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FESTSCHRIFT FOR RAUL V. FABELLA

Guest Co-editors — **Emmanuel S. de Dios**, **Sarah Lynne S. Daway-Ducanes**

ARTICLES IN THIS ISSUE

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PRE

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Festschrift for Raul V. Fabella

This special edition of the *Philippine Review of Economics* honors Dr. Raul V. Fabella in his 70th year and recognizes his invaluable contribution to the economics discipline and profession. This edition comprises 13 articles from his colleagues and several generations of former students inspired or mentored by Dr. Fabella who are themselves making their mark in economics. The broad spectrum of topics covered—agricultural economics, competition policy, contract theory, game theory, history of economic thought, international economics, issues in productivity, growth and development, monetary policy, political economy and rent-seeking, public economics, and the theory of teams—are issues that Dr. Fabella himself has written on or taught his students during his long, productive years as a Professor of Economics at the UP School of Economics, nurturing an "oasis of excellence" in his spheres of influence, as well as advocated as a roving academic in his later years, endeavoring to engage policymakers and the public in general, in pursuit of welfare-improving changes for a better Philippines.

The wide gamut of topics in this issue is a testament to Dr. Fabella's eclectic intellectual interests yet unwavering devotion to upholding a high standard of academic excellence. As his biographical sketch at the National Academy of Science and Technology summarizes:

> Fabella's very development as a scholar and intellectual leader presents numerous paradoxes: a classicist turned mathematical economist; a rational-choice theorist who derives material and metaphor from both history and physics; a solitary thinker who agonizes over pedagogy; a pure theorist immersed in policy-debate; an inherently shy, private man who must deal with crowds. His career displays to the fullest the range of issues – from the mathematical to the moral – that economists can and must confront if they are to attain to that "cool head and warm heart" that was Marshall's ideal. A classicist, however, might simply recall Terentius: *Homo sum: humani nil a me alienum puto*.

Indeed, to Dr. Fabella, nothing related to human behavior is outside his interest. At 70 years of age, National Scientist of the National Academy of Science and Technology (Philippines) and Professor Emeritus at the University of the Philippines, he is yet to reach the zenith of his intellectual verve: Fabella the economist is transfiguring into Fabella the social scientist – one to whom *homo economicus* is no longer the norm, but the exception in the vast complexity of human interactions in society. It is thus unlikely that this will be the last festschrift in his honor.

Sarah Lynne S. Daway-Ducanes
Emmanuel S. de Dios

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Digit ratio and prosocial behavior: the role of innate aggression in public goods and trust games

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Following previous studies that found individuals with shorter index fingers relative to ring fingers (low digit ratio) exhibit aggressive behavior in adulthood, in this study we use the left digit ratio, a putative marker for in-utero testosterone exposure [Manning et al. 1998], as an indicator of predisposition towards aggression to investigate its relation to prosocial behavior in the context of economic games. First, we ask if aggressive individuals and not-aggressive ones inherently differ in their prosocial behavior, independent of the features of the game. Second, we ask if the differences in their initial or subsequent prosocial behavior, if any, are conditioned by their respective experiences as the game progresses. Applying regression analyses on sample observations from two classroom experiments of modified public-goods games and trust games (by Carlos and Marasigan [2017] and Amante and Daro [2018], respectively), our results show that innate aggression per se is not associated with prosocial behavior. We find some evidence that innately aggressive, prosocial players who have experienced unfavorable or unfair outcomes in previous rounds tend to punish more intensely the non-cooperative players in public goods games, but continue to be generous towards selfish co-players in trust games. Thus, we posit that aggressive individuals who want to establish their perceived dominance (status) in a team behave prosocially initially, then later either elicit the cooperation of other players through aggressive punishment in the public goods game or unilaterally improve social welfare even at a personal cost to them in the trust game.

JEL classification: C71, C91, C92, D91
Keywords: Digit ratio, 2D4D, prosocial behavior, aggression, public goods game, trust game

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1. Introduction

This paper is concerned with understanding the role of innate aggression in select economic games, specifically about its possible effects on prosocial behavior in the context of public goods and trust games. Understanding the factors that motivate (or dissuade) prosocial behavior is important because prosocial behavior, such as altruism, empathy or general regard for the welfare of others, can help avoid sub-optimal outcomes in collective action situations.

While there is increasing evidence that players behave prosocially in economic games, they are likewise observed to be most prosocial in the initial stages of the game then become less so as the game progresses (Chaudhuri et al. [2017]; Yamagishi et al. [2017]). Other studies have found that such variations in prosocial behavior are conditioned by game features (e.g., varying payoff sizes, punishment mechanisms, etc.) [Fehr et al. 2000], affinities of the players involved (e.g., friends versus strangers) (Güth et al. [2008]; Ben-Ner et al. [2009]), and other player-specific characteristics like age [Matsumoto et al. 2016], patience score [Espín et al. 2015], religion [Everett et al. 2016], and personality types (Schroeder et al. [2015]; Zhao et al. [2016]). Given these factors, players then may be expected to exhibit different prosocial tendencies across periods of changing player-specific or game-specific conditions. Put differently, as the base game is played repeatedly, players accumulate experiences that shape their expectations of other players' altruism or selfishness. Moreover, their past experiences may incite their own natural predisposition towards cooperation or non-cooperation in collective action games. Thus, understanding the triggers for and the extent of adjustments in subsequent behavior of players who are manifestly prosocial in the beginning is important, especially for policy since many collective action problems are recurring in nature.

Here, we investigate the role of aggression in economic games by asking: Do inherently aggressive individuals differ from inherently not-aggressive ones in their prosocial behavior? Specifically, do they differ in their initial, subsequent or overall prosocial behavior? On the one hand, an answer to the first question will let us know whether innate aggression per se condition prosocial behavior in economic games. On the other hand, an answer to the second question will let us know if the effect of innate aggression on pro-social behavior depends on how the game has been played so far and the history of the outcomes as experienced by the players. The second question is important since two prosocial players, one innately aggressive and the other innately not aggressive, who have the same game experience may differ in their intensity in punishing or rewarding other co-players. In such cases, innate aggression in players is triggered not so much by the structure of the game as by its history.

To answer these questions, we first distinguish the aggressive player from the not-aggressive player using the digit ratio, a putative marker for in-utero testosterone exposure, which is commonly associated with aggressive behavior in adult life [Manning et al. 1998]. Then, we probe differences in the prosocial behavior of these two types of players in classroom experiments of the modified versions of the public-goods game (PG) and trust game (TG), using the samples in Carlos and Marasigan [2017] (henceforth, CM [2017]) and in Amante and Daro [2018] (henceforth, AD [2018]), respectively.

2. Review of relevant literature

The digit ratio or the 2D:4D ratio is defined as the ratio between the lengths of the 2nd digit (index finger) and the 4th digit (ring finger) and is considered a putative marker of in-utero testosterone exposure for humans [Manning et al. 1998]. This association is a research breakthrough especially because fetal exposure to sex hormones has been associated with various developmental, pathological, and behavioral conditions (Wu et al. [2013]; Bönte et al. [2017]; Myers et al. [2018]). Having the digit ratio as a non-invasive summary measure does away with the ethical concerns of experimenting with the concentration of sex hormones during pregnancy.

