# Money in the schoolyard: young children use commodities as an indirect medium of exchange *

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**Abstract**

How innate is the human ability to trade? Barter economies organize trade through a simple principle of double coincidence of needs. Commodity markets require to recognize the value of commodities as a medium of exchange. Both have been ubiquitous throughout history, suggesting that humans are wired to exploit profitable exchange opportunities. This paper studies our innate ability to trade through a developmental approach. We present the first market experiment involving children who have not yet developed trading habits and are relatively unfamiliar with the concept of money. Namely, we ask 117 children aged 5 to 8 to trade in situations in which efficient market outcomes can either be achieved through simple barter or else necessitate the endogenous emergence of commodity money. We find that market equilibrium outcomes are pervasive (74% to 82% of groups depending on the treatment). Pareto efficient trading occurs in 82% of barter economies and 53% of commodity markets. Finally, 47% of the children are involved in efficient trades in all markets. The results indicate that young children have an intrinsic aptitude to organize market exchanges.

Keywords: laboratory experiment, market experiment, developmental decision making, money, trade.

JEL Classification: C92.

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# 1 Introduction

Commodity money – a medium of exchange using goods with an intrinsic value – has been present in societies since the neolithic (Davies, 2010). Markets based on commodity money have been long recognized as a significant improvement over barter economies (which require a double coincidence of needs) and gift-exchange economies (which require trust and repeated interactions) (Smith, 1887; Jevons, 1885). Modern anthropologists argue against the existence of any large scale economy that operated without some form of currency (Humphrey, 1985), and case studies report that commodity markets spontaneously develop in closed economies such as prisons and POW camps (Radford, 1945), or in periods of monetary instability (Friedman, 1994). The ubiquitous presence of commodity money suggests that humans are wired for market interactions and to exploit profitable exchange opportunities (Einzig, 2014; Quiggin, 2017).

In the last decades, economists have made significant progress in understanding the role of money as a medium of exchange (see e.g., Kiyotaki and Wright (1989, 1993); Lagos and Wright (2005)). Theories have been tested in controlled laboratory environments in adults (see e.g., McCabe (1989); Lian and Plott (1998); Duffy and Ochs (1999); Camera et al. (2013); Duffy and Puzzello (2014); Camera and Casari (2014); Jiang and Zhang (2018)).[1] However, the question of how innate is our ability to trade and, more specifically, how innate is our capacity to recognize the value of commodities as a medium of exchange has never been addressed. Such questions require a developmental perspective. Indeed, adults are presumably "experts" at monetary exchanges. By asking children to trade at an age at which trading habits are not fully developed and money is still a relatively unfamiliar concept, we can assess their instinctive aptitude to organize market exchanges.

To address this question, we design a controlled market experiment with young children – 5 to 8 years of age – and determine whether they can identify market opportunities and gains from trade in environments of different complexity. We consider three situations. In the *barter* treatment, trading is 'easy': the Pareto optimal outcome can be achieved through a series of bilateral trades where all parties benefit from every exchange. This environment is closest to barter economies, since trading is based on the double coincidence of needs. In the *commodity* treatment, trading is 'hard': some participants need to accept a temporary bookkeeping loss in order to eventually reach the Pareto optimal outcome. This situation is closest to commodity money markets, since trading only occurs if individuals recognize the value of a commodity as an indirect medium of exchange. In the *no trading* treatment, there are no direct or indirect profitable trades, and any exchange is necessarily detrimental for at least one party. This environment is used as a control, and helps measure

[1] We refer to Duffy (2016) for a comprehensive survey.

trading for motives other than a payoff improvement.

The paper characterizes the equilibria in those markets and addresses two sets of questions. First, we investigate the empirical properties of our experimental markets, testing both for equilibrium compliance (is an equilibrium reached?) and for equilibrium selection (which equilibrium is reached?). Given our markets differ in trade complexity, we compare compliance and selection across markets. This analysis focuses on the performance of children at the group level (three subjects, each in a different role). We study the sequence of trades, final allocations and efficiency. Second, we examine individual trading decisions across markets and we assess differences related to age and individual characteristics elicited through a short questionnaire. This aims to reveal the developmental trajectory in our window of observation and to identify traits that promote market performance.

We show that 82% of groups in the barter treatment and 79% in the commodity treatment reach an equilibrium outcome, that is, a situation where no pair of subjects can improve their payoffs with a bilateral trade. More impressively, groups reaching the unique Pareto efficient outcome (where all subjects obtain their highest payoffs) are frequent – 82% in the barter treatment and 53% in the commodity treatment – suggesting that young children understand and exploit market opportunities. The data also confirms the nested difficulty of these two treatments. We also show that deviations across treatments are qualitatively and quantitatively different. In the barter treatment, there is excessive trading that results in minor (8%) aggregate payoff losses. In the commodity treatment, there is insufficient trading, mainly because some subjects decide to keep their initial endowment and remain in the Pareto inferior equilibrium. These deviations imply significant (24%) payoff losses. In the no trading treatment, there is a small but statistically significant number of inefficient trades (one every nine subjects). Since these trades typically benefit one subject more than it hurts the other, they translate into small but positive welfare gains. Third, the analysis at the individual level shows that subjects are more likely to obtain the Pareto optimal equilibrium payoffs in the barter and no trading treatments compared to the commodity treatment. Equilibrium payoffs are also more prevalent for subjects with a self-reported preference for STEM over Arts and Humanities. By contrast, we found a negligible effect of age within our window of observation.

