992), hinting at the idea that in an antibourgeois convention no subject could hold an asset for long enough to benefit from it.[9] Kokko *et al.* (2006) provide an extension with eco-evolutionary feedback where both the value of the asset and the cost of fighting are endogenized. Finally, *value asymmetry* is a possible mechanism; once one becomes possessor of the asset, its value increases vis-à-vis the value the intruder places on it, and this increases the basin of attraction of the bourgeois convention while decreasing convergence on the antibourgeois one (Sherratt & Mesterton-Gibbons, 2015). Why does the possessor value the asset more than the intruder? There are some very plausible rational explanations for this, such as settlement cost (establishing relationships with neighbors, discovering the best feeding places, and so on). In fact, the current holder has to pay the same settlement costs again if he is displaced by the intruder but does not if he manages to keep the current possession, whereas the intruder will have to pay the settlement cost either way (Kokko, 2013).

Asymmetries in valuation that arise endogenously to the simple fact of being possessors have long been observed; this behavioural phenomenon has been called the "endowment effect" (Kahneman *et al.* , 1991; Ericson & Fuster, 2014). Gintis (2007b) has been the first to bridge the literature on the

[9]See Mesterton-Gibbons & Sherratt (2014), who show that even when considering the costs of swapping ownership, under certain conditions (cost of fighting and relatively low population size) infinite regress does not always render the antibourgeois convention nonviable. Another explanation concerns *uncertainty over roles*; when there is confusion over who is the possessor (for instance, because the current possessor may temporarily leave, only to find the asset possessed by someone else upon returning), the evolution of bourgeois behavior is more likely. Further explanations favoring the emergence of the bourgeois strategy concern; *continued investment in conflict* (sunk costs) and *winner and losers effects*. See Sherratt & Mesterton-Gibbons (2015) for a complete survey.

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Hawk–Dove game with the literature on the endowment effect by showing that the endowment effect generates a disutility in giving up the asset for the actual possessor that exceeds the utility gain experienced by the intruder. Therefore, because individuals' effort in the contest is endogenously determined by the private evaluation of the asset, the model predicts that in equilibrium the actual owner devotes a greater effort in protecting his property than the effort exerted by an intruder trying to expropriate it, and this makes the bourgeois convention more likely to prevail. Along similar lines, Eswaran & Neary (2014) model how an *innate sense of property* rights may have emerged in humans and other animal species as a result of evolutionary forces. The authors move from Locke's (1988 [1689]) theory of property, according to which labor expended on an asset results in an innate psychological claim over the asset itself. This claim leads the producer to develop a stronger preference for such asset compared to an intruder who seeks to appropriate it. In a potential conflict over the attribution of this asset, these asymmetric valuations are reflected in the owner-producer being willing to expend more effort defending his claim relative to the intruder.

Against this background, our experiment is a pure Hawk–Dove set-up with asymmetry in the form of either color or possession, which are totally uncorrelated with the payoff structure of the game. None of the theoretical extensions that might explain the prevalence of the bourgeois convention reviewed above could possibly apply to our set-up. In other words, our experiment is an ideal testbed to see whether the predominance of the bourgeois strategy can really be observed in a plain vanilla Hawk–Dove game and whether possession, through the endowment effect and/or the innate sense of property, is the natural culprit that explains the commonsense emergence of the bourgeois convention.

We conclude this section with a short review of the experimental economic literature relevant to our paper. Surprisingly, the Hawk–Dove game has been little explored in economic labs and never, to our knowledge, explicitly using possession as the UA. Older papers used the Hawk–Dove game to examine the impact of cheap talk (Cooper *et al.* , 1989) and of forward induction (Cooper *et al.* , 1993; Berninghaus *et al.* , 2012) in such games. More recently, Neugebauer *et al.* (2008) have shown that most subjects in Hawk–Dove games do not display any social preference, and Duffy & Feltovich (2010) use the Hawk–Dove game to explore the existence of correlated equilibria. Finally, Oprea *et al.* (2011) alternate one and two populations matching protocols with the UA being the distinction between "row" and "column" subjects. Their main innovation is the use of a continuous time design that allows for asynchronous decisions with instantaneous feedback and the possibility of altering their decisions an unlimited number of times, thus approximating the "long run" time horizon. In comparison, previous experiments used a limited number of synchronous repetitions; for instance, Van Huyck *et al.* , 1995 use 70 repetitions.

3 The experiment

Each experimental session is composed of a first phase in which an initial endowment is assigned or gained and a second phase divided into 30 rounds. At the beginning of the second phase, each subject is assigned to a group of six. In each round, subjects are randomly re-matched with one of the other group members (stranger matching) so that for each group, three pairs are formed in each round.

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Each round is divided into two parts. In the first part of the round, a UA is introduced among subjects according to a procedure that varies with the treatment, as described in the next subsection. In the second part of the round, subjects play a Hawk–Dove game with parameters $v = 50$, $c = 100$, and $a = 10$ so that we obtain the payoff matrix as in the right quadrant of Figure 1.[10] Under these parameters, the symmetric NE in mixed strategies is given by subjects choosing strategy H with probability $p = \frac{7}{12}$. The expected payoff for each subject of the mixed strategies equilibrium is then $pH + (1-p)D = 7.5$, well below the payoff of 25 yielded by the two pure NE. Notice that the mixed NE is $\frac{3}{10}$ as efficient as any of the two pure NE. Our payoff structure produces two pure NE with highly inequitable (50;0) outcomes, thus providing strong incentives for a non-owner to resist convergence toward the bourgeois strategy.

The payoffs are described as Experimental Currency Units (ECU) that will be converted to cash at the end of the experiment at the rate of $50\,ECU = 1$ euro. In each round, participants can either maintain, lose, or increase their endowment of tokens [11]. In order to avoid introducing a second UA, all the subjects see themselves as "row subjects". In each round, they can choose between strategy H (labeled "A", in order to maintain a neutral language) and strategy D (labeled "B"). At the end of each round, participants receive the following feedback information:

- Their opponent's choice (and thus payoff for the round);
- Their 6-player group aggregate behavior in the last round and average behavior in all previous rounds (e.g., in last round, 30% of the subjects chose strategy H; on average so far, 23% of the subjects chose strategy H);
- The total and average individual payoff up to that round;
- The average payoff of all subjects in the same group up to that round, divided by player's type.

At the beginning of the experiment, subjects receive an initial endowment of roughly 300 ECU depending on the procedure specific to each treatment, as described in the next subsection. In our instructions, we never use the words "property" or "possession" and we never refer to subjects' roles as "owner/possessor" or "intruder". In the first part of each round where "possession" in fact comes into play we use different wording depending on the treatment.

3.1 Treatments

The treatment variation happens in the first part of each round. We have a total of five treatments organized along two main dimensions. The first dimension concerns the type of information provided

[10]Instructions read as follows: During the contest for these 50 tokens, you can adopt behavior A or B. At the same time, the other participant can adopt behavior A or B. If you choose A and the other participant chooses A, the tokens are destroyed. Moreover, you lose an additional 25 tokens to the ones you accumulated to that point. If you choose A and the other participant chooses B, you appropriate all 50 tokens. If you choose B and the other participant chooses A, the other participant appropriates all 50 contested tokens. If you choose B and the other participant chooses B, you appropriate 15 tokens and the other participant appropriates 15 tokens. The 20 tokens that are left are destroyed.

[11]Participants are informed that, in the case their endowment of tokens falls below zero before the last round, they will have to choose between either leaving the experiment and receiving only the participation fee or continuing the experiment and using the participation as a guarantee against final losses.

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(the UA is either *possessory* or *colored*), and the other dimension concerns the process of acquisition (the UA is either *arbitrary* or *meritorious*).

Figure 3: Experimental treatments

		Process of acquisition		
		Arbitrary	Meritorious	
			effort	*first possession*
Type of information provided	Possessory	**Gift**	**Labor**	**Treasure Trove**
	Colored	**Lucky Red**	**Master Red**	

In the ***Gift*** treatment, the computer randomly assigns *50* tokens to one of the two subjects, who thus becomes the *possessor*. The other subject (the *intruder*) does not receive any tokens. In the first phase before the beginning of the 30 rounds, each participant is endowed with 300 tokens as windfall money.

In the ***Labor*** treatment, participants have to perform an individual effort task following Gill & Prowse (2012).[12] Each participant has one minute to move the cursors of as many 0–100 scale sliders as possible to the position indicated by the computer. For each matched pair of subjects, the one that correctly positions the highest number of cursors gains possession of 50 tokens. In the first phase, each subject can work on a similar task to accumulate the initial endowment. [13] Because this activity does not require any particular ability or knowledge to complete, it is likely that participants perceive the endowment gained through individual performance to be correlated with individual effort. By using a meritorious mechanism of acquisition based on effort, this treatment intentionally mimics labour as an almost universal mechanism for legitimizing property (Locke, 1980; Henry, 1999).