The seminal work on the topic was by Manning et al. [1998] which found that (i) the ratio of the 2nd to the 4th digit length is set before two years of age; and (ii) there is a negative relationship between testosterone levels in men and their digit ratio. These findings led Manning et al. [1998] to suggest that a higher concentration of in-utero testosterone is negatively correlated with the digit ratio, although this suggestion has never been tested directly and experimentally in humans. Perhaps the closest to a direct study in humans is the examination of testosterone in maternal plasma and amniotic fluid (AF) during amniocentesis. For example, Ventura et al. [2013] found that both hands of newborn females were negatively correlated with AF testosterone while newborn males did not show any significant associations; and that there exists only a weak negative correlation between maternal plasma testosterone and digit ratios in both sexes. A similar result is confirmed in Lutchmaya et al. [2004] where the AF testosterone is found to have significant negative association with the right digit ratio in both sexes for two-year old children. In experimental studies on mice, which are believed to exhibit the same development of 2D:4D ratio as in humans, the findings likewise suggest a negative association between digit ratio and gestational testosterone exposure (Zheng and Cohn [2011]; Auger et al. [2013]).

While the digit ratio is generally accepted as a putative marker for prenatal testosterone exposure, there is little consensus on whether it manifests greater in the left hand or in the right hand (Lutchmaya et al. [2004]; Hönekopp and Watson [2010]) , or equally in both [Ventura et al. 2013]. Furthermore, following Manning et. al [1998], numerous studies have considered the digit ratio as a sexually dimorphic trait, where males tend to exhibit lower digit ratios than females. There is likewise evidence that digit ratios vary across ethnicities, where Whites, Non-Chinese Asians, and Middle-Easterners exhibit higher digit ratios than Chinese and Black samples [Manning et al. 2007].

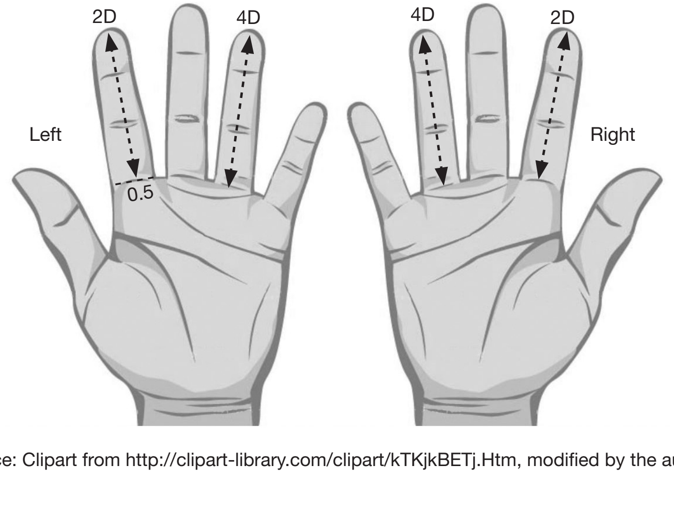
2.1. Measurement of the digit ratio

There are two methods of measuring the digit ratio. In the so-called direct measure (d2D:4D), the 2nd and 4th digits are directly measured using a Vernier calliper during the data collection or experiment. In the so-called indirect measure (i2D:4D), the measurement is usually done post-experiment using scans or photocopies of the hands of the participants. Both methods, however, measure the lengths of digits starting from the midpoint of the crease proximal to the palm of the hand to the fleshy tip of the digit [Fink and Manning 2018] (Refer to Figure 1).

The literature is divided between the use of the two methods. Several studies have questioned the reliability of indirect measures of the digit ratio. The initial challenge was raised by Manning et al. [2005] which found that the mean d2D:4D is greater than the mean i2D:4D. This result is further corroborated in other studies (Fink and Manning [2018]; Ribeiro et al. [2016]). In contrast, Voracek and Dressler [2006] find the mean d2D:4D to be less than the mean i2D:4D. For this reason, studies suggest that at least a common method of measurement must be employed in between-population studies (Manning et al. [2005]; Ribeiro et al. [2016]).

Employing a different method, Auger et al. [2013] used X-ray machines to measure a mice's forepaws. They argued their method to be more precise and sensitive to subtle differences in size compared to other methods such as the aforementioned. However, they also noted their method to be highly labor-intensive and costly [Auger et al. 2013]. The use of X-rays may also be undesirable in experiments with human subjects, especially so when the measurement error is expected to be random and not correlated with the observed digit ratio. Notwithstanding the lack of consensus about the proper method, the generally accepted range of the digit ratio as measured is [0.8, 1.2], and any ratio outside this range is considered an error [Bönte et al. 2017].

FIGURE 1. Measurement of left and right digit ratios



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2.2. Digit ratio and aggressive behavior

Motivated by findings that identify testosterone level as a determinant of aggression (Archer [2006]; as cited in Cleveland [2014]), subsequent studies explored the digit ratio as a potential biomarker for an individual's predisposition to aggressive behavior. Across studies, however, aggression is defined in various ways. According to Cleveland [2014], aggression is defined in terms of, on the one hand, the physical or verbal domain, or, on the other, the social or relational domain, with most studies observing that physical or verbal aggression is typical among males, while social or relational aggression is typical among females. Noting further most previous studies failed to display associations between digit ratio and aggression in females, Cleveland [2014] adopts both definitions and finds that the left digit ratio (along with emotional intelligence and parenting styles) to be negatively correlated with aggression. Other studies similarly find a negative correlation between digit ratio and outcomes associated with aggressive behavior, such as the number of traffic accidents [Havârneanu et al. 2014], violent behavior [Hoskin and Meldrum 2018], and boxers' fractures [Joyce et al. 2013].

2.3. Digit ratio and prosocial behavior

Other empirical studies have found links between the digit ratio and prosocial behavior. In a study of children ages six to nine years, it is found that the children with high right 2D:4D ratio (i.e., ratio measured in the right hand) demonstrate a greater tendency to share with others than those with low ratio [Horn et al. 2018]. In other words, high right digit ratio (indicating less tendency toward aggression) is positively associated with prosocial behavior (since sharing can be considered "a voluntary behavior that is intended to benefit another person other than oneself" [Horn et al. 2018]).

In a study involving adult subjects, Kovářík et al. [2017] find the association between digit ratio and the tendency to engage in friendship and maintain social ties to vary between the sexes. In particular, they report that men with low digit ratios tend to bridge gaps between disconnected parts of social networks, while women with low digit ratios tend to be more embedded in social circles (i.e., more people name them as friends). While these findings would seem to imply that a greater tendency toward aggression (low digit ratio) leads adults to behave prosocially, it should be noted that some people establish friendship or social ties primarily to gain social status and not necessarily to help others. Indeed, Kovářík et al. [2017] concluded that their subjects manifested status-seeking behavior.