## 2 The experiment

To the best of our knowledge, this is the first market experiment (of trading or any other kind) with a population entirely comprised of children.[2] A population of children presents

[2]The only other market experiment with children we are aware of is List and Millimet (2008), where 48 children with some limited market experience (10-12 years old) play the role of buyers in a double

interesting methodological challenges for laboratory experiments in general (see Brocas and Carrillo (2019b) for a methodological overview and discussion of these challenges, and List et al. (2018) and Sutter et al. (2019) for recent surveys of experiments with children). These challenges are more pronounced in market settings, where protocols are generally more involved, and with younger children, who are more prone to distractions and less capable of abstract reasoning. As developed below, we address these obstacles with a novel design where treatments are identified by animals, roles are identified by colors, and endowments take the form of cards with different values for different roles.

### 2.1 Population

We recruited 117 children in three grades: 38 from kindergarten (K, ages 5-6), 37 from first grade (1, ages 6-7) and 42 from second grade (2, ages 7-8), at the Lycée International de Los Angeles (LILA), a french-english bilingual private school in Los Angeles. Families at LILA are predominantly of caucasian ethnicity and upper-middle socio-economic status. The population is homogeneous although not representative of the US.[3]

### 2.2 Game and treatments

We conduct a market experiment to study the ability of young children to engage in efficient trade, avoid inefficient trade, and understand the monetization value of exchanges. The experiment is an implementation of a simplified version of the Kiyotaki and Wright (1989) model. We formed groups of six participants, mixing males and females from the same grade. Children could not choose the groups they were in, and groups remained fixed for the entire session. We use a within-subject design where each group played the three trading treatments $\mathbf{t} \in \{\mathbf{B}, \mathbf{C}, \mathbf{N}\}$ in a randomized order, which we call 'barter' (**B**), 'commodity market' (**C**) and 'no trading' (**N**) for reasons that will become clear in the next section.

The rules of the three treatments are identical. For each treatment, there are three roles $r \in \{a, b, c\}$, and each group has exactly two subjects in each role. A subject in role $r$ of treatment $\mathbf{t}$ is initially given a card with three values $(x_r^{\mathbf{t}}, y_r^{\mathbf{t}}, z_r^{\mathbf{t}})$, representing the points that roles $a$, $b$ and $c$ would get if they hold that card when the trading period ends. The two subjects in the same role always receive the same initial endowment. Each

auction against adult professional (sportscard dealers) sellers. The authors show convergence to equilibrium independently of the level of market experience and rationality of the children.

[3]Ideally, we would have wanted a larger sample size but it is difficult to get a vast population of homogenous children. On the positive side, there is little self-selection within the school, since 73% of the children in these grades took part in the study. Also, given the reduced age span and the negligible effect of age (see later), 117 subjects is a good sample size to conduct regression analysis.

subject can trade cards with any of the five other members of the group. Trade requires mutual agreement as detailed in the procedures below and we imposed no limit on time or number of trades. Treatments differ exclusively in the value of the cards that subjects initially get. The initial endowments for each role in each treatment are summarized in Table 1.

| | role $a$ | role $b$ | role $c$ |
|---|---|---|---|
| **B** | $(1,2,3)$ | $(3,1,2)$ | $(2,3,1)$ |
| **C** | $(2,3,1)$ | $(1,2,3)$ | $(3,1,2)$ |
| **N** | $(3,3,3)$ | $(2,1,1)$ | $(2,3,2)$ |

**Table 1:** Initial endowments by role $r \in \{a, b, c\}$ and treatment $\mathbf{t} \in \{\mathbf{B}, \mathbf{C}, \mathbf{N}\}$.

In treatment **B**, participants are initially endowed with the card of lowest value to them. Treatment **C** has the same cards as **B**, but participants are endowed with the card of medium value to them. In treatment **N**, each role has a different card. We notice that in **B** and **C**, roles are symmetric and therefore labels $a$, $b$ and $c$ are interchangeable, whereas in **N** roles are asymmetric. Overall, we propose a commodity market where all cards are intrinsically valuable. Differences in valuations facilitate trade. As we will develop below, profitable trades are more immediately obvious in some treatments than in others.

### 2.3 Implementation with children

In economic experiments with young children, it is of paramount importance to provide a fun and concrete environment that subjects with limited attention and prone to distraction can easily grasp and find engaging (Brocas and Carrillo, 2019b). This ensures focus, comprehension and eager participation. Also, we cannot overemphasize the importance of using a simple and visual procedure, with as little analytical description as possible. To achieve this, we referred to **B**, **C** and **N** as the "dog game," the "cat game" and the "kangaroo game" respectively. Roles were identified by colors (green-blue-red in the dog game, purple-orange-grey in the cat game and brown-pink-yellow in the kangaroo game).[4] At the beginning of each treatment, we put a tag around the neck of each participant with the color corresponding to their role and the animal representing the treatment (e.g., a green dog represents role $a$ in **B**). All subjects could then remember their role and easily identify that of their peers. We then placed a card attached to an elastic wristband on the wrist of each child. The children were instructed to not remove the wristband. The card

[4]While there is a risk that children had preferences over animals and colors, we opted for this presentation to make it engaging. During debriefing, subjects reported that they liked some animals and colors better than others, but tried to maximize points in order to get their favorite rewards.

visually described its value as a function of the subject's role. Figure 1 describes the cards initially endowed by the green, blue and red roles ($a$, $b$ and $c$) in the dog game (treatment **B**). In the leftmost card, we can see that the card is worth one point for the green role, two points for the blue role and three points for the red role. The cat and kangaroo games (treatments **C** and **N**) followed similar procedures.