In the ***Treasure Trove*** treatment, at the beginning of each round subjects participate in a treasure trove contest. Each pair sees the same 25 squares on the computer screen, as in the upper screenshot of Figure 4, and can uncover their content by pressing on each of them. Hidden behind one of the squares is a 50-token treasure in the form of a code composed of numbers and letters. Whoever registers its trove in the dedicated filling area at the bottom of the screen takes possession of the 50-token treasure that will then be contested in the second part of each round.

[12] We chose this particular effort task because it does not require any specific skill (for a discussion, see Gill & Prowse, 2012). However, to control for possible differences in individual ability to complete the slider task, we have a standardized measure of ability built on participants' performance in the one-minute piece-rate effort task, where "0" indicates the lowest ability and "1" the highest. We include this control in the regressions.

[13] This initial task is divided in two parts. In the first part, each subject gains 250 tokens if he or she correctly positions at least 40 cursors within nine minutes. This goal was intentionally set to ideally have every subject gain the initial endowment, and indeed, 87 out of 90 subjects reached the goal. The results remain qualitatively the same whether we exclude the three subjects who did not reach the goal or not. In the second part lasting 1 minute each correctly positioned slider is worth eight tokens. This second part was devised to have a measure of individual productivity in the effort task. At the end of the 10-minute initial period, subjects gained possession of an average of 329 tokens.

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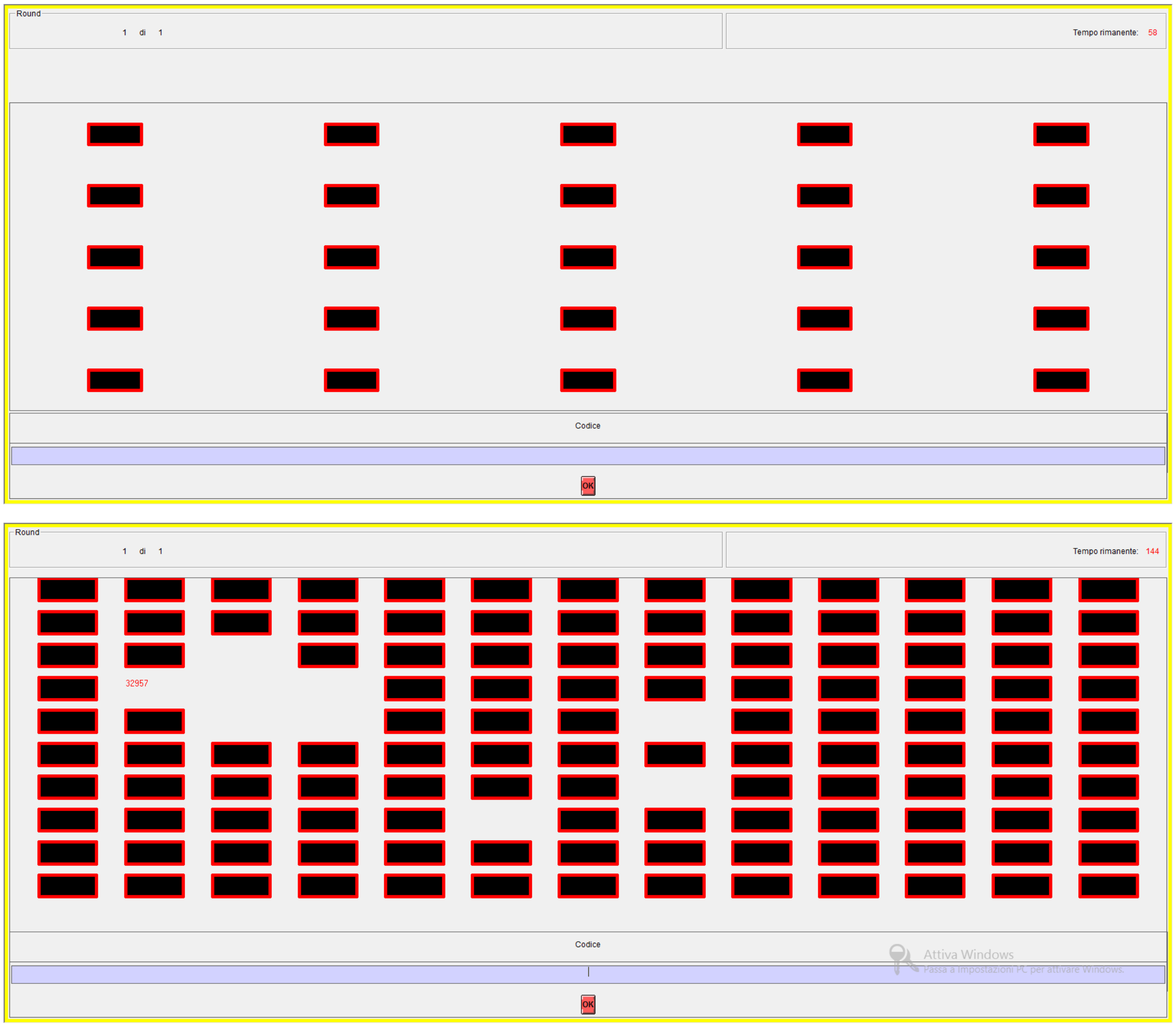

Figure 4: Treasure Trove treatment

In the first phase before the beginning of the 30 rounds [14], each subject can find additional treasures to build their initial endowment.[15] This mechanism of acquisition implies a mix of luck (uncover the "right" square) and individual ability (being faster than competitors in registering the codes). The way assets are acquired in this contest closely resembles a classic first-possession mechanism that has

[14] This initial phase is divided in two parts. In the first part each subject sees 130 squares as in the lower portion of Figure 4. There is one code for each subject to be found. Subjects have 3 minutes to find and register the code. If they succeed they gain 250 tokens. Three minutes was a time-frame large enough for having most of the subjects finding the code and indeed 95 out of 96 subjects found the treasure. . In the second part of this initial phase, subjects see 130 squares again behind which there are 10 treasures of 10 tokens value each. Subjects have 1 minute to register as many codes as possible. This second part allows us to have a measure of individual ability in this specific task. Based on the result of this second part of the first phase, we created a standardized measure of individual ability (where "0" indicates the lowest ability and "1" the highest), and we introduced this measure as a control in the regression analysis.| Results reported in the next section are virtually identical whether we introduce this control.|

[15] Due to a technical problem, in one session the number of treasures registered by subjects in this second phase were not recorded. We assigned 50 additional tokens to these subjects and we assigned them an average level of individual ability.

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long been considered a legitimate approach to the establishment of property rights (Grotius, 2012; Pufendorf *et al.* , 1991) that is recognized in virtually any legal system (Lueck, 1995; Ellickson, 1989).

In the ***Lucky Red*** treatment, each subject is randomly labeled either *Red* or *Blue* at the beginning of each round so that a UA is introduced along the lines of Hargreaves-Heap & Varoufakis (2002). However, this color label is not related to the initial possession of the 50 tokens; in fact nobody possesses the tokens before the contest. Furthermore, in the first phase before beginning the 30 rounds, each participant is endowed with 300 tokens as windfall money.

In the ***Master Red*** treatment, subjects participate in a treasure hunt at the beginning of each round as in the Treasure Trove treatment. Each pair sees the same 25 squares on the computer screen, as in the upper screenshot of Figure 4, and can uncover their content by pressing on each of them. Hidden behind one of the squares is a code consisting of numbers and letters. Whoever registers their trove in the dedicated filling area at the bottom of the screen is assigned color Red (Blue)[16]. Notice that the assignment of this color label is not related to the initial possession of the 50 tokens; in fact, nobody possesses the tokens before the contest. In the first phase before the beginning of the 30 rounds, each subject can find additional treasures to build her initial endowment. This phase is identical to the one used in the Treasure Trove treatment.

3.2 Predictions and potential experimental outcomes

Before proceeding with the results section, it is useful to organize our thoughts on the several different patterns that might be observed in the data. Against the theoretical background of the Hawk–Dove game, and given our experimental design, we can expect to observe different behaviors that can be illustrated graphically with some stylized scenarios that depend on whether subjects will coordinate and, in case they do, whether they will make use of the UA or not. These scenarios are stylized insofar as they envisage all subjects behaving the same way.

Scenario 1. **No convention.** If no subject exploits the UA, no convention is established and all subjects–in each group–play the mixed strategy equilibrium (play H with $p = 7/12$). If a subject happens to be red/possessor with $p = 1/2$ then the probability that the red/possessor plays H and the blue/intruder plays H is the same and is equal to $7/24$. This strategy is inefficient (see section 2). In a graph depicting the average frequencies of hawkish behavior of, respectively, possessors and intruders over the 30 rounds, under Scenario 1 we should observe two lines overlapping around the value of $7/24$, as in the first quadrant of Figure 5.

Scenario 2. **Two conventions**. If all subjects fully exploit the UA, they perfectly coordinate on one of the two pure NE. Because each convention is equally likely to emerge ($p = 1/2$) in each group, looking at the average behavior across groups one should observethat the red/possessor plays H and the blue/intruder plays H with roughly the same frequency of $1/4$, as depicted in the middle quadrant of figure 5 (remember that subject happens to be red/possessor with $p = 1/2$). This scenario yields an efficient result because coordination

[16]In some experimental sessions the treasure trovers were consistently assigned the color Red while in other sessions they were assigned the color Blue.