2.4. Digit ratio in economic games

Arguably, the direction and strength of association between digit ratio and prosocial behavior are better observed in controlled settings. Thus, many studies have investigated the effects of digit ratio on altruism in different economic games. In a dictator game, Millet and Dewitte [2009] finds that, in a "neutral" condition, dictators (first player) with low digit ratio are more generous towards recipients (2nd player) than dictators with high digit ratio. When players are exposed to aggression cues (e.g., exposed to an aggressive music video), however, dictators with low digit ratio become less generous.

Also, in the context of dictator game, Galizzi and Nieboer [2015] discovered an inverted U-shaped relationship between the right digit ratio and allocation level, which differs from the negative monotonic relationship noted in Millet and Dewitte [2009]. In another study of dictator game, Parslow et al. [2019] find no significant evidence between the dictator's digit ratio and allocation level. Brañas-Garza et al. [2019] also report no robust relationship between the digit ratio and generosity, bargaining, and trust-related behaviors in a dictator game, ultimatum game, and trust game.

In an ultimatum game, Dreher et al. [2016] studied the effects of administered testosterone to adults on their prosocial behavior. They find that participants administered with testosterone are more likely (i) to punish their partners who made unfair offers, and (ii) to reciprocate with monetary rewards proposers who offered larger amounts of money. While these findings are based on administered testosterone, they are broadly consistent with those reported in other literature that use the digit ratio as a proxy for prenatal testosterone concentration.

In sum, Millet and Dewitte [2009] and Dreher et al. [2016] seem to agree on two things about observed behavior in economic games and testosterone levels, whether administered artificially in adulthood or determined before birth (i.e., digit ratio). First, both underscore the importance of the features of the social environment (i.e., as captured by the features of the economic games) in discerning the impact of testosterone on social behavior. For example, aggression cues trigger a high testosterone player's tendency to be less altruistic [Millet and Dewitte 2009]. Second, while testosterone levels correlate with aggression, aggression per se does not necessarily induce altruism. What seems more obvious is that aggression leads to bold or forthright deed or actions in society, which could be motivated by either altruism or inclination for social dominance (or status-seeking) [Kovářík et al. 2017]. These two motivations may lead to the same observed behavior. For example, in a PG, a player with high testosterone level (or low digit ratio) may contribute more than another with low testosterone level (or high digit ratio) because of altruism, while another high-testosterone-level player will do the same to improve his social status by appearing generous.

3. Experiment design

In this section, we describe the design of the experiments employed in the modified PG in CM [2017] and TG in AD [2018]. We draw from these two studies the data used in this paper. It is useful to note the implementation of these games and their design features (i.e., players, strategies, endowments, payoffs), which are calibrated to induce changes in the observed prosocial behavior of the game participants. The results are analysed in CM [2017] and AD [2018]. These studies also collected pertinent information about digits from the same subjects but never used such information. This gives us the opportunity to analyse them here.

3.1. Recruitment, orientation, and assignment of participants

CM [2017] and AD [2018] have the same sample of sixty (60) participants who joined the classroom experiments held at the University of the Philippines School of Economics (UPSE) on October 11, 2017. All UPSE undergraduate students, the participants were offered incentives[1] to join the experiments. Prior to the start of either, the sixty participants were each randomly assigned an identification (ID) number that ranges from 1 to 60. Then, they were all led to one room for the orientation and to answer a short questionnaire.

The authors of the PG study (Franz Nicole L. Carlos and Mariella Jasmin P. Marasigan) and the authors of the TG study (Charlotte May DC. Amante and Arlene B. Daro) presented the objectives and purposes of their respective experiments[2], answered queries and concerns, and acted as game administrators assisted by a few aides during the conduct of the experiments.

After the orientation, Carlos and Marasigan asked the participants to sign a consent form and answer a questionnaire with three modules common to both games. The first common module is set to capture basic demographic and socioeconomic characteristics, and some academic performance indicators; the second module is a personality test based on the Five Factor Model of Personality [McCrae and John 1992]; and the last module tasked each participant to trace out his or her left hand on a piece of clear paper using his or he right hand. From this replica, we indirectly measure the digit ratio using a standard desk ruler.

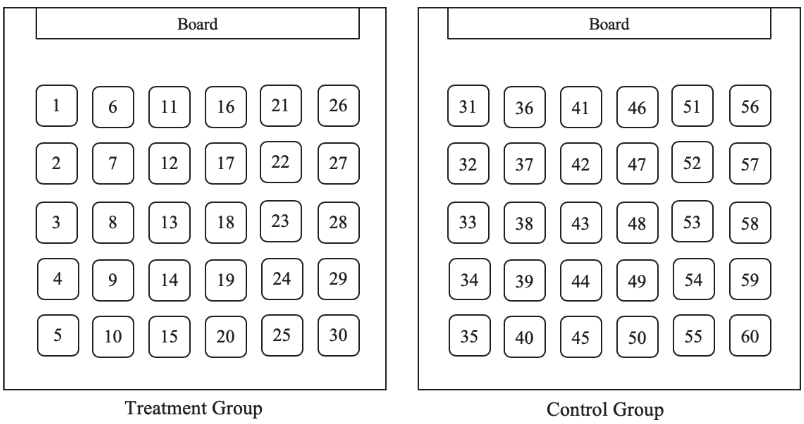
After completing the questionnaires, players with ID numbers 1-30 were led to a separate room, and players with ID numbers 31-60 to another room. Each of these rooms had six columns of chairs all facing the board in front. Each column had five chairs. In the first room, the players with ID numbers 1-5 were seated according to their numbers in the first column, the players with ID numbers 6-10 were seated also according to their numbers in the second column, and the rest

[1] Mostly in the form of bonus points given by their course teachers who agreed to support the conduct of the experiments.

[2] Dubbed as “E199 Game 1” and “E199 Game 2”, respectively, so as not to clue in the participants.

of the players were seated following the same procedure. The same procedure was used in seating the 30 participants in the other room. Unbeknownst to the participants, the group of players with ID numbers 1-30 and the other group of the 30 players were pre-designated as the treatment group and control group, respectively (Refer to Figure 2). The participants played the PG first, and then then TG, with a short break in between. In both games, the players had the same ID numbers, room and seat assignments, and treatment/control group classification.