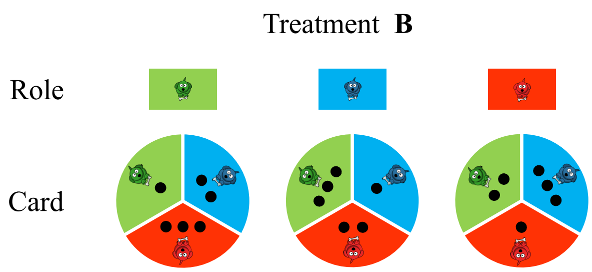



**Figure 1:** Initial endowments of green, blue and red role in the dog game.

The games were administered in a covered patio at the school. Before the trading game started, participants were encouraged to look at the roles (tags) and endowments (cards) of the five other subjects in their group. Once they were familiar, we implemented the following procedure in each group. Participants could discuss with each other in any way they wanted. However, we assigned strict property rights. Indeed, when a pair of subjects agreed to trade, they would come to the trading table. The experimenter would request from both subjects verbal confirmation of the willingness to trade and proceed to exchange their corresponding wristbands. Participants were not allowed to touch their wristbands or to come in groups of more than two for an exchange. However, a third subject could (and sometimes did) wait in line to subsequently perform a trade with one of the subjects involved in a current trade. If one subject did not verbally confirm a willingness to trade (which also occurred sometimes), we would not implement it. The process would continue with no time limit as long as there was a pair of subjects willing to trade. It took approximately 20 minutes to conduct the experiment. We deliberately stayed in a table at the corner of the patio, away from the conversations, to encourage the free exchange of information. We only intervened to enforce property rights, making sure that both parties agreed to a trade.[5]

[5]The drawback is that we do not have recorded information of the trading processes or the mechanisms that lead to agreements (for example, who initiated the conversation). In our view, any intervention would have heavily polluted the natural flow of exchanges.

## 2.4 Rewards

Games were highly incentivized. We set up a shop with 20 to 25 pre-screened, age appropriate toys (gel pens, friendship bracelets, erasers, figurines, die-cast cars, trading cards, squishies, bouncy balls, fidget spinners, etc.). Different toys had different point prices. Before the experiment, children were taken to the shop and showed the toys they were playing for. They were instructed about the price of each toy, and were explicitly told that more points would result in more toys. At the end of the experiment, subjects learned their point earnings. We accompanied the children to the shop to exchange points for toys and helped them determine the toys they could afford with their budget. We made sure that every child earned enough points to obtain at least three toys.[6]

## 2.5 Other information

To control for age-related differences within grade, we collected information regarding the age (in months) of our participants at the time of the study.[7] We also recorded the gender, number of older and younger siblings and preferred school topic, which we then coded into two broad categories (STEM vs. Arts & Humanities).[8] We report in Table 2 a descriptive summary of individual characteristics.

| | K | 1 | 2 | All |
|---|---|---|---|---|
| Age (months) | 72 | 85 | 97 | 86 |
| % male | 49 | 54 | 45 | 49 |
| % with siblings | 70 | 84 | 79 | 78 |
| % STEM | 27 | 20 | 31 | 26 |

**Table 2:** Individual characteristics.

A copy of the read aloud instructions can be found in the Appendix. Unless otherwise noted, when comparing aggregate choices we perform two-sided t-tests of mean differences. Standard errors are clustered at the individual level whenever appropriate. We use a p-value of 0.05 as the benchmark threshold for statistical significance.

[6]Overall, the procedure emphasized the importance of accumulating points while making the experience enjoyable for everyone (see Brocas and Carrillo (2019b) for a discussion of the importance of an adequate incentive system). Most children are familiar with this method of accumulating points or tickets that are subsequently exchanged for rewards, since it is commonly employed in fairs and arcade rooms. We spent an average of $4 in toys per child.

[7]The study was conducted in May, that is, at the end of the school year.

[8]STEM refers to a self-reported preferences for Mathematics or Science. Consistent with the curriculum of the school, the other categories offered were Languages, History/Geography and Arts/Music, which we globally refer to as 'Arts & Humanities'.

# 3 Theory and predictions

## 3.1 Definitions

As it is well-known, theoretical predictions heavily depend on the equilibrium concept employed as well as the extensive-form representation of the game. Given the extreme simplicity of our setting and the free-form procedure, we take an informal approach. We call "myopic improving" a trade that results in a strict improvement for both parties (e.g, $a$ trades with $c$ in **B**). We then call "forward looking improving sequence" a series of two trades that result in a strict improvement for all parties involved but requires a (transitory) bookkeeping loss for one of them (e.g, $a$ trades first with $b$ and then with $c$ in **C**). The former is the most basic form of trade, typical of barter economies, where exchanges are facilitated by the double coincidence of needs. The latter is substantially more sophisticated and requires understanding the relevance of commodities, not as intrinsically valuable, but as an indirect medium of exchange.

With these premises in mind, we define an "equilibrium" as an outcome where no pair of subjects can improve their payoff with a bilateral trade.[9] Trivially, under this definition an outcome cannot be an equilibrium if a myopic improving trade exists. At the same time, a Pareto superior outcome may not necessarily be reached if it requires a forward looking improving sequence of trades. Overall, it is a weak equilibrium concept, prone to multiplicity.

We classify outcomes in four categories: $PO_M$, $PO_F$, $EQ$ and $NO$. A $PO$ is a Pareto optimal equilibrium outcome. However, we distinguish between two types, depending on whether that equilibrium is reached exclusively through myopic improving trades ($PO_M$) or with at least one forward looking sequence of trades ($PO_F$). We then call $EQ$ a Pareto inferior equilibrium outcome and $NO$ any other outcome, that is, an outcome which is not an equilibrium of the game.