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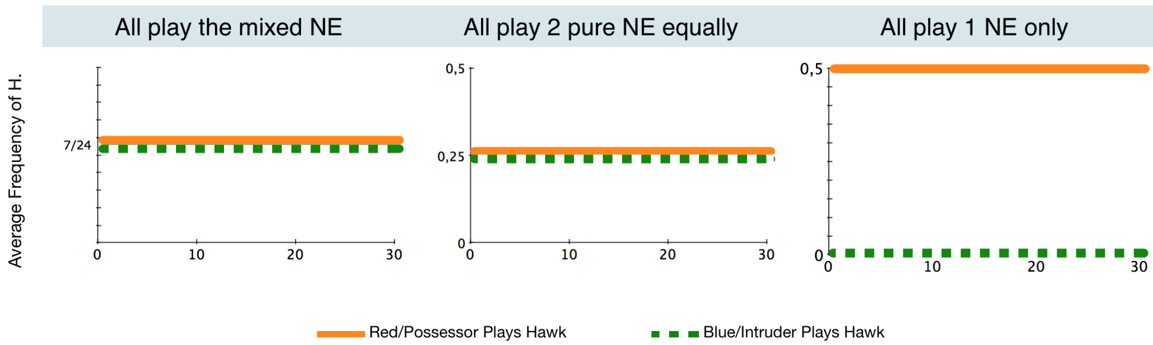

Figure 5: Scenarios about the expected frequency of Hawkish behavior by subjects, organized in accordance with the UA (either Red/Blue or Possessor/Intruder). The orange continuous line depicts the frequency with which subjects play Hawk when they are either Red in the color treatments or Possessors in the possessory treatments. The green dashed line instead depicts the frequency with which subjects play Hawk when they are either Blue or Intruders.

in each group happens in all the rounds. However, there is no dominant convention, and each group coordinate on one convention at random.

Scenario 3. **One convention.** If all subjects fully exploit the UA and they all coordinate across groups on just one of the two conventions (red/possessor plays H(D) while blue/intruder plays D(H)), then we should observe in all rounds the red/possessor subjects playing H(D) and the blue/intruder subjects playing D(H) as in the last quadrant of figure 5. This scenario also yields an efficient result.

Notice that in all treatments we provide a UA, and therefore we should expect one of the two conventions to emerge. Furthermore, given the standard Hawk–Dove game we implement, there is no theoretical reason to anticipate that only one convention should be selected, and therefore we should expect to observe Scenario 2.

Scenario 1 should emerge only if subjects fail to take advantage of the UA, while Scenario 3 should emerge only if the UA triggers individuals to collectively select one equilibrium over the other. This might resemble the innate sense of property evoked by Eswaran & Neary (2014).

3.3 Procedures

We conducted 27 laboratory sessions with 12 or 18 subjects each, for a total of 474 participants (45% female).[17]. Each subject participated one session only.

The experiment was conducted using computer interfaces at the CESARE lab of LUISS Guido Carli University. To program the experiment, we used the software Z-tree (Fischbacher, 2007). The vast majority of participants were graduate and undergraduate students at the University and were recruited using the online system ORSEE (Greiner, 2015).

[17] We had a total of 15 six-subject groups participating in the Gift and Labour treatments, 16 groups participating in the Treasure Trove treatment, 15 groups participating in the Lucky Red treatment, and 18 groups in the Master Red treatment.

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At the beginning of each session, instructions were read aloud by the experimenter[18] to ensure common knowledge. Before the experiment started, all the participants had to correctly answer some control questions. Throughout the reading of the instructions and the control questions stage, participants had the opportunity to ask the experimenter questions in private . After the experiment ended, each subject was asked to fill in a questionnaire reporting socio-demographic characteristics. Communication among participants was not allowed during the experiment.

Each session lasted approximately 70 minutes. During the sessions, subjects' endowment and payoff were expressed in tokens. Final payment was made in euros at the exchange rate of 50 tokens for €1. Participants earned €14 on average, including a €2 show-up fee. To guarantee anonymity, cash payments were distributed individually and privately at the end of each session.

4 Empirical analysis

4.1 Aggregate coordination

We begin the analysis by investigating whether our treatment manipulations affect participants' aggregate level of coordination. The aggregate level of coordination is measured as the number of paired subjects who coordinate on a pure strategy NE (playing H-D or D-H) in each group. The variable can take four values: 1) 0 out of 3 pairs coordinate; 2) 1 out of 3 pairs coordinate; 3) 2 out of 3 pairs coordinate; and 4) 3 out of 3 pairs coordinate. Figure 6 provides a graphical representation of the levels of coordination over the 30 rounds, organized by treatment. Each line depicts the relative frequency of coordination (frequency of H-D or D-H play) over the periods under each treatment. The black continuous horizontal line represents the aggregate level of coordination achieved when subjects play the mixed strategy NE[19]. Aggregate levels of coordination seem to be similar among treatments (see Figure 6), independent of the type of UA provided; at the same time, they are substantially above the level of coordination predicted by the mixed strategy NE.

This first graphical and descriptive insight can be further investigated by employing inferential methods, such as a regression analysis that is able to account for potential group-specific effects. We therefore focus on data aggregated at the group level and consider a hierarchical/multilevel model for longitudinal data. In detail, we assume the existence of a latent variable in round t for the g-th group:

$$y^*_{tg} = \nu_{tg} + \epsilon_{tg} = \mathbf{x}'_{tg}\boldsymbol{\gamma} + \eta_g + \epsilon_{tg}$$

where ν_{gt} is the linear predictor decomposed in two parts, the first one explained by observed covariates $\mathbf{x}_{tg}$ and the second one being a group-specific random variable η_g. ϵ_{tg} is an error term, and the four observed response categories $\{1, 4\}$ are generated, conditionally on η_g, by applying thresholds κ_s to

[18] To better control for potential demand effect, the experimenter remained the same in all sessions.

[19] Calculated as $2p(1-p)$ where $p = 7/12$

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y^*, as follows:

$$y_{tg} = \begin{cases} 1, & y^*_{tg} < \kappa_1 \\ 2, & \kappa_1 y^*_{tg} < \kappa_2 \\ 3, & \kappa_2 < y^*_{tg} < \kappa_3 \\ 4, & \kappa_4 < y^*_{tg}. \end{cases}$$

Assuming a logistic cumulative density function $F(\cdot)$ for ϵ_{tg}, the model considered has the following general form:

$$\Pr(y_{tg} < a_s \mid \mathbf{x}_{tg}, \eta_g) = F(\mathbf{x}'_{tg}\boldsymbol{\gamma} + \eta_g) = F(\nu_{tg}).$$

To have a well-defined probability, we would like to remark that the restriction $\Pr(y_{tg} < a_s \mid \mathbf{x}_{tg}, \eta_g) < \Pr(y_{tg} < a_{s+1} \mid \mathbf{x}_{tg}, \eta_g)$ has to be fulfilled. As a further remark, in this model the effective thresholds vary across groups. The parameters estimation is performed in a maximum likelihood, leaving unspecified the distribution of the random term η_g, as in Aitkin (1996, 1999). Several empirical models are specified; that is, different sets of $\mathbf{x}_{tg}$ are considered. We start by regressing the variable *totalcoordination* on different treatments' dummies.

The results of Models 1 and 2 are shown in Table 1. The Labor treatment constitutes our baseline treatment and generates the lowest amount of aggregate coordination in our experiment. The differences between treatments are not statistically significant at the conventional level. In model 2, we investigate the presence of general and treatment-specific trends as a sign of increasing coordination during the experiment. A positive trend is estimated in all treatments, confirming the intuition behind figure 6. We do not estimate any significant difference between treatments, with the exception of the Master Red treatment that , compared to Treasure trove, displays a marginally-significant faster increase in the coordination growth rate.