FIGURE 2. Layout of classroom experiments in CM [2017] and AD [2018]



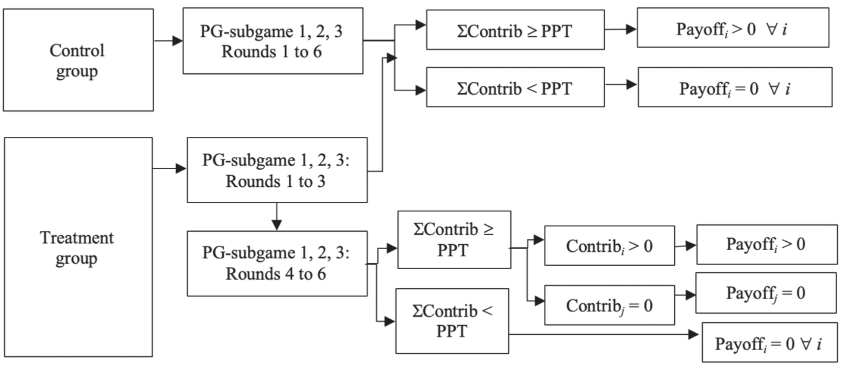
3.2. Public goods game: Features, equilibria, and prosocial behavior

Before the start of the PGs, the participants seated in the same column of chairs are designated as a team. Thus, there are six teams in the treatment group and another six in the control group. Then, the participants are each given three candy stubs as initial endowments, and which they may keep or contribute towards the provision of public goods that would benefit all team members. In each round, the participants simultaneously place their own contributions (in terms of candy stubs) in front of them, which the game administrators (and their aides) note to compute the total contributions per team and determine whether the total is enough to meet the requirements for public goods provision. At the end of the entire PG, the players can exchange one for one their remaining candy stubs for real candies.

The entire PG consists of three sub-games with six rounds each. In each subgame, the pooled contributions of a team must reach a pre-set minimum amount called the provision point threshold (PPT) before the public goods is supplied to the team. The PPTs are one candy stub, three candy stubs, and twenty candy stubs in the first subgame (PG-subgame 1), second subgame (PG-subgame 2) and third subgame (PG-subgame 3), respectively. If a team meets the relevant PPT in a round, then it is supplied the corresponding public goods, which effectively leads to payoffs for each team member equivalent to one candy stub in the PG-subgame 1, two stubs in the PG-subgame 2, and four stubs in the PG-subgame 3. If the team does not meet the relevant PPT, no public goods is supplied to them and no team member may get back whatever candy stubs he or she has contributed in that round. The accumulated candy stubs by the end of PG-subgame 1 or PG-subgame 2 are carried over as endowments at the start of PG-subgame 2 or PG-subgame 3, respectively.

Unlike the control group, the treatment group faces a punishment mechanism that is applied in rounds 4-6 of each PG subgame. Triggered only when the PPT is met in a round, the punishment leads to the exclusion of non-contributing members from any payoffs derived from the PG for that round. In the same round, the contributing members still get the same payoffs due them as if without the punishment mechanism. The game design is summarized in a flowchart in Figure 3.

FIGURE 3. Public goods game design flowchart in CM [2017]



The PG game admits several equilibria depending on whether the players behave selfishly or prosocially. If the players are the typical *homo economicus*, each would play in all rounds and subgames the dominant strategy: do not contribute, and get a free ride on somebody else's contribution. If none contributes in a round, in equilibrium no public good will be provided in that round. The same equilibrium may be expected in all rounds of any subgame. In PG-subgame 1, however, free-riding is a weakly dominant strategy. Anybody who contributes one 1 stub is sure to get it back, since the PPT is only 1 stub and the payoff is stub. Whether or not the player free-rides, the player ends up with at least 3 stubs in PG-subgame 1, which is as good as the initial endowment. It is possible therefore that both the selfish and prosocial players may each contribute a stub in all six rounds, but perhaps only the latter will be concerned when the non-contributing members are excluded in rounds 4-6 from receiving the same payoffs.

In PG-subgame 2, the demands on the prosocial player are heavier. If he risks all his endowments and nobody else contributes in the first round, then he would get back only two of three stubs he contributed. Two stubs will not be enough to meet the PPT in the second round, unless somebody else picks up the slack. So, in the first round, even a prosocial player may behave strategically by contributing one stub and hope two other players will each chip in the same amount.

In the PG-subgame 3, no prosocial player may unilaterally cause the public good to be supplied to the team. If he alone played cooperatively in all previous rounds, he will be left with just 2 stubs at the start of PG-subgame 3.[3] With such meagre budget, he alone will not be able to afford the cost of providing the public good. So even a prosocial player will not contribute unless he expects other players to behave prosocially as well. So like PG-subgame 2, a cooperative equilibrium here hinges on the mutual expectations of altruism among some of the players.

3.3. Trust game: Features, equilibria, and prosocial behavior

After the PG, the participants played the “E199 Game 2”, as how the TG was introduced to them by Amante and Daro. In this game, the players in one room were informed that they were each paired up with a unique player in the other room. At the start of every round, each player was given an endowment of ten Philippine pesos (₱). They were told that they can send any portion of their endowments to their respective partners in the other room, who may then reciprocate or not. In addition, the money sent by the partner-sender doubles once it reaches the partner-receiver, who then may choose to return any amount from zero to twice the money contributed by the partner-sender. In this case, the partner-receiver can “return the same gift” to the partner-sender and remain better off and the partner-receiver no worse off than when the partner-sender in the first place did not trust the partner-receiver to return the favor.

Together with the monetary endowments, the players were also given envelopes and two sheets of papers with questions. In the first paper they were asked to indicate how much they would send to their partner, while in the other paper they would indicate how much they expect to receive from the same. They were also asked to put their contributions in their envelopes. After answering the questions, the game facilitators collected the first paper and the envelopes with the contributions. Then, they transmitted the envelopes to the relevant partners in the other room. Upon their return, the facilitators collected the second paper and handed back to the partner-sender the envelopes that contained the money

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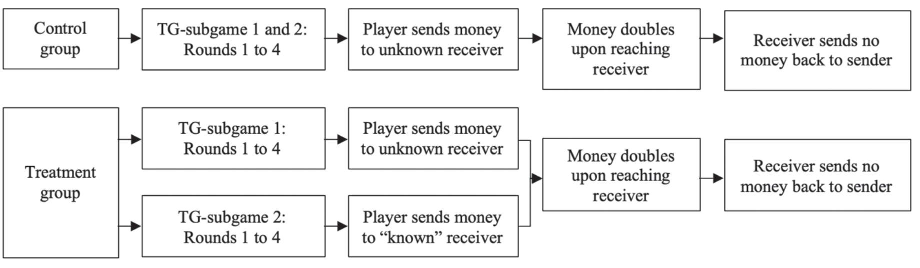
[3] Assuming the player contributes one stub in each round in the PG-subgame 1, and then 3 stubs in round 1 of PG-subgame 2. At the start of the second round of PG-subgame 2, he will only have 2 stubs, which are not enough to meet the PPT (3 stubs). So, he will keep the 2 stubs and not contribute from the 2nd to the 6th round of PG-subgame 2. He’ll be left with the same at the start of PG-subgame 3.

returned by their partner-receiver. Unbeknownst to the players in the two rooms, each was paired up with a faux partner-receiver, who always sent back an empty envelope each round.[4] Effectively then, all players were senders in the usual TG, where only the first player (sender) is given an endowment and the second player gets a payoff only when it receives a gift from the sender.