## 3.2 Equilibrium outcomes by treatment

We study outcomes separately for each subgroup to allow for the possibility that, within a given group of six, one subgroup of three reaches the equilibrium while the other does not. However, it is important to note that subgroups are endogenously formed, with subjects deciding with whom to trade. This means that while groups are composed of the same six subjects in all three treatments, subgroups may involve different partitions.

The treatments described in Table 1 vary in the type of trades that are required to

[9] We also impose that no subject is worse-off than with her initial endowment only to rule out trading by a subject who can never benefit from any sequence of trades.

improve payoffs, which determines the complexity of the trading environment and the equilibrium that can be reached. In the 'barter' treatment **B**, all participants in a group can reach $PO_M$, a Pareto optimal equilibrium with payoff of 3 for every subject exclusively through *myopic* improving trades (for example, $a$ trades with $c$ and then $a$ trades with $b$). The problem, however, is more subtle. Indeed, with groups of six, it is possible that one subgroup reaches the $PO_M$ while the other is stuck in a situation with payoffs of 2 for every subject and no myopic improving trades available. In that case, the second subgroup can either stay in this inferior equilibrium $EQ$ or else reach the $PO_F$ equilibrium through a forward looking sequence of trades.

In the 'commodity market' treatment **C**, the same Pareto optimal equilibrium with payoff of 3 for everyone can be achieved. However, it is now a $PO_F$ in that it requires a *forward looking* sequence of trades (for example, $a$ trades with $b$, suffering a temporal bookkeeping loss that subsequently permits a mutually improving trade between $a$ and $c$). Naturally, subjects in a subgroup can also stay in the no-trade inferior equilibrium ($EQ$), where all subjects keep their initial endowments and obtain a payoff of 2.

Payoffs in the 'no trading' treatment **N** are selected in a way that no myopic or forward looking improving trade exists. Role $a$ can only lose by trading with other subjects, and role $c$ can only lose by trading with $b$. Therefore, there is trivially a unique $PO_M$ equilibrium with no trading.

To sum up, the set of equilibrium outcomes is: $PO_M$, $PO_F$ and $EQ$ in **MT**, $PO_F$ and $EQ$ in **FT**, and $PO_M$ in **NT**. With this taxonomy in mind, we can test for *equilibrium compliance* (how many groups reach an outcome other than $NO$) and for *equilibrium selection* (how many groups reach $PO_M$ or $PO_F$ vs. $EQ$) as a function of the trading conditions.

## 3.3 Predictions

Remember from section 2.2 that all the parameters of the game are identical in **B** and **C** except for the initial distribution of endowments. This means that the two treatments are comparable. At the same time, remember from section 3.2 that groups start at equilibrium only in **C** and that myopic improving trades are sufficient to reach Pareto optimality only in **B**. We therefore expect to observe a higher total proportion of equilibrium outcomes ($EQ + PO$) in **C** than in **B** but a lower proportion of Pareto optimal equilibrium outcomes ($PO$) in **C** than in **B**. We also expect an overwhelming majority of no-trade Pareto optimal equilibrium outcomes in **N**. Summing up, the treatments provide three market situations, that can be informally characterized as "easy" trading (**B**), "hard" trading (**C**) and "no" trading (**N**). As for age trends, we expect the most difficult $PO_F$ outcome to increase with age and the $NO$ outcomes to decrease with age. However, it is possible that the age span is too small to observe differences.

While these theoretical predictions seem natural, we can also foresee several reasons conducive to deviations from theory. Despite the simplicity of the environment, a subject may feel satisfied after a trade that resulted in partial improvement and not seek further exchanges. Concerns about the rationality of others may prevent reaching the $PO_F$ outcome, whereas socially oriented subjects might engage in "altruistic trading" whenever the benefit to another subject is sufficiently larger than their own loss.

# 4 Group behavior

The experiment consisted of nine sessions with two groups of six and one session with one group of six and one group of three. The group of three had K children who followed with remarkable exactitude the Pareto Optimal equilibrium predictions in all treatments. The analysis focuses on the remaining 114 subjects split in 19 groups of 6 players: 6 groups of grade K children, 6 groups of grade 1 children and 7 groups of grade 2 children (one grade K group had one subject from grade 1; we pooled it with the five other K groups). Since we found no treatment order effects, in the analysis we pool together all the data from each treatment.

## 4.1 Equilibrium outcomes

Figure 2 reports the empirical distribution of final outcomes by treatment and grade. The unit of observation is a "subgroup" of three participants – one in each role – for a total of 38 subgroups in the sample. Since groups have six participants, each group is composed of two subgroups, of which it is possible that one reaches an equilibrium while the other does not. Also, we notice that the number of trade combinations is limited. It is therefore important to provide a benchmark of comparison. To this purpose, we simulate a group of 6 subjects in **B** and **C** and assume that they engage in four consecutive random trades. We then compute the proportion of subgroups that reach the different equilibrium outcomes given this random strategy. The results of this exercise are reported in Figure 2 (right).