Claim 1. **The level of total coordination (on any of the two NE) and the speed of convergence toward coordination is substantially similar across treatments.**

Claim 2. **The level of total coordination is significantly higher than predicted by the NE in mixed strategies.**

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Table 1: Aggregate coordination

Dep. Variable	Model 1 totalcoord.	Model 2 totalcoord.	Model 3 bourgeoiscoord.	Model 4 antibourgeoiscoord.
LuckyRed	0.095		-0.636***	1.705 ***
	(0.166)		(0.194)	(0.153)
Gift	0.088		-0.382*	0.211
	(0.151)		(0.206)	(0.167)
TreasureTrove	0.014		-0.142	-0.250
	(0.155)		(0.187)	(0.226)
MasterRed	0.242		-0.118	0.030
	(0.155)		(0.180)	(0.171)
Period		0.032***		
		(0.007)		
Period x LuckyRed		0.006		
		(0.008)		
Period x Gift		-0.000		
		(0.008)		
Period x TreasureTrove		-0.001		
		(0.008)		
Period x MasterRed		0.011		
		(0.008)		
N.obs.	2370	2370	2370	2370

Notes: Multilevel model for longitudinal data, Ordinal Logit link function. Model 1 includes the whole sample, Model 2 considers the interaction between the variable *Period* indicating the round in the experiment, and the dummies for treatment, Model 3 is identical to model 1 except for the use of *bourgeois* as dependent variable, Model 4 is identical to model 1, except for the use of *antibourgeois* as dependent variable. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

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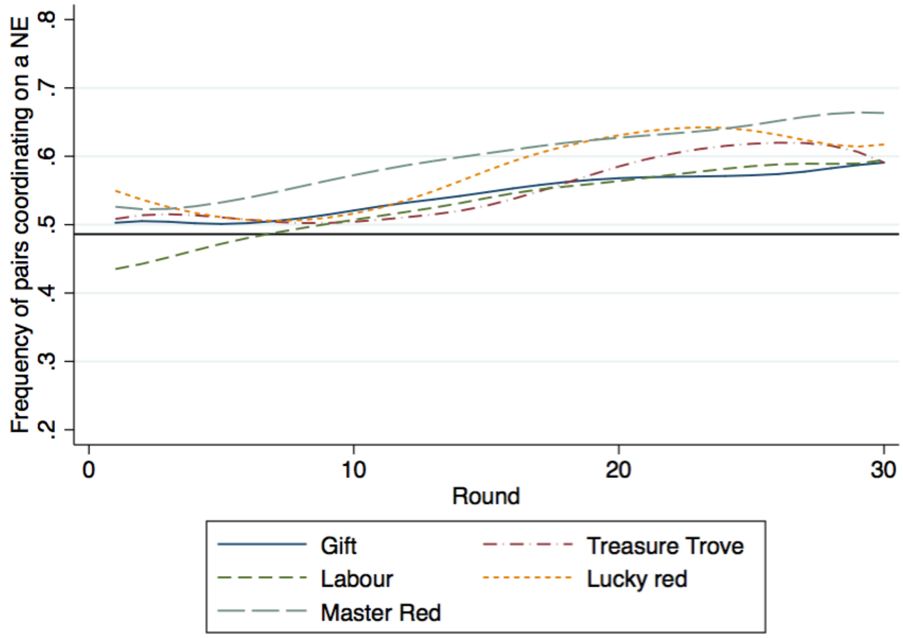
Figure 6: Frequency of coordination by treatment



Each line depicts the frequency with which the NE is played over the 30 rounds for each treatment. The continuous black line depicts the hypothetical level of coordination if all subjects played the mixed NE. In this case, coordination happens with probability $2p(1-p) = \frac{35}{72}$ where $p = \frac{7}{12}$. Data is graphed using a locally weighted scatter plot smooth (LOWESS) function.

Looking at the total level of coordination, our treatment manipulation seems not to have produced any noticeable effect. However, overall coordination may be achieved by establishing one of the two conventions that take advantage of the UA (bourgeois and antibourgeois in the possessory treatments) or in some other ways. Our analysis therefore moves on to check whether different ways of establishing the initial claim to the asset (our treatment manipulation) affect the type of convention adopted. We create two categorical response variables, *bourgeoiscoord* and *antibourgeoiscoord,* that take values $\{1, 4\}$ indicating for each sic-player group in each round how many pairs of subjects implement a bourgeois (i.e. owner plays H, intruder plays D) or an antibourgeois (intruder plays H, owner plays D) convention, respectively. We apply the same settings used for model 1 and model 2 to these two new variables.

Before proceeding and in order to define the two variables *bourgeois* and *antibourgeois*, we need to identify who is the possessor and who is the intruder. This is immediate in the possessory treatments (the *possessor* is the subject in the pair that possesses the 50 tokens at the end of the first part of each round and the *intruder* is the other subject).[20] Identifying the *possessor* is also simple in the Master Red treatment; even if there is no possession, the Treasure Trove introduces a sort of "meritorious incumbency" that translates into the assignment of the red color[21] to the winner. Assigning the

[20]As remarked above, no such labels were used in the instructions during the experiment.

[21]In half of the experimental sessions, the meritorious subject was actually assigned the blue color. We implemented this variation to make sure that the estimated effect of gaining a color meritoriously in the interaction preceding the H-D contest was not confused with the effect of being labeled "blue" or "red" subject. For the sake of simpler presentation,

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possessor label in the Lucky Red treatment is less straightforward because there is no possession or any meritorious incumbency. We proceed as follows. First, we identify for each group of six subjects interacting throughout a session the convention that is established more often in the initial 10 rounds.[22] To do so, we count the number of times that i) red plays H while blue plays D and ii) blue plays H while red plays D. If (i) is larger than (ii), then we claim that the convention "red plays H while blue plays D" is the established convention and we label red as *possessor*. Conversely, if (ii) is larger than (i), we label blue as *possessor*.[23]

during the exposition of the results that follows we will pretend the meritorious subject was always assigned the color Red.

[22]As a robustness check, we have replicated the procedure over 5 and 15 rounds as well. We obtained very similar results (and qualitatively the same results in the statistical tests described below) whichever number of initial rounds is used. In what follows, we report the results derived using a threshold number of 10 rounds.

[23]To provide an example, let us consider a group of sic subjects over the first 10 rounds for a total of 30 potential Hawk–Dove contests. Suppose we observe eight contests where "blue plays H while red plays D", 10 contests where "red plays H while blue plays D", and the other 12 contests end up with no coordination. In order to establish the convention "red plays H while blue plays D" it is sufficient that red subjects play H marginally more often than blue subjects, and this is the case. It should be noted that given our weak definition of convention, even if subjects ignore the UA in choosing their strategy, a convention almost surely emerges by design, at least nominally, as even if subjects play completely randomly, the two conventions (H-D and D-H) happen with $p = 1/4$ each. As we compare the frequency of possessors playing H across the possessory and color treatments, this definition of the convention works against the hypothesis that possessory treatments may produce more coordination than the colored ones.

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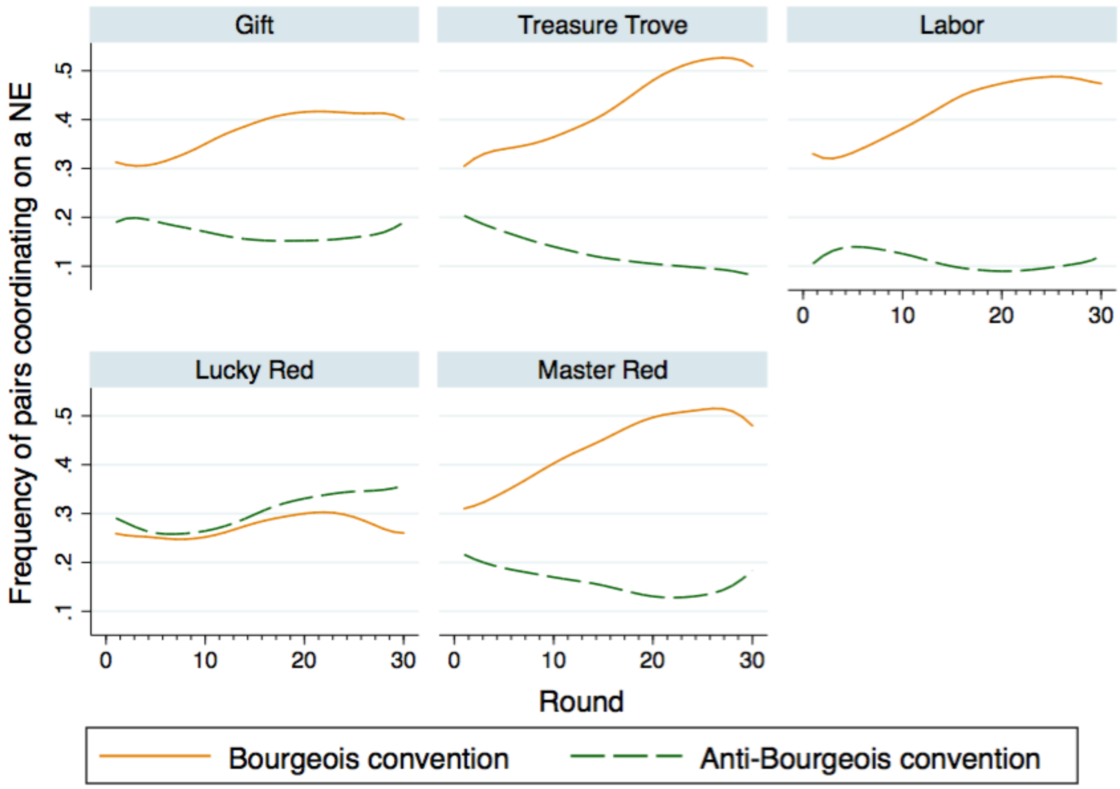
Figure 7: Level of bourgeois and antibourgeois coordination



The frequencies of bourgeois and antibourgeois coordination are depicted for each treatment separately using a locally weighted scatter plot smooth function.