The TG consists of two subgames, each with four rounds. In the first subgame (TG-subgame 1), the players were not made aware of the identity of their respective partners. In the second subgame (TG-subgame 2), the players were shown the school IDs of their respective putative partners in the other room. They are only putative partners because the school IDs of the participants in one room were randomly distributed to the participants in the other room, with no assurance that each pair will get exactly each other's school ID. The random assignment is not revealed to the players. Thus, they were only made to believe that they know their partners, their partners know them, and that both know that each knows about the other. The game design is summarized in a flowchart in Figure 4.

FIGURE 4. Trust game design flowchart in AD [2018]



Like the PG, the TG admits several equilibria depending on whether the partner-sender is selfish or altruistic. In this case, however, the degree of trust or risk aversion of the partner-sender also matters. One type of equilibrium is characterized by zero contribution made by the partner-sender and the partner-receiver (who is a stingy faux partner), who sends nothing back. In the first round and perhaps in a few more thereafter, it is possible for a selfish player to act cooperatively if he trusts enough the other player to reciprocate. However, he may switch to noncooperative strategy if his generosity is not rewarded. In contrast, an altruistic player may send a positive amount to the stingy partner-receiver in every round since he knows he can unilaterally improve the overall social welfare. As in the case of the PG, it is worthwhile to check if the contributions in the TG are consistent with prosocial behavior.

[4] The facilitators did not actually transmit the envelopes from the partner-sender to the partner-receiver or collected envelopes with contributions from the partner-receiver. They simply distributed empty envelopes back to the partner-sender.

4. Preliminary observations

Here, we assess the extent of prosocial behavior of the participants in the PG and TG. We measure each player's prosocial preferences with their observed contributions per round in the two games. However, since the size of endowments and payoffs, which determine the levels of contributions, are measured differently in the two games, it is necessary to standardize the contributions to facilitate analysis. Thus, we use the player's contribution as percentage of his or her available resources per round as an index of prosocial preferences. (In their studies, CM [2017] and AD [2018] used the level of contribution as a metric of prosocial behavior)

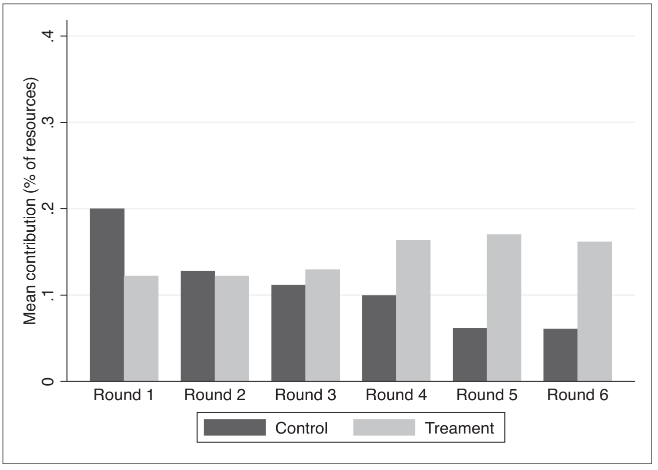
The mean contributions per round per subgame in the PGs and TG are shown in Figure 5 and Figure 6, respectively. The mean contributions are further classified by treatment group and control group. A few patterns can be discerned from the mean contributions in the PG as shown in Figures 5(a), 5(b) and 5(c). First, they are all positive across rounds and subgames. In fact, they are positive even in the first few rounds of the first subgames of the PG and TG. This implies that the players are possibly inherently prosocial.

Second, the average of the mean contributions for all rounds in PG look less than that in the TG. In the TG, for example, the minimum mean contribution is about 10 percent (in Round 2 of TG-subgame 1), whereas it is below that in all the last three rounds of each PG subgame. Since the PG and TG had the same participants on the same day, the differences in their average mean contributions per round must be related to the specific features of two games. In other words, the manifestation of prosocial behavior may be conditioned by the underlying incentives and constraints in a game situation as faced by the players who must act collectively.

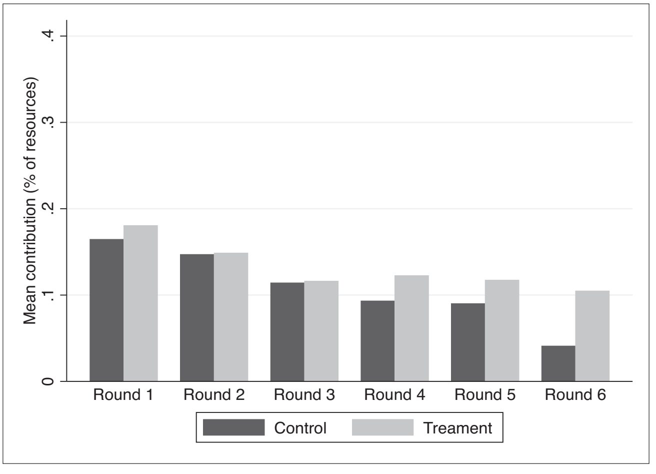
Even if we fix the situation (i.e., type of game), we also see the mean contributions to fluctuate from round to round, for both the treatment group and control group. In the PG, for example, the mean contributions of the treatment group were rising slightly as PG-subgame 1 evolved, was declining slightly as PG-subgame 2 evolved, and fell sharply towards the end-round in PG-subgame 3. In the TG game, the mean contribution followed a U-shape in the first subgame, but it rose monotonically in the second subgame. We also observe similar variations in mean contributions of the control group across rounds and across subgames in both the PG and TG. While the mean contributions remain positive in each round, the variations across rounds imply that the players' tendencies to manifest their prosocial proclivities also depend on their experiences of how the others behave in previous engagements.

To be sure, CM [2017] and AD [2018] have investigated the extent to which game features account for the variations in the level of contributions across rounds and subgames in the PG and TG, respectively. In the next section we describe our strategy for investigating the link between a player's digit ratio and the share of his or her contribution to the total resources, controlling for the features of PG and TG, using the same sample as CM [2017] and AD [2018].

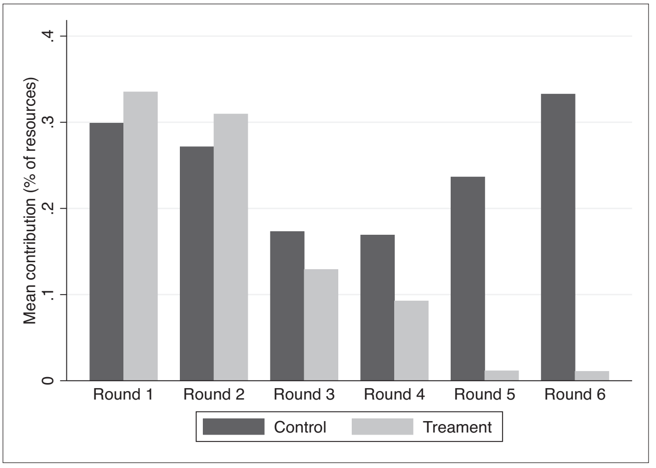
FIGURE 5. Mean contributions (% of resources) per round of control group and treatment group, by PG-subgame