The majority of groups reach an equilibrium outcome in all treatments (82% in **B**; 79% in **C**; 74% in **N**). Equilibrium levels in both barter and commodity markets, **B** and **C**, are significantly higher than if participants engaged in four random consecutive trades (test of equality of proportions, $p < 0.001$).[10] Our first conclusion is that young

[10]For comparability, the number of random trades considered is similar to the empirical average in **B** (see next section). Behavior with three random trades (which is closer to the empirical average in **C**) is very similar than with four random trades: 10% of $PO$ subgroups and 10% of $EQ$ in **B**, 10% of $PO$ subgroups and 18% of $EQ$ in **C**. The exercise is of no interest in **N** since, by construction, any trade constitutes a

| | **B** | **C** | **N** |
|---|---|---|---|
| $PO_M$ | 22 [6,5,11] | — | 28 [8,9,11] |
| $PO_F$ | 9 [2,4,3] | 20 [5,7,8] | — |
| $EQ$ | 0 [0,0,0] | 10 [2,4,4] | — |
| $NO$ | 7 [4,3,0] | 8 [5,1,2] | 10 [4,3,3] |

# of subgroups from grades [K,1,2] in brackets

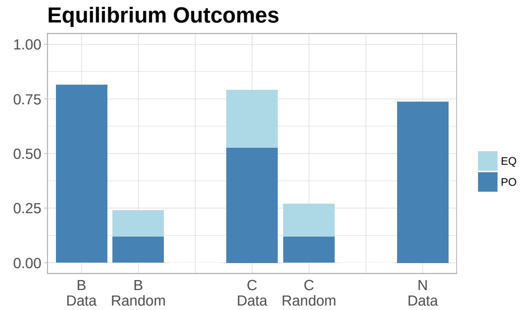



**Figure 2:** (Left) Subgroup outcomes by treatment. (Right) Pareto optimal and Pareto inferior equilibrium outcomes empirically observed and assuming random behavior.

children seem to understand and exploit myopic and forward looking market opportunities whenever they are present, and avoid to a large extent trading when it is detrimental. Contrary to our prediction, differences in equilibrium compliance across treatments are not statistically significant (test of equality of proportions, $p = 1$), mostly because it is always high. Behavior is similar across grades, with a possibly slightly lower rate of equilibrium compliance in K.

Although Pareto optimality is pervasive in **B**, it is not always reached in the simplest possible way ($PO_M$). Indeed, initial trading patterns is such that optimality is achieved through a forward looking sequence of trades ($PO_F$) in 24% of subgroups. Also, while several subgroups reach at some point the Pareto inferior equilibrium ($EQ$), none of them stay there.

The picture is different in **C**. Since subjects are initially at equilibrium and no myopic improving trades exist, 26% of subgroups do not trade, thereby staying at the inferior equilibrium ($EQ$). In 53% of subgroups, participants recognize the value of cards as a medium of exchange and accept a transitory loss in order to reach the Pareto optimal equilibrium. Consistent with our prediction, $PO$ rates are significantly lower in **C** than in **B** (test of equality of proportions, $p = 0.015$). The anticipatory forward looking behavior of half the subgroups is present even among our youngest population of kindergartners.

There are at least three reasons for not reaching a $PO$ equilibrium outcome: (i) satisfaction with current payoff, (ii) inability to perform a forward looking sequence, and (iii) concern about the rationality in trading ability of others. Recall that **B** and **C** differ exclusively on the distribution of initial endowments. Also, notice that a forward looking individual can achieve $PO$ in **C** even if she trades exclusively with myopic peers, since we only need one subject in the subgroup to accept a transitory loss in the process. This

deviation from theory.

means that only argument (ii) can explain the difference in the proportion of $PO$ between **B** and **C**. Overall, we argue that subgroups that are unable to recognize gains of trading are responsible for the fraction of non-equilibrium outcomes in **B** and **C** (around 20%). Those able to recognize the value of barter but not of commodity money are responsible for the difference in $PO$ outcomes between the two treatments (around 26%). The remaining subgroups recognize both simple (barter) and complex (commodity money) trading opportunities (around 53%).

It is also instructive to compare the behavior of each group across treatments. Such analysis cannot be made at the subgroup level, since subgroups are endogenously formed, so they contain different subsets of subjects across treatments. A Pareto Optimal Equilibrium of the Group, POEG, is defined as a situation where all six members of the group reach the Pareto optimal outcome. When we compare the behavior in **B** and **C**, we find that 5 groups reach the POEG in both treatments, 10 groups reach POEG only in **B**, and 4 groups do not reach POEG in either treatment. No group reaches POEG only in **C**. The result reinforces the nested difficulty of the barter and commodity markets.

Finally, subjects in the control treatment **N** stay mostly at the no-trading Pareto optimal equilibrium, although we also observe a number of deviations. These deviations are analyzed in the next section.

### 4.2 Trades and payoffs

To provide a descriptive idea of group trade behavior, we report in Figure 3 a representative (though non-exhaustive) list of examples of trading dynamics in the different treatments.[11] In these graphs, each node represents one participant. The group is composed of two participants (1 and 2) in each of the three roles ($a$, $b$ and $c$). The number in the red box reflects the order of trades in the group. The exchanges and corresponding final outcomes are summarized in the right side.[12]

These examples of trade dynamics provide informal, suggestive evidence that equilibrium outcomes in a given subgroup are typically reached through a short sequence of trades that closely follow the theoretical predictions: two myopic improving trades to reach $PO_M$ in **B** (upper left), one sequence of forward-looking improving trades to reach $PO_F$ in **C** (bottom left) and no trade to reach $EQ$ in **C** (bottom left) or $PO_M$ in **N** (bottom right). By contrast, non-equilibrium outcomes ($NO$) are mostly characterized by longer than optimal strings that mix improving and non-improving trades both in **B** (upper right) and

[11] Labels are interchangeable in **B** and **C**, so a group where $a_1$ trades with $b_1$ and then $b_1$ trades with $c_1$ is indistinguishable from a group where $b_1$ trades with $c_1$ and then $c_1$ trades with $a_1$.

[12] The fonts employed are: regular for myopic improving trades, bold for forward-looking improving sequence of trades, and red for inefficient trades).