In model 3 of Table 1 we investigate bourgeois behavior. Here a clear treatment effect emerges, with Labor being the treatment where the bourgeois convention emerges more frequently, along with the Master Red and the Treasure Trove treatments. The Lucky Red and Gift treatments are the ones less likley to induce bourgeois coordination (albeit only marginally less so for Gift). Significant differences are also estimated between the Lucky Red and the Master Red, between the Lucky Red and the Treasure Trove, and between the Gift and the Master Red treatments. This suggests that bourgeois behavior is implemented to a larger extent in the treatments characterized by a meritorious process of acquisition of the UA (Labor and Treasure Trove). Moreover, the meritorious acquisition is effective in inducing bourgeois coordination, even in the absence of an ex-ante explicit assignment of possession (Master Red).

Antibourgeois behavior has a significantly higher likelihood of being observed in the Lucky Red treatment (see model 4 in table 1) compared to all other treatments. Furthermore, a significant difference is estimated between the Gift and the Treasure Trove treatments, with the former increasing the probability of behaving in an antibourgeois manner. Finally, no significant differences are estimated

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between Labor and the other treatments.

Claim 3. **In the meritorious treatments (Labour, Treasure Trove, and Master Red), subjects predominantly coordinate on the bourgeois convention. In the Gift treatment, subjects achieve marginally significantly lower levels of coordination on the bourgeois convention. In the Lucky Red treatment, coordination on the bourgeois convention is significantly lower and coordination on the antibourgeois convention is significantly higher compared to the other treatments.**

4.2 Individual behavior

In the previous section, we focused on the six-subject groups as units of observation, measuring participants' ability to achieve coordination and to converge on a specific convention given the different types of UA provided. In this section, we focus instead on decisions at the individual level, independent of whether the subject pair achieved coordination, and we measure the actual outcomes against the scenarios hypothesized in section 3.2. We introduce the dummy variable *defend* that takes the value 1 when a subject is a possessor and chooses the H strategy. Similarly, we create the dummy *steal* that takes the value 1 when the subject is an intruder and chooses the H strategy. Figure 8 shows the fraction of subjects playing the H strategy when they are either possessors (orange continuous line) or intruders (green dashed line) through the 30 periods for each treatment[24]. In all the possessory treatments (Labor, Treasure Trove, and to a lesser extent Gift) and in the Master Red treatment, the introduction of the UA seems to induce possessors to play H at higher frequencies than intruders, thus supporting Scenario 3 where only one convention is established. In particular, the established convention is always the bourgeois. Conversely, in the Lucky Red treatment the two lines are close and cross both the $1/4$ and the $7/24$ line. This graphical finding is compatible with both Scenario 1 (where no convention is established but coordination over the mixed NE is realized) and Scenario 2 (where both conventions are established, with each one played with roughly equal frequency). An examination of Figure 11 in the Appendix shows that in none but one of the Lucky Red groups a clear pattern of coordination on one convention emerges. Therefore, the graphical evidence of Figure 8 suggests that the Lucky Red treatment induces behavior in accordance with Scenario 1.

[24]Figure 11 in the Appendix reports the evolution of the variables *defend* and *steal* for each six-subject group for each treatment.

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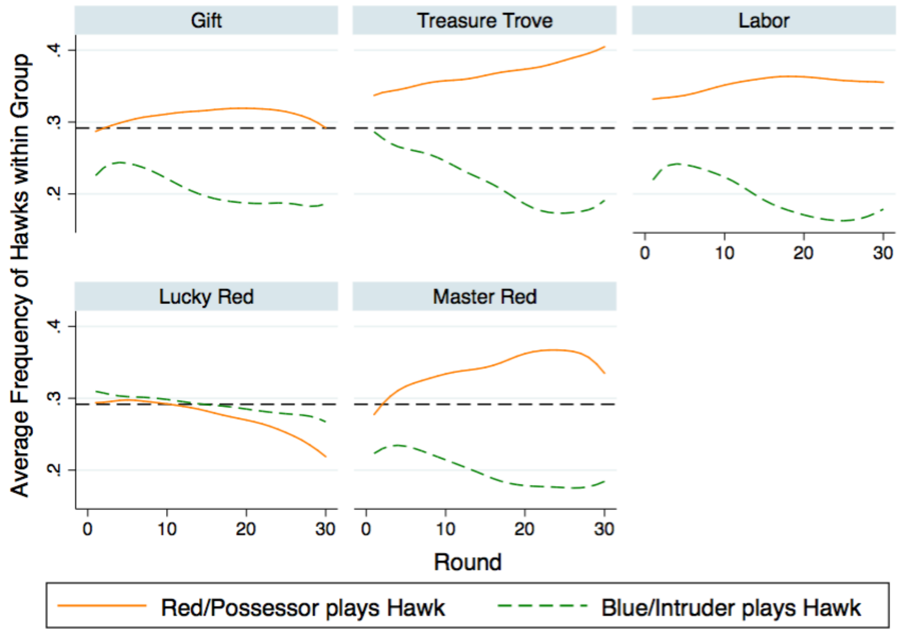
Figure 8: Evolution of hawkish behavior dependent on the UA in each treatment.



The orange line depicts the frequency of players playing H when their role is either possessor (in the possessory treatments) or red (in the colored treatments). The green line depicts the frequency of players playing H when their role is either intruder (in the possessory treatments) or blue (in the colored treatments). The black dashed line represents the expected frequency (7/24) of hawkish behavior in cases where subjects played the NE in mixed strategies.

We verify these graphical impressions using a regression analysis. The individual data is in the form of panels of individual behavior clustered within groups. A clear hierarchy can be detected in the data structure, and different sources of heterogeneity might arise at different levels of the hierarchy. Therefore, we have to slightly modify the previous regression setting to allow for multilevel random effects, capturing the correlation between repeated individual measurements and the group-specific effect. Hierarchical/multilevel random effects are often used in the analysis of binary hierarchical data (Goldstein, 2011), as they provide a flexible strategy to account for complex correlation structures in the analysis of longitudinal data; see, for example, Skrondal & Rabe-Hesketh (2004); Steele (2008); Muthén & Asparouhov (2009). Here, a hierarchical mixed-effects logistic regression is employed, containing both fixed effects and random effects. The random effects are useful for modeling intra-panel correlation, as observations share common panel-level random effects.

In the following, we specify a three-level model by introducing random effects for six-player groups interacting for 30 rounds and individuals nested within groups; the time-specific observations comprise the first level, the individuals comprise the second level, and the groups comprise the third level. Formally, let y_{tig} be the behavior at time t for the i-th individual clustered within the g-th group, the three-level mixed-effects logistic model is defined as:

$$\text{logit}[\Pr(y_{tig} = 1 \mid \mathbf{x}_{tig}, u_{ig}, v_g)] = \mathbf{x}'_{tig}\boldsymbol{\beta} + u_{ig} + v_g. \tag{1}$$

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Here, $\mathbf{x}'_{tig}$ is a vector containing all covariates, u_{ig} is a random intercept varying over individuals (level 2) and v_g is a random intercept varying over groups (level 3). The random intercepts u_{ig} and v_g are assumed to be independent of each other and independent across communities, and u_{ig} is assumed to be independent across individuals as well. Both random intercepts are assumed to be independent of the covariates $\mathbf{x}_{tig}$. The responses y_{tig} are independently Bernoulli distributed given the random effects and covariates. The model (1) can be alternatively written as a latent-response model, widely used in the econometric literature,

$$y^*_{tig} = \mathbf{x}'_{tig}\boldsymbol{\beta} + u_{ig} + v_g + \epsilon_{tig} \tag{2}$$

where ϵ_{tig} has a standard logistic distribution with variance $\frac{\pi^2}{3}$. The ϵ_{tig} are assumed to be mutually independent and to be independent of u_{ig}, v_g and $\mathbf{x}_{tig}$. The observed binary responses are then presumed to be generated by the threshold model

$$y_{tig} = \begin{cases} 1, & y^*_{tig} > 0 \\ 0, & otherwise \end{cases}$$

To ensure model identifiability, the random effects u_{ig} and v_g are assumed to have zero-mean. Furthermore, a Gaussian distribution is often taken for granted for the random terms. Here, to specify the distributions of the random terms, we take a non-parametric approach (Aitkin, 1999) and assume that the random-effects are drawn from discrete distributions with a finite number of mass points, associated to some mass points probabilities. This involves an additional step in the model selection, because the support of these distributions is not known in advance; it must be selected by evaluating the goodness of fit that different supports obtain. However, there are several advantages that compensate for this complication. First, the random effects model reduces to a finite mixture model with a computationally tractable likelihood function. Second, the possibly inappropriate and unverifiable parametric assumptions about the distribution of the random effects are avoided. Third, the outcomes are clustered in a finite number of latent classes that can have an economic meaning. Parameters estimates are obtained in a maximum likelihood framework by using the Expectation-Maximization algorithm (Dempster *et al.* , 1977).