(a) PG-subgame 1

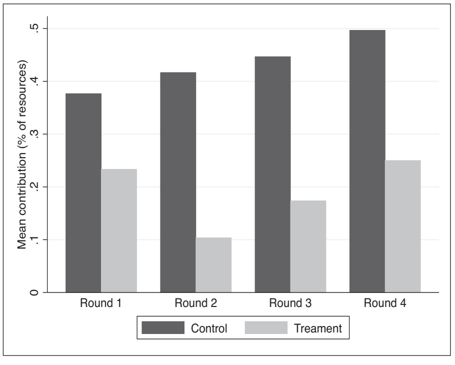


(b) PG-subgame 2

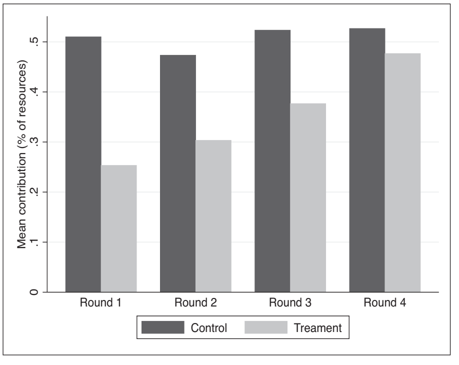


(c) PG-subgame 3

FIGURE 6. Mean contributions (% of resources) per round of control group and treatment group, by TG-subgame



(a) TG-subgame 1



(b) TG-subgame 2

5. Methodology

5.1. Data sources and analytic sample

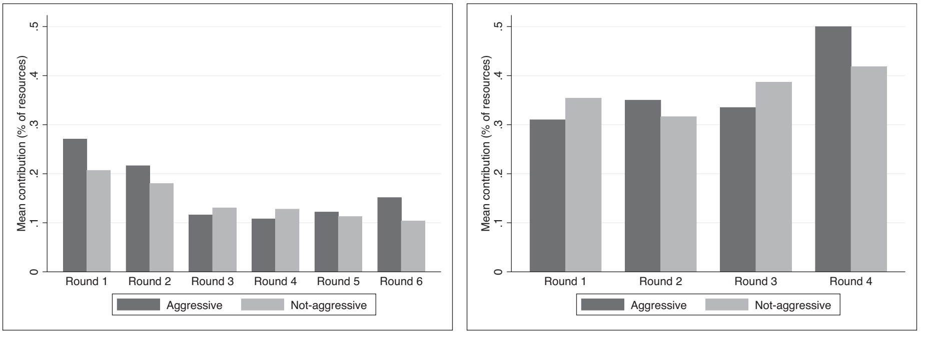
In this paper, we pool the observations used in CM [2017] and AD [2018]. With sixty players and a total of twenty-six (26) rounds for both PG and TG, the total observations should be 1,560. Our analytic sample, however, is slightly less than this, for two reasons. First, we exclude one player whose measured digit ratio is outside the conventional range (i.e., [0.8, 1.2]) accepted in the literature. This reduced our sample to 1,534. Second, a few players opted out before some subgames ended, which reduced our sample further by 31 observations. Our final analytic sample therefore is 1,503, of which 1,031 are from the PG and 472 are from the TG. As will be noted below, less than 1,503 will be used in some regression runs due to missing covariates.

5.2. Contribution and aggression indicators

From the raw data, we construct our main variables of interest. As a measure of prosocial behavior, we define *contribution* as the portion of the player's total resources (or endowments) in each round that he or she contributed towards the provision of public goods in the PG or sent to the partner-receiver in the TG. Following the literature (Joyce et al. [2013]; Havârneanu et al. [2014]; Cleveland [2014]; Hoskin and Meldrum [2018]), we construct a binary indicator of innate aggression based on the measured left digit ratio (L2D:4D). Specifically, we define *aggressive* (*A*) as a dummy that takes a value of 1 if L2D:4D is less than 1 and 0 otherwise. We also refer to the player whose L2D:4D<1 as "aggressive" and to the player whose L2D:4D≥1 as "not-aggressive". The mean digit ratio is 1.0488 and the standard deviation is 0.486. The minimum and maximum observed values are 0.9329 and 1.1690, respectively. The mean values and standard deviation of aggressive are 0.1695 and 0.3753, respectively. This means that a huge majority of the observations are "not-aggressive".

Figure 7(a) and Figure 7(b) show the mean contributions by round of the aggressive and not-aggressive players in the PG and TG, respectively. We cursorily note three broad patterns. First, the mean contributions are positive for both aggressive and not-aggressive players in all rounds and across economic games. Second, the mean contributions for both type of players tend to decrease as rounds of the PG progress and tend to increase slightly across TG rounds. Last, the average mean contributions are higher in the TG than in the PG. Thus, on the face of it, the variations in prosocial behavior may be systematically related to the differences in innate aggression.

FIGURE 7. Mean contributions (% of resources) per round of aggressive players and not-aggressive players in the PG and TG



(a) PG (b) TG

5.3. Regression models

We introduce three sets of regression models to test if innate aggression predicts social behavior. Since the mean contribution in consistently positive across economic games and rounds, we examine in the first set if innate aggression, by itself and without controls for game features or details of the outcomes in the previous rounds, can account for the observed prosocial behavior. Since the mean contributions also varies between the PG and TG, in the second set we interact our indicator of innate aggression with game features. Finally, in the third set, we interact our indicator of innate aggression with variables related to outcomes in previous rounds (i.e., "game experience") to account for the changes in mean contribution across rounds. In all three sets, we also introduce additional controls for socioeconomic, demographic characteristics, academic performance and personality types.

As mentioned above, we indicate the innate aggression of the i^{th} player with binary indicator A_i that takes the value of 1 if the left digit ratio is less than one and 0 otherwise (i.e., when the left digit ratio is greater than or equal to one). The degree of prosocial behavior of the i^{th} player in the t^{th} round is C_{it} measured as the proportion of contribution against available resources in that round. Subscript i represents player ID number, where i=1,2,...,60, and subscript t represents round number, where t=1,2,...,6 for the PG and t=1,2,3,4, for the TG.

Our first set of regression models, of which there are two sub-models (M1-a and M1-b), tests whether innate aggression *per se*, affects prosocial behavior:

$$C_{it} = \alpha_0 + \alpha_1 A_i + \varepsilon_{it} \qquad \text{(M1-a)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{X}_i^{'}\boldsymbol{\beta} + \varepsilon_{it}, \qquad \text{(M1-b)}$$

where $\boldsymbol{X}$ is a vector of covariates which contains the players' socioeconomic characteristics (i.e., age, sex, religion, household income, and year level) and personality scores, the α's and $\boldsymbol{\beta}$ are parameters to be estimated, and ε_{it} is the error term. If $\hat{\alpha}_1 \neq 0$ in M1-a or especially in M1-b, it would suggest then that innate aggression has an independent effect on prosocial behavior.