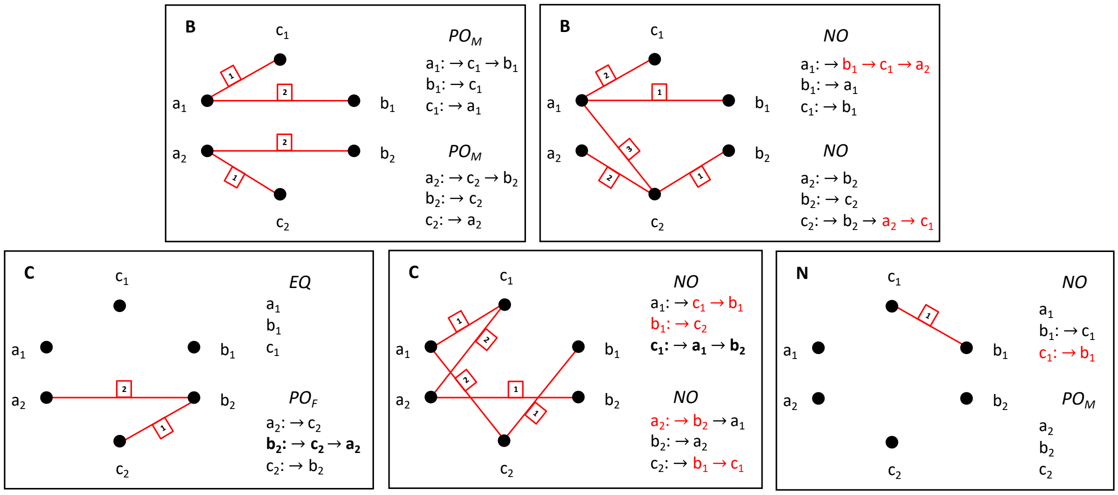



**Figure 3:** Representative examples of group trade dynamics by treatment.

**C** (bottom center).

To formally investigate trade and payoffs across treatments, we report in Figure 4 the average number of trades per subgroup (with the grey line representing the minimum number of trades to reach the *PO* equilibrium outcome, namely 2 in **B** and **C** and 0 in **N**) as well as the average payoff loss of the subgroup relative to the payoff obtained in the *PO* equilibrium outcome.

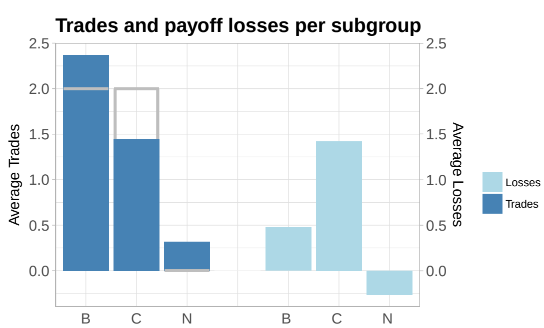
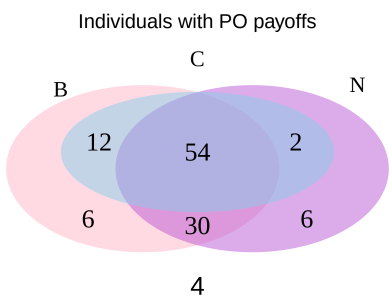



**Figure 4:** Trades and payoffs by treatment.

Despite similar aggregate proportions of equilibrium outcomes (Figure 2 - right), Figure 4 shows that behavior is substantially different across treatments. Participants trade excessively in **B** (two sided t-test, $p = 0.049$) and insufficiently in **C** (two sided t-test, $p = 0.016$). The former reflects a (small) number of suboptimal exchanges and translates into minor losses (0.16 points or 8% loss on average per participant). The latter is due to a fraction of subgroups that remains at the no-trading inferior equilibrium. These participants sacrifice significant payments to maintain their initial position, which results in substantially larger losses (0.47 points or 24% loss on average per participant). Finally, deviations in **N** are statistically significant (two sided t-test, $p = 0.004$) but small in absolute terms (1 trade for every 9 participants). These non-equilibrium trades are typically welfare improving, as reflected by the small but positive net gains of the subgroup (0.08 points or 4% gain on average per participant). It is plausible that a few "altruistic traders", willing to sacrifice one point to increase in two points the payoff of another player, are responsible for some of these sporadic deviations.

## 5 Individual analysis

We next study behavior at the individual level. Figure 5 (left) presents a Venn diagram with the number of individuals with *PO* payoffs in the different treatments (payoff of 3 in **B** and **C** and initial payoff in **N**). Figure 5 (right) reports a comparison of the proportion of individuals with *PO* payoffs by grade empirically observed and assuming three or four random trades in the group (random 3 and random 4).




| | **B** | **C** | **N** |
|---|---|---|---|
| K | 0.80 | 0.57 | 0.80 |
| 1 | 0.87 | 0.59 | 0.76 |
| 2 | 1.00 | 0.62 | 0.86 |
| Total | 0.89 | 0.60 | 0.81 |
| Random 3 | 0.26 | 0.26 | — |
| Random 4 | 0.29 | 0.29 | — |