Table 2 reports the results. In models 5 and 6, the dependent variable is *defend*, but model 6 that differs in that it also controls for individual risk preferences, logical abilities, and socio-demographic characteristics. The coefficients of the treatment dummies show that players in the Labor and Treasure Trove treatments play H when they are possessors significantly more frequently than in the other treatments (in Labor, weakly significantly more than in Treasure Trove, once we control for individual characteristics). Notice that both *meritorious possession* treatments–but especially the labor one–are the ones generating the highest rates of defend behavior. However, *arbitrary possession* (in the Gift treatment) or the *meritorious assignment of the color* (in the Master Red treatment) do not induce as much hawkish behavior as in the *meritorious possession* treatments.

Claim 4. **Both meritorious possession treatments induce the highest frequency of hawkish behavior among possessors. The effect is marginally stronger in the Labor treatment than in the Treasure Trove treatment.**

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Table 2: Individual behavior

Dep. Variable	Model 5 defend	Model 6 defend	Model 7 steal	Model 8 steal
LuckyRed	-0.430***	-0.551***	0.621***	0.481**
	(0.108)	(0.117)	(0.150)	(0.189)
Gift	-0.362***	-0.497***	0.141	0.049
	(0.102)	(0.120)	(0.175)	(0.128)
TreasureTrove	-0.116	-0.246*	0.340**	0.198
	(0.107)	(0.127)	(0.143)	(0.158)
MasterRed	-0.270**	-0.314***	-0.036	-0.203
	(0.112)	(0.112)	(0.143)	(0.144)
male		0.319***		0.077
		(0.073)		(0.091)
age		0.040**		0.008
		(0.018)		(0.020)
HLriskfinal		0.092***		0.086*
		(0.031)		(0.047)
logic		-0.030		0.022
		(0.058)		(0.092)
impulsivity		-0.019		0.055
		(0.031)		(0.044)
education		0.071		-0.119*
		(0.058)		(0.071)
Constant	-0.559***	-2.257***	-1.674***	-2.310***
	(0.081)	(0.441)	(0.112)	(0.460)
N.obs.	14220	14220	14220	14220

Notes: Dependent variable: In models 5 and 6 the dummy *defend=1* when a subject plays H if possessor; in models 7 and 8 *steal=1* when a subject plays H if intruder. Multilevel model for longitudinal data. Compared to models 5 and 6, model 7 and 8 control for individual risk preferences, logic abilities, impulsivity, and education levels. Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

Overall, gaining possession of an asset through effort induces the highest rates of hawkish behavior. This result seems to support the John Locke theory of property (Henry, 1999) that justifies and legitimizes property in terms of labor. In addition, the other mode of acquisition via first possession mimicked in the Treasure Trove treatment produces high rates of hawkish behavior; this mode of acquisition constitutes the base of other important theories of property proposed by Grotius ([1625] 2012) and Pufendorf *et al.* ([1708] 1991).

In models 7 and 8, the dependent variable is *steal* (model 8 additionally controls for individual risk preferences, logical abilities, and socio-demographic characteristics). The coefficients of the treatment dummies reveal that, with the exception of the Lucky Red where intruders choose H at a significantly higher rate, intruders in the remaining treatments have the same likelihood to choose the hawk strategy.

There emerges an asymmetry in behavior between the hawkish and dovish behavior. While being a possessor induces a clear hierarchy of hawkish behavior among treatments (Labor > Treasure Trove > Master Red > Gift > Luky Red), being an intruder causes little dovish behavior in the Lucky Red treatment and an greater–but approximately similar–dovish behavior in the remaining four treatments.

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Claim 5. **In the Lucky Red treatment, intruders are significantly more likely to play H compared to the other treatments. Intruders play H with the same frequency in the remaining treatments.**

4.3 Welfare effects and inequality

As discussed in section 2, the Hawk–Dove game achieves the highest level of efficiency when subjects coordinate on one of the two NE in pure strategies. Claim 3 shows how the bourgeois coordination emerging in the three possessory treatments and in the Master Red treatment has no match in the Lucky Red treatment. However, we also saw in Claim 1 that the level of total coordination is very similar in the five treatments, suggesting that players in the Lucky Red treatment also achieve a substantial amount of coordination on an efficient equilibrium. Indeed, an examination of figure 9–thatplots the average individual profits across the 30 rounds for each treatment–suggests that profits in the Lucky Red treatment seem to be no lower than in other treatments.

This graphical impression resonates with the quantitative evidence reported in models 9 and 10 of table 3. In both models, we implement a hierarchical-multilevel model for longitudinal data considering the individual participant as the unit of observation and including controls for risk preferences and socio-demographic characteristics. In model 9 and 10 the dependent variable is *profit*; furthermore, in model 10 the variable *period* is included and interacts with the treatment dummies.

The results of model 9 show that the absolute level of profits is not statistically different among treatments, with the exception of the Treasure Trove one, which has significantly lower average profits compared to the Master Red and (marginally) the Lucky Red treatments. Furthermore, model 10 shows that the Lucky Red treatment registers the highest profit growth over the experimental rounds, and the difference is statistically significant compared to the Treasure Trove treatment. In other words, even without establishing either the bourgeois or the antibourgeois conventions (see claim 3) subjects in the Lucky Red treatment achieve profit levels and profit growth rates similar or higher (compared to Treasure Trove) than in all other treatments. How does this happen?

The answer is suggested by Figure 10 that plots for each treatment the frequency distribution of hawkish behavior of subjects (regardless of whether they are possessors or intruders) over different experimental periods. In the left column, it is reported the distribution of players choosing strategy H over the initial 10 rounds, while in the right column there is the same distribution over the final 10 rounds. Notice that in the first 10 rounds the frequency distributions are similarly dispersed in all five treatments and tend to concentrate in the last 10 rounds. However, in the last 10 rounds a clear difference in how they concentrate emerges. In the three possessory treatments and in the Master Red treatment the distribution clearly becomes unimodal, with "play H half of the time" as the modal choice. This first behavior is compatible with the emergence of the bourgeois convention (see Claim 3) where subjects happen to be the possessors around half of the time. However, the frequency distribution in the Lucky Red treatment clearly becomes bimodal, with either "play always D" or "play always H" being the two modal behaviors. This means that in the Lucky Red treatment some subjects consistently play H from the very first rounds, ignoring the color assigned them. As a consequence, after a few rounds other subjects in the group desist any attempt to coordinate on the UA and start always playing D in order at least not to be damaged. In other words, the Hawk–Dove game is here

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resolved by some “hawk-type players” bullying other subjects into becoming D and into surrendering the profits in each round. The uncorrelated asymmetry provided–the color randomly assigned at the beginning of each round–is ignored. They therefore fail to become bourgeois.

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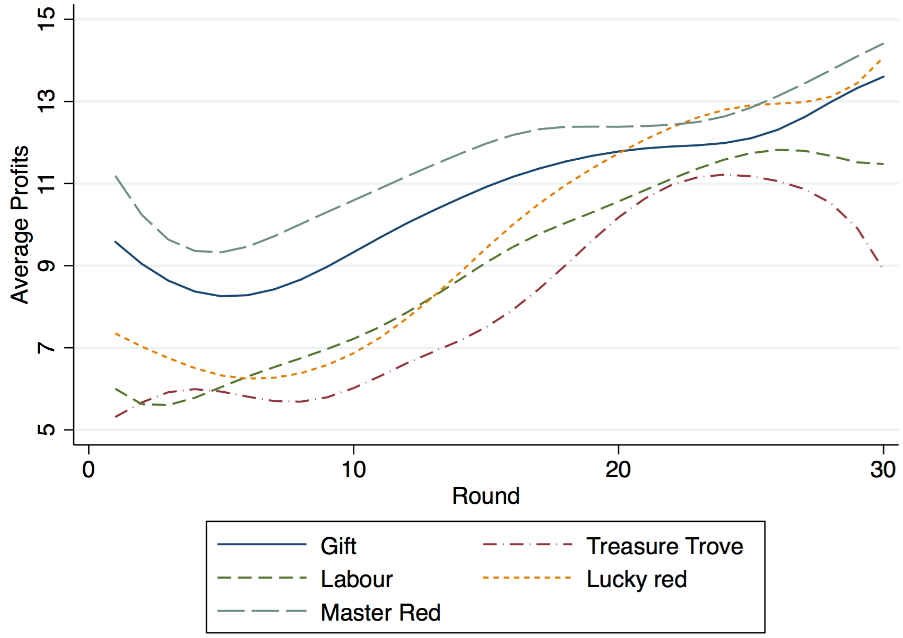
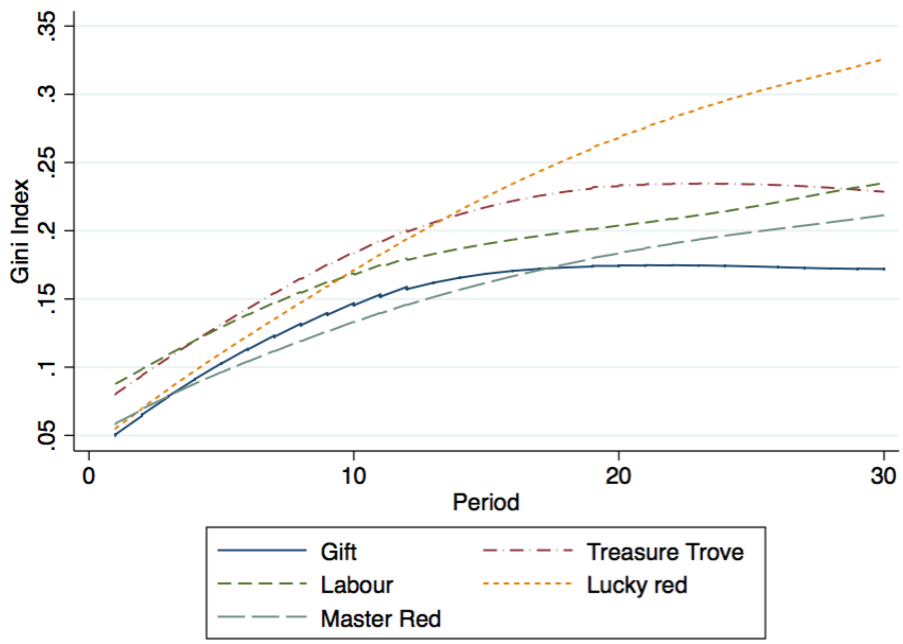
Figure 9: Average profits over the 30 rounds and the Gini index





The average individual profit in the upper graph and the Gini index in the lower graph are depicted using a locally weighted scatter plot smooth function.