To the extent that aggression is brought out by the conflicts and incentives built into the game design, we examine the second set of regression models, of which there are three variants (M2-a, M2-b and M2-c):

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{G}^{'}\boldsymbol{\delta} + \varepsilon_{it} \qquad \text{(M2-a)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{G}^{'}\boldsymbol{\delta} + \left(A_i \times \boldsymbol{G}\right)^{'}\boldsymbol{\phi} + \varepsilon_{it} \qquad \text{(M2-b)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{G}^{'}\boldsymbol{\delta} + \left(A_i \times \boldsymbol{G}\right)^{'}\boldsymbol{\phi} + \boldsymbol{X}_i^{'}\boldsymbol{\beta} + \varepsilon_{it}, \qquad \text{(M2-c)}$$

where $\boldsymbol{G}$ is a vector that captures the key design features of a game, $\boldsymbol{\delta}$ and $\boldsymbol{\phi}$ are vectors of additional regression parameters. The first model variant (M2-a) tests the impact of aggression *per se* with the game design as controls, while M2-b and M2-c additionally test whether the impact of aggression varies with the game design. In other words, the interaction term $(A_i \times \boldsymbol{G})$ tests the hypothesis that aggression manifests only in games with specific features, e.g., level of PPT and exclusion mechanism in the PG, and revelation of identities in the TG. An estimate of $\hat{\alpha}_1 \neq 0$ in M2-a suggests a role for innate aggression in predicting prosocial behavior; while an estimate of $(\hat{\alpha}_1 + \boldsymbol{G}'\hat{\boldsymbol{\phi}}) \neq 0$ in M2-b suggests that the role of innate aggression in predicting prosocial behavior varies by game design. The latter estimate may be confirmed in M2-c, which controls for any potential omitted variable bias through the inclusion of vector $\boldsymbol{X}$.

Arguably, there are some players whose innate aggression is provoked only or more strongly when the outcomes are favorable or unfavorable to him or her in whatever game. Since the outcomes are specific to each player, each would draw on his or her experience in making decision on how much to contribute in each round. For each player in either the PG or TG, the outcome of the previous round can be classified into four types of experience: first, the player did not contribute a positive amount but received positive payoff (player free-rode); second, the player contributed a positive amount but did not receive a positive payoff (player is duped); third, the player neither contributed nor received a positive payoff (mutual non-cooperation); and fourth, the player both contributed and received a positive payoff (mutual cooperation). We represent each outcome as a binary indicator and include the four indicators in the vector $\boldsymbol{E}_{i,t-1}$, to summarize for the i^{th} player the outcome she experienced in the preceding round.

Thus, in our third set of regression models, of which there are three variants (M3-a, M3-b, M3-c), we test for the effect of aggression conditioned by the unique game experience of each player.

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{E}_{i,t-1}'\boldsymbol{\varphi} + \boldsymbol{G}'\boldsymbol{\delta} + \varepsilon_{it} \qquad \text{(M3-a)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{E}_{i,t-1}'\boldsymbol{\varphi} + (A_i \times \boldsymbol{E}_{i,t-1})'\boldsymbol{\theta} + \boldsymbol{G}'\boldsymbol{\delta} + \varepsilon_{it} \qquad \text{(M3-b)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \boldsymbol{E}_{i,t-1}'\boldsymbol{\varphi} + (A_i \times \boldsymbol{E}_{i,t-1})'\boldsymbol{\theta} + \boldsymbol{G}'\boldsymbol{\delta} + \boldsymbol{X}_i'\boldsymbol{\beta} + \varepsilon_{it} \qquad \text{(M3-c)}$$

where $\boldsymbol{\varphi}$ and $\boldsymbol{\theta}$ are vectors of additional regression parameters. Note that we include game features $\boldsymbol{G}$ as additional covariates. If $\hat{\alpha}_1 \neq 0$ in M3-a, then this suggests a role for innate aggression in predicting prosocial behavior. If $(\hat{\alpha}_1 + \boldsymbol{E}_{i,t-1}'\hat{\boldsymbol{\theta}}) \neq 0$ in M3-b, this implies that the impact of innate aggression is conditioned by game experience. The latter estimate may be confirmed in M3-c, which controls for any potential omitted variable bias through the inclusion of vector $\boldsymbol{X}$.

Possibly, some players may have long memory. That is, they base their move in the current round not only on their experience in the immediately preceding round but on their accumulated experiences thus far. To test this, we introduce a variable D_{it} that is equal to the total number of times the i^{th} player was duped from first round up to the t^{th} round. This case is examined in the last set of regression models, which has three variants as well.

$$C_{it} = \alpha_0 + \alpha_1 A_i + \gamma D_{it} + \boldsymbol{G}'\boldsymbol{\delta} + \varepsilon_{it} \qquad \text{(M4-a)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \gamma D_{it} + \rho(A_i \times D_{it}) + \boldsymbol{G}'\boldsymbol{\delta} + \varepsilon_{it} \qquad \text{(M4-b)}$$

$$C_{it} = \alpha_0 + \alpha_1 A_i + \gamma D_{it} + \rho(A_i \times D_{it}) + \boldsymbol{G}'\boldsymbol{\delta} + \boldsymbol{X}_i'\boldsymbol{\beta} + \varepsilon_{it}, \qquad \text{(M4-c)}$$

where γ and ρ are additional regression coefficients. As in the previous models, the main parameters are the estimates of α_1 in M4-a, and of $(\alpha_1 + \rho D_{it})$ in M4-b and M4-c.

We estimate all our regression models using ordinary least squares (OLS) method. We use pooled OLS models rather than panel-data regression models since most of our right-hand side variables are player-specific characteristics like gender, age, school year level and personality scores. So, while a fixed-effect panel regression model would control for unobserved heterogeneity among the players, due to collinearity, it will not provide an estimate for most of our explanatory variables, including the main one, *aggressive*. We believe, however, that to the extent that aggression in later life is correlated with prenatal testosterone level, the left digit ratio is exogenous, and that the additional controls for game features and other player-specific characteristics mitigate the bias due to omitted variable. Further, we estimate robust standard errors adjusted for clustering by player ID.[5]

Our pooled sample for the first and second sets of regression models comprises 1,503 observations. For the third set (which includes M3 and M4 regressions), where we use lagged values for some variables, we have 295 fewer observations because game experience is nil for the first rounds of all PG and TG subgames. Note that we estimate all our models using the pooled sample, and, in the third set of models, we also use the PG sample and TG sample separately.

5.4. Regression variables

The names, definitions and basic descriptive statistics of the regression variables are shown in Table 1. For our sample of players with digit ratios within the conventional range, the average and standard deviation of the left digit ratio (l2d4d) are 1.0488 and 0.0486, respectively.[6] This implies the average player is *not-aggressive*. The average contribution is at 0.2180. In other words, on average a player contributes about 22 percent of his resources per round. Our indicators of game features pertain to whether the round is part of the PG game, whether the player belongs to the treatment group, or whether the treatment (exclusion

[5] Essentially, we control for correlation for errors for the same player across rounds.