**Figure 5:** Number (left) and proportion (right) of equilibrium players

By construction, the proportion of subjects at equilibrium (57% to 100% depending on the treatment and age group) is higher than the proportion of *PO* subgroups. Indeed, all subjects in a *PO* subgroup play at equilibrium while some subjects in the other subgroups may still play at equilibrium. According to Figure 5, 58% of participants reach *PO* under both barter and commodity markets **B** and **C** while only 7% to 8% would reach it with random trading. This difference is statistically significant (test of comparison of proportions, $p < 0.001$). Furthermore, 47% of the population reaches the *PO* equilibrium payoff in all three treatments. Only 11% of participants play at equilibrium in **B** and **C** but not in **N**. This constitutes the absolute upper bound on the proportion of rational but altruistic players: they reach the *PO* equilibrium when everyone can benefit but are willing to sacrifice some payoffs otherwise.[13] This small number is not surprising since we know from previous research that altruism is uncommon at this age (Fehr et al., 2008; Brocas et al., 2019). The diagram also illustrates the nested difficulty of barter and commodity markets. Indeed, 97% of individuals who play at equilibrium in **C** also play at equilibrium in **B**. At the same time, 83% of individuals who do not play at equilibrium in **B** do not play at equilibrium in **C**. Finally, for treatment **B** there is a significant difference across grades in the proportion of equilibrium choices (3-sample test for equality of proportions, $p = 0.013$). This difference is largely due to the higher performance of participants in grade 2 compared to grade K (test for equality of proportions, $p = 0.025$) and to some extent compared to grade 1 (test for equality of proportions, $p = 0.091$). There is no significant difference in performance across grades in treatments **C** and **N**.

To investigate the determinants of individual choice, we run Probit regressions where the dependent binary variable is whether the subject obtained the *PO* equilibrium outcome. Our independent variable is the Age in months of the participant at the date of the experiment. We perform regressions for each treatment separately (**B**, **C**, **N**), as well as a combined measure of equilibrium choice in all three treatments (**All**). We then control for the demographic variables described in section 2.5: gender, a dummy variable indicating whether participants have siblings, and their self-reported favorite school topic (STEM vs. Arts and Humanities). The results are presented in Table 3.

| | **B** | **C** | **N** | **All** | **B** | **C** | **N** | **All** |
|---|---|---|---|---|---|---|---|---|
| *Age* | 0.038* | 0.002 | 0.001 | -0.003 | 0.032° | -0.001 | -0.007 | -0.008 |
| | (0.016) | (0.011) | (0.012) | (0.011) | (0.018) | (0.012) | (0.013) | (0.011) |
| *STEM* | — | — | — | — | 0.442 | 0.593° | 0.263 | 0.723* |
| | | | | | (0.537) | (0.321) | (0.361) | (0.314) |
| *Male* | — | — | — | — | -0.142 | -0.333 | -0.253 | -0.280 |
| | | | | | (0.406) | (0.272) | (0.309) | (0.272) |
| *Siblings* | — | — | — | — | -0.493 | -0.304 | -0.139 | -0.382° |
| | | | | | (0.321) | (0.203) | (0.229) | (0.203) |
| Constant | -1.878 | 0.058 | 0.755 | 0.156 | -0.761 | 0.673 | 1.710 | 1.039 |
| | (1.269) | (0.930) | (1.056) | (0.922) | (1.421) | (1.005) | (1.180) | (0.999) |
| # obs. | 114 | 114 | 114 | 114 | 102 | 102 | 102 | 102 |
| AIC | 74.759 | 157.72 | 115.83 | 161.66 | 60.051 | 139.13 | 103.57 | 141.57 |

(standard errors in parenthesis); ° $p < 0.1$; * $p < 0.05$; ** $p < 0.01$

**Table 3:** Probit regressions of equilibrium choice by treatment and overall

[13] Notice that when two participants are in this group, at most one is sacrificing payoffs.

Equilibrium behavior is associated with age only in **B** but its significance decreases in the presence of controls. This confirms our previous findings that age is not a major determinant of optimal play in our window of observation. Participants with a preference for STEM are also significantly more likely to play at equilibrium in **C** and in all markets together compared to participants with a preference for Arts or Humanities. This is an intriguing finding, especially since it relies on non-incentivized, self-reported preferences. By contrast, gender and siblings have no significant effect on equilibrium behavior.

We next perform a Logistic regression of individual equilibrium behavior. We include dummies for each treatment (**C** is the omitted treatment) and the same variables as before (age, topic preference, gender, and siblings). We report the findings in Table 4.

| | **(1)** | **(2)** |
|---|---|---|
| *B* | 1.757*** | 1.938*** |
| | (0.305) | (0.346) |
| *N* | 1.046*** | 1.064** |
| | (0.299) | (0.331) |
| *Age* | 0.015 | 0.004 |
| | (0.013) | (0.013) |
| *STEM* | — | 0.824° |
| | — | (0.433) |
| *Male* | — | -0.365 |
| | — | (0.315) |
| *Siblings* | — | -0.558 |
| | — | (0.384) |
| Constant | -0.870 | 0.554 |
| | (1.127) | (1.110) |
| # obs. | 342 | 342 |
| AIC | 348.843 | 303.548 |

(clustered standard errors in parenthesis)
° $p < 0.1$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

**Table 4:** Overall logistic regressions of equilibrium choice

The differences across treatments in Pareto optimal behavior described in Figure 2 (right) are reflected in the regressions. Indeed, equilibrium behavior is significantly more likely in **B** and in **N** than in **C**. As in the previous regression, participants with a preference for STEM perform better. Again, neither age nor the other individual characteristics (gender, siblings) are predictors of performance.

## 6 Conclusion

This study is the first to examine the ability to develop commodity markets at an age where money is still an unfamiliar object. Our developmental approach allows us to investigate if humans are intrinsically wired to find trading arrangements or, instead, if market exchanges are based on skills that are gradually acquired through observation and imitation. We have reported that children reach Pareto optimal outcomes more often in barter economies compared to commodity markets. Yet, half of the groups accepted transitory losses to reach the Pareto optimal equilibrium, suggesting that many children as young as 5 years old can use commodities as a medium of exchange.