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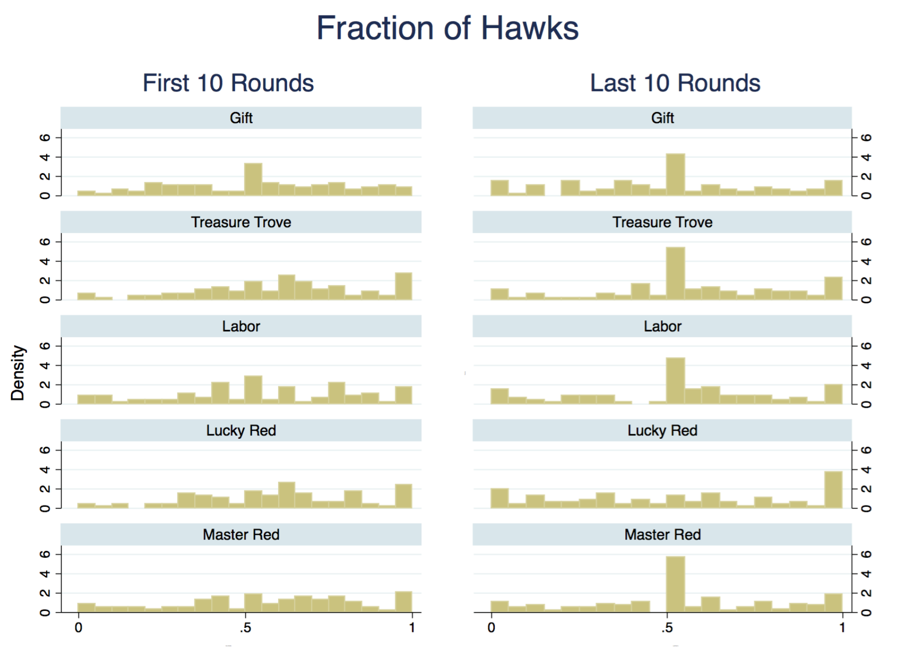
Figure 10: Fraction of players choosing "H" in the first and last 10 rounds divided by treatment



Notes: Each line depicts the frequency distribution of hawkish behavior for each treatment. In the left column, the distribution is calculated over the initial 10 periods. In the right column, the distribution is calculated over the final 10 rounds.

This dynamic has a strong impact on the evolution of the Gini coefficient, a measure of wealth distribution among players (right panel of Figure 9). While in the first 10 experimental periods profit inequality grows at basically the same pace in all four treatments, it later flattens out in the three possessory treatments and in the Master Red treatment but keeps on steadily rising in the Lucky Red treatment. These results are confirmed by a regression analysis. In models 11 and 12 of Table 3, we implemented a hierarchical-multilevel model for longitudinal data in which the Gini coefficient of the the six-player group is the dependent variable. Coefficients of model 11 show that the level of inequality as measured by the Gini index is statistically significantly higher in the Lucky Red treatment than in the other treatments. The regression also shows that the Treaure Trove treatment generates significantly higher inequality compared to the other treatments. Model 12, in which we repeat the regression interacting the treatment dummies with the experimental period, confirms that profit inequality increases the fastest in Lucky Red treatment. At the opposite end, the Labor and Gift treatments display the lowest growth in inequality.

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Table 3: Welfare effects

Dep. Variable	Model 9 profit	Model 10 profit	Model 11 Gini	Model 12 Gini
LuckyRed	2.432		0.067***	
	(1.485)		(0.004)	
Gift	1.791		-0.001	
	(1.433)		(0.004)	
TreasureTrove	-1.028		0.024***	
	(1.459)		(0.004)	
MasterRed	2.500		0.007	
	(1.467)		(0.004)	
Period		0.225***		0.003***
		(0.050)		(0.000)
Period x LuckyRed		0.102		0.004***
		(0.065)		(0.000)
Period x Gift		0.010		-0.000*
		(0.065)		(0.000)
Period x TreasureTrove		-0.037		0.001***
		(0.065)		(0.000)
Period x MasterRed		0.007		0.001***
		(0.063)		(0.000)
Constant	8.364*	5.111	0.099***	0.041*
	(4.810)	(4.720)	(0.033)	(0.024)
N.obs.	14220	14220	2370	2370

Notes: Dependent variable: for models 9 and 10 the dependent variable is *profit* and for models 11 and 12 it is *Gini index*. Multilevel model for longitudinal data. Models 9 and 11 look at average profit and the Gini index. Models 10 and 12 look at trends over the experimental periods of profit and the Gini index, respectively. Each model controls for individual risk preferences, logic abilities, impulsivity, and education levels (averaged at the six-player group level in models 11 and 12). Symbols $***$, $**$, and $*$ indicate significance at the 1%, 5% and 10% level, respectively.

Claim 6. **Without possession or merit, subjects ignore the UA provided and instead coordinate on a "Hobbesian" strategy: some subjects consistently play H, while other subjects surrender and play D. This equilibrium produces the highest wealth inequality.**

In our lab experiment, the tenet of many political philosophers–such as Rousseau and Marx–that a system of private property rights introduces and exacerbates inequality seems to find no ground. In fact, it is quite the opposite; it is only the eventual establishment of the property convention that limits wealth inequality among participants.

5 Discussion and conclusions

The present work is situated within the Humean tradition that sees property as a convention emerging from the deliberate and rational coordination of individuals over the appropriation, production, and use of assets (Waldron, 2013). This longstanding tradition has been reinvigorated in the last 40 years by the contribution of natural sciences both at the theoretical level with biologists' work on evolutionary game theory and at the empirical level with the study of the respect many species have for territoriality

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and property. Quite surprisingly, this prolific literature on the Hawk–Dove game and its implications for understanding the nature of property institutions has received little attention from economists, with the few notable exceptions of Sugden (1989, 2004); Gintis (2007a); Eswaran & Neary (2014) and, among the law and economics scholars Rose (2014); Lewinsohn-Zamir (2015).

Even more strikingly, the Hawk–Dove game has received very limited attention by experimental economists and, to our knowledge, it has never been studied in the lab by introducing possession as the UA.[25] In our experiment, we manipulate on the one hand the type of UA provided, and in particular whether the two subjects play the Hawk–Dove game as possessor vs. intruder or red vs. blue; on the other hand, we manipulate the process of acquisition of the UA, that is to say whether the role of possessor/red player is acquired arbitrarily or meritoriously. Our experimental results show that subjects learn and achieve a considerable amount of coordination on a pure NE and this happens irrespective of our treatment manipulation. However, the overall level of coordination hides some very interesting differences. In fact, substantial bourgeois (and never antibourgeois) coordination emerges whenever the information is based on possession (Gift, Treasure Trove and Labor) but also when its attribution is meritorious (Master Red). Indeed, the highest level of coordination is achieved when possession and merit are combined. The type of coordination that emerges in the Lucky Red treatment is instead of a very different nature because some subjects that invariably play H bully others into playing D, which produces a very inequitable social outcome.