Overall, deviations in our experiment are unlikely to be driven by lack of understanding (only 4 subjects never reached the Pareto optimal outcome), altruism (it can explain non-equilibrium in **N** and only in **N**), or beliefs about myopia of others (a rational forward-looking individual can reach the equilibrium in both **B** and **C** even if everyone else only engages in myopic improving trades). Instead, we have argued that one quarter of subjects (or less) does not realize the gains from barter and another quarter of subjects (or less) understands barter but is not forward looking enough to accept transitory bookkeeping losses. The remaining population behaves as rational homo-economicus agents.

Being able to evaluate options and to reason logically and strategically are arguably prerequisites for optimal trading. Those abilities are, however, developing during early elementary school and students in that age range are still transitioning towards rational economic behavior. In particular, they have been shown to have unstable preferences (Harbaugh et al., 2001; Brocas et al., 2019) as well as limited logical (Tecwyn et al., 2014) and strategic thinking (Sher et al., 2014; Barash et al., 2019) abilities. Yet, participants in our study are able to play at equilibrium, suggesting that market forces are helping the decision-making process. This finding echoes experimental results in adults, where it is common to observe higher compliance with equilibrium predictions in market situations than in two-person contexts. The results put together suggest that humans at all ages are wired to reach, perhaps intuitively, efficient market outcomes.

This does not mean that logical abilities are irrelevant in that process. Recent research shows that math and cognitive abilities help strategic choices both in children (Czermak et al., 2016; Fe and Gill, 2018) and adults (Gill and Prowse, 2016; Proto et al., 2019). The positive correlation between a preference for STEM and a Pareto optimal behavior suggests the possibility that players prone to logical thinking may have guided collective choices towards equilibrium. While a preference for STEM is neither a guarantee that a participant thinks more logically than others nor evidence of causality, such correlation has already been established in other strategic contexts (Brocas and Carrillo, 2019a). It is therefore plausible that children who like activities based on logical thinking are more attracted by STEM topics and vice-versa. However, a definite relationship cannot be inferred without further research on the topic.

The fact that age is associated with the ability to barter but not with the ability to use commodities as a medium of exchange is intriguing. It suggests that trading through myopic improvements relies on an ability that is developing through our window of observation whereas trading through forward looking improvements requires an ability that for some children develops after the age considered here. A tentative explanation is that barter relies on number comparison and simple logic that is known to develop early and gradually, even before mathematics are introduced to children (Fisher et al., 2012). By contrast, forward looking improvements rely on more abstract forms of reasoning such as mentalizing (anticipating the efficient outcome and backward inducting the optimal sequence of trades). Although a fraction of children might have already acquired that logic (Tecwyn et al., 2014), the development is heterogenous (Bishop et al., 2001), so it is possible that further improvements occur after our window of observation.

Last, it is not uncommon in a first study to raise more question than answers are provided. We know from previous research that the behavior of children is affected by friendship ties (Chen et al., 2016) and the socio-economic status of the family (Charness et al., 2019). One can only speculate if our results would hold under anonymous interactions and with disadvantaged children. Robustness to larger groups and younger subjects (pre-kindergartners) is also unknown. We hope that the paper will stimulate future research in the area.

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# Appendix: sample of instructions

[these are instructions for the treatment order **B-C-N**; instructions are analogous for the other orders of play]

Hello,

We are going to play a few games. In all the games, you will earn points. At the end of the experiment you will go to the toy shop and buy toys with your tokens. Are you excited?

Let's start with the "dog game". First, we are going to distribute tags with different colors for different people.

[distribute two red dog tags, two blue dog tags and two green dog tags in each group]

You can look at the color of your friends' tags. Colors will be important to get points.

[give them some time to look at the tags of others]

Now, we are going to attach one card to your wrist. It is very important that you never remove the card from your wrist.

[attach the wristband of each card to each player; make sure that each color gets the card that has one point for themselves]

Look at your card. It has points on it. The points in the red area are the points that the card is worth for the person with the red tag. The points in the green area are the points that the card is worth for the person with the green tag. The points in the blue area are the points that the card is worth for the person with the blue tag. Different players have different cards, and some cards are worth more for some people than others

[give an example of a card, ask some questions about how much they are worth].

We are going to give you some time to look at your card and the cards of your friends. If you find someone who wants to exchange a card with you, you can both come to me and I will exchange the cards for you. I will be sitting over there. You can only exchange a card for a card. It is also very, very important that you do not exchange cards by yourself. Only I can exchange the cards for you. Is it clear?

You can exchange your card as many times as you want, as long as you find someone who is willing to exchange with you. If you do not want to exchange your card, it is also ok. You don't have to.

At the end of the game, I will look at the card you have and write the points you got given the color of your tag.

[give another example and ask a question to check understanding]

Is this clear to everyone? Do you want to play?

[start; make sure they don't trade by themselves; when a pair of children comes, ask for verbal confirmation from both children of their willingness to exchange; write down every exchange; at the end, write down the points of each player]

We are going to play now the "cat game". The rules are very similar. We are going to give one tag and one card to each of you.

[distribute two purple cat tags, two orange cat tags and two grey cat tags in each group; distribute the cards; make sure that each color gets the card that has two points for themselves]

Look at your card and the cards of your friends. Note that the colors and points are different than before. Just like before, if you find someone who wants to exchange a card with you, you can both come to me and I will exchange them. Are you ready to play?

[start]

Our last game is the “kangaroo game”. It is the same rules as before but with new cards and new colors.

[distribute the tags and cards; make sure to give the correct cards to the correct colors]

If you want to exchange cards come to see me over there. Ready?

[start; at the end of the game]

Now we are going to tell you how many points you got in total. We will write the points in a piece of paper and you can exchange the points for toys in the toy shop. Thanks for playing with us.

[proceed to compute points and distribute notes with the points accumulated]