Our results contribute to the longstanding philosophical and political debate on property. In *Leviathan*, Hobbes ([1651] 2016) depicted the state of nature, where no institution exists, as a state of war where *every man* takes what *he can get and for so long as he can keep it.* The Hawk–Dove game captures the potentially catastrophic outcomes of endemic fighting over the appropriation of resources. Hobbes offered a top-down solution to this *nasty, brutish, and short* equilibrium with the establishment of a property rights' regime by the Leviathan. Without the need for a Leviathan, David Hume in his *Treatise of Human Nature* provided a bottom-up theory of the emergence of the property convention out of the voluntary coordination of individuals: *I observe, that it will be for my interest to leave another in the possession of his goods, provided he will act in the same manner with regard to me* (Hume ([1738] 2007, pg 315). As Sugden (1989) points out, the bourgeois strategy in the Hawk–Dove game is indeed the contemporary game theoretic modeling of the modern era Humean property convention, and our experiment shows that possession is indeed sufficient to ignite coordination around the property convention. Compared to Hobbes, Locke ([1689] 1980) had a more positive idea of the state of nature and envisaged the existence of natural law, *which obliges every one* not *to harm another in his life, health, liberty, or possessions;* and it is by virtue of natural law

[25] There might be an intuitive and at the same time important reason why previous implementations of the Hawk–Dove game avoided using possession as UA (see Neugebauer *et al.* 2008; Oprea *et al.* 2011; Berninghaus *et al.* 2012). The reason is that possession may be culturally loaded, while other asymmetries, such as colors or "row" vs. "column" roles previously used, are almost certainly not. However, as the focus of the paper is exactly the role of possession in establishing the property convention, we used possession along the color label as our UA. While our experimental subjects, mainly university students, could have been nurtured to some extent to coordinate on the property convention, the results of some recent experiments done with young children (Rochat *et al.* , 2014; Rossano *et al.* , 2011; Goulding & Friedman, 2018) seem to suggest that the disposition to respect and enforce property rights is innate and thus it is also driven by nature. Our current treatment variation is not meant to answer the question of whether the property convention is driven by "nature or nurture", and further research is needed to shed light on the neurobiological origins of property as a social convention.

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that the *labour of his body, and the work of his hands* legitimizes the existence of individual property rights. Indeed, our Labor treatment, where possession is gained in exchange for effort, triggers the highest willingness of the possessor to defend her endowment. . This supports the idea that while individuals recognize other means of acquiring possession of a resource as legitimating its ownership, they perceive labor as the most natural condition to legitimize the property convention. We conclude our brief excursus of the modern debate on property by referring to the ideas of Rousseau highlighted in his *Discourse on Inequality* ([1754] 1984) and of Marx in *The Communist Manifesto* ([1848] 2013) on the relationship between property and inequality. They supported slightly different versions of the same argument that the institution of property is the instrument by which the ruling class (the bourgeoisie in the nineteenth century) extracts rents from the other classes. Contrary to their claim that property is an institution that exacerbates inequality, in our treatments the establishment of the property convention limits inequality, in particular when possession of the resources is legitimated by labor (Labor treatment) or by luck (Gift treatment). Conversely, in the only treatment where a property convention is not established (the Lucky Red treatment) inequality reaches the highest level.

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Appendix: Additional Graphs

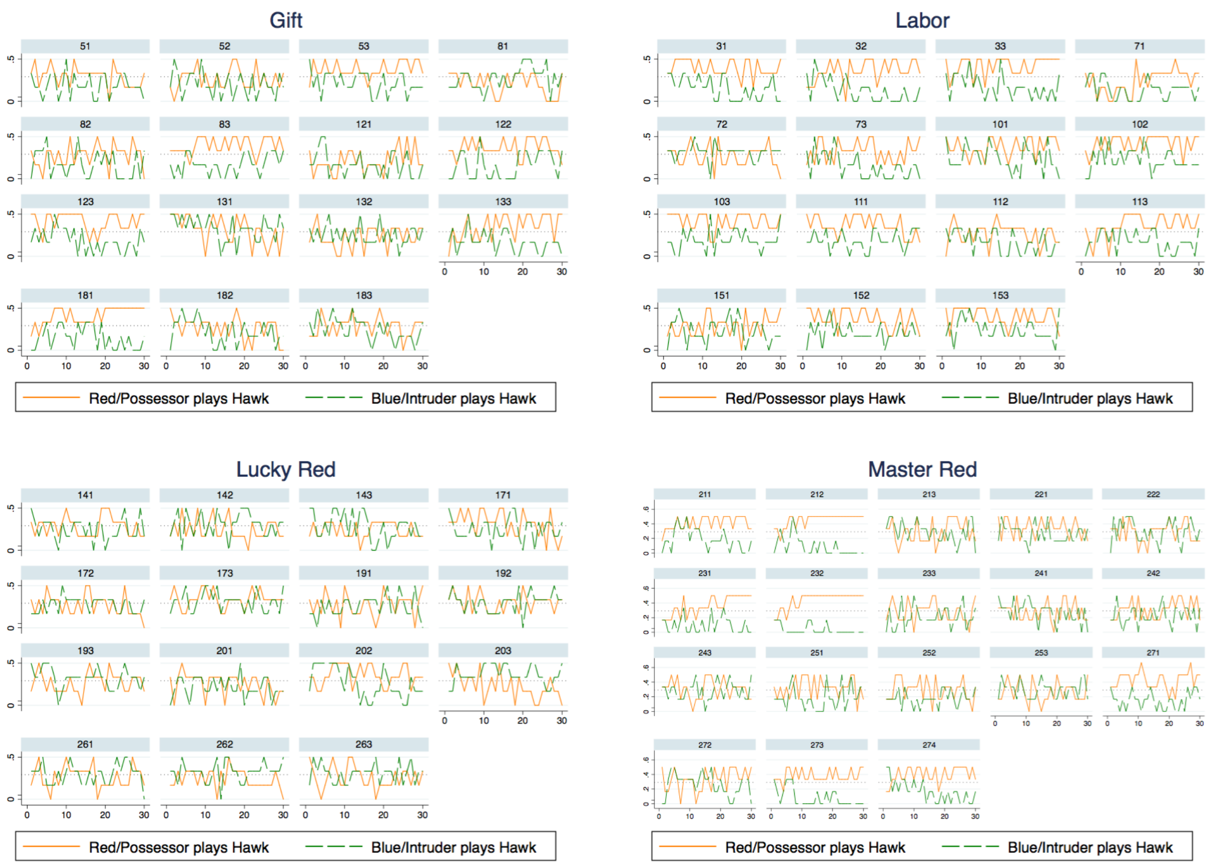

Figure 11: Evolution of Hawkish behavior dependent on the UA in each group of the some treatments. The Orange line depicts the frequency of subjects playing Hawk when their role is Red. The green line instead depicts the frequency of subjects playing Hawk when their role is Blue.

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Appendix: Instructions

BEGINNING OF SECOND STAGE:

This part of the experiment is composed by 32 rounds. At the beginning of each round, the computer will randomly pair you with one of the other 7 other participants. In each round, once the pairs are formed, the computer randomly selects one of the two players in the pair. The latter has the possibility to contend a fraction of the endowment of the other player equal to 4 units. Whether you are the player selected by the computer or not, you have to state a decision regarding your behavior during the contest for this fraction of endowment. The allocation of the 4 units of endowment, and therefore your total endowment at the end of the round, is determined by your choices and by the choices of the players paired with you during the rounds.

INSTRUCTIONS FOR EACH ROUND (what players see on their screens):

Player 1: At this point, your endowment amount to 15(?) units. The other player has been selected by the computer. Therefore, you and the player matched with you in this round are now going to contend a fraction of your endowment equal to 4 units. You have to choose your behavior during the contest:

- If you choose behavior A (Hawk) and the other player chooses behavior A (Hawk), the 4 units of resources will be destroyed. Additionally, both you and the other player will suffer a damage equal to 1 unit. Your total endowment by the end of the round will be 10.

- If you choose behavior A (Hawk) and the other player chooses behavior B (Dove), the 4 units of resources are allocated to you and the other player gets 0. Your total endowment by the end of the round will be 15.

- If you choose behavior B (Dove) and the other player chooses behavior A (Hawk), the 4 units of resources are allocated to the other player and you get 0. Your total endowment by the end of the round will be 11.

- If you choose behavior B (Dove) and the other player chooses behavior B (Dove), 2 units of resources are allocated to you and 2 units to the other player. Your total endowment by the end of the round will be 13.

Player 2: At this point, your endowment amount to 15(?) units. You have been selected by the computer. Therefore, you and the player matched with you in this round are now going to contend a fraction of the other player's endowment equal to 4 units. You have to choose your behavior during the contest:

- If you choose behavior A (Hawk) and the other player chooses behavior A (Hawk), the 4 units of resources will be destroyed. Additionally, both you and the other player will suffer a damage equal to 1 unit. Your total endowment by the end of the round will be 14.

- If you choose behavior A (Hawk) and the other player chooses behavior B (Dove), the 4 units of resources are allocated to you and the other player gets 0. Your total endowment by the end of the round will be 19.

- If you choose behavior B (Dove) and the other player chooses behavior A (Hawk), the 4 units of resources are allocated to the other player and you get 0. Your total endowment by the end of the

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round will be 15.

- If you choose behavior B (Dove) and the other player chooses behavior B (Dove), 2 units of resources are allocated to you and 2 units to the other player. Your total endowment by the end of the round will be 17.

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N.B. if we only play the labor\treasure-finding task once at the beginning of the experiment, after some rounds the source of endowment might become less salient and the endowment might become kinda product of stealing\defending activity One possibility to make more salient the endowments' source might be exploiting mental accounting. There is an "account 1" that only keeps track of the modification to the initial endowment collected according to the treatment (e.g. therefore registers only losses) and an "account 2" that keeps track only of the surpluses acquired through stealing. The final payoff is the sum of the two accounts so it doesn't change anything.

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