[6] We test for the difference in the distribution of digit ratio between the control group and the treatment group using the Kolmogorov–Smirnov equality-of-distributions (KS) test. The KS test computes for the largest difference between two distribution functions and the corresponding approximate p-value. We find that the combined difference (that is, either the control group contains larger values or it contains smaller values of digit ratio than the treatment group) of the distributions of digit ratio between the two groups is statistically significant. This result leaves us room for further analysis to determine the extent of the effect of innate aggression on prosocial behavior

mechanism or revelation of the partner-receiver ID) is introduced in the current round. Game experience is denoted with dummy variables for zero contribution in previous rounds and number of times duped so far. The other individual-level characteristics are age, gender (female), religion (Roman Catholic), annual family income, year level (in college), and five personality scores (openness, conscientiousness, extraversion, agreeableness, and neuroticism).[7]

TABLE 1. Variable definitions and summary statistics

Variable	Definition	N	Mean	Stdev.	Min	Max
Aggression indicator						
l2d4d	L2D4D ratio within the [0.8, 1.2] range	1534	1.0488	0.0486	0.9329	1.1690
aggressive	= 1 if L2D4D ratio is less than 1, 0 otherwise	1534	0.1695	0.3753	0	1
not-aggressive	= 1 if L2D4D ratio is greater than or equal to 1, 0 otherwise	1534	0.8305	0.3753	0	1
Game features variables						
pgame	= 1 if round is part of public goods game, 0 otherwise	1560	0.6923	0.4617	0	1
treatment	= 1 if player is part of treatment group, 0 otherwise	1560	0.5000	0.5002	0	1
pg1ctrl	= 1 if round is part of PG-subgame 1 (no exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
pg1treat	= 1 if round is part of PG-subgame 1 (with exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
pg2ctrl	= 1 if round is part of PG-subgame 2 (no exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
pg2treat	= 1 if round is part of PG-subgame 2 (with exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
pg3ctrl	= 1 if round is part of PG-subgame 3 (no exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
pg3treat	= 1 if round is part of PG-subgame 3 (with exclusion), 0 otherwise	1560	0.1154	0.3196	0	1
tgctrl	=1 if round is part of TG-subgame 1, 0 otherwise	1560	0.1538	0.3609	0	1
tgtreat	=1 if round is part of TG-subgame 2, 0 otherwise	1560	0.1538	0.3609	0	1

[7] Both CM [2017] and AD [2018] performed equality of means of the covariates between the treatment and control groups. They found the two groups balanced in nearly all pre-treatment characteristics.

Variable	Definition	N	Mean	Stdev.	Min	Max
Game experience variables						
contribution	contribution per available resource	1529	0.2180	0.3044	0	1
no $contribution_{t-1}$	= 1 if did not contribute in the immediately preceding round, 0 otherwise	1249	0.4219	0.4941	0	1
with $contribution_{t-1}$	= 1 if contributed in the immediately preceding round, 0 otherwise	1249	0.5781	0.4941	0	1
$zeropayoff_{t-1}$	=1 if player received a zero payoff in the immediately preceding round, 0 otherwise	1249	0.5180	0.4999	0	1
$duped_{t-1}$	= 1 if player was duped in the immediately preceding round, 0 otherwise	1249	0.3547	0.4786	0	1
times duped	cumulative number of times player has been duped before the current round	1249	0.8799	1.0064	0	5
Socioeconomic characteristics and OCEAN personality score						
age	age in years	1560	19.7500	1.3743	17	28
female	= 1 if player is female, 0 otherwise	1560	0.6000	0.4901	0	1
rcatholic	= 1 if player is Roman Catholic, 0 otherwise	1560	0.8000	0.4001	0	1
rich	=1 if annual family income is above PhP1.3 million, 0 otherwise	1560	0.4333	.4957	0	1
junior	=1 if year level is 3, 0 otherwise	1560	0.4667	0.4990	0	1
openness	openness score	1560	25.7333	5.7169	13	38
conscientious-ness	conscientiousness score	1560	23.7167	5.4180	12	34
extraversion	extraversion score	1560	19.3333	8.1954	1	34
agreeableness	agreeableness score	1560	29.8167	4.9022	17	38
neuroticism	neuroticism score	1560	18.9000	7.9957	5	36

6. Results

6.1. Does aggression per se determine prosocial behavior?

In Table 2, *aggressive* is positive in the first three columns, which are the models that test for the independent effects of innate aggression on prosocial behavior. In all three cases, however, the estimate is not significantly different from zero.

In the next set of estimates (last two columns), we interacted *aggressive* with various indicators of game features. We tried all combinations, but report only two of the results, which are attempts to test whether innate aggression might be induced to affect contribution under extreme game conditions. Thus, we choose two sub-games, namely PG-subgame 3 which has the highest PPT (twenty candy stubs) and the rounds where the exclusion mechanism is applied, and the TG subgame where the identity of the partner is revealed to the player (i.e., TG-subgame 2). As shown in M2-b and M2-c, consistently *aggressive* alone and its interaction with indicators of whether the round is a treatment round in the PG and whether the round is a treatment round in the TG are insignificant. Noticeably in the last column, the sign of *aggressive* reverses to negative with the introduction individual-level covariates.

Overall, the results here do not support the usual supposition that innately aggressive persons are prone to be less generous in their contributions. In fact, inherently aggressive players and inherently non-aggressive players, as distinguished by their left digit ratios, do not systematically differ in their prosocial behavior irrespective of the underlying incentives in the economic games depicted here.

TABLE 2. Regression results: Aggressive, with and without interaction with game features

Dep. var. = contribution	M1-a	M1-b	M2-a	M2-b	M2-c
aggressive	0.0165	0.00767	0.00830	0.00718	-0.0120
	(0.0343)	(0.0316)	(0.0342)	(0.0335)	(0.0288)
(pg3treat) x (aggressive)[a]				0.0617	0.0695
				(0.0955)	(0.0927)
(tgtreat) x (aggressive)[a]				-0.0305	-0.0309
				(0.144)	(0.144)
Constant	0.231***	-0.0761	0.178***	0.177***	0.00278
	(0.0287)	(0.225)	(0.0368)	(0.0365)	(0.178)
Game features [b]	No	No	Yes	Yes	Yes
Covariates [c]	No	Yes	No	No	Yes
N	1,503	1,503	1,503	1,503	1,503
R-squared	0.000	0.042	0.157	0.158	0.198
F-statistic	0.23	1.88	16.18	13.45	9.72

Figures in parentheses are robust standard errors adjusted for clustering.

[a] We included all possible combinations of game features and aggressive in a separate regression and arrived at similar results; hence, we only included and presented in this paper the extreme case.

[b] Game features include variables treatment, pg1ctrl, pg1treat, pg2ctrl, pg2treat, pg3ctrl, pg3treat, tgctrl, and tgtreat.

[c] Covariates include variables age, female, rcatholic, rich, junior, openness, conscientiousness, extraversion, agreeableness, and neuroticism.

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

6.2. Does aggression modify prosocial behavior as the game evolves?

If innate aggression whether by itself or in conjunction with the incentives embedded in economic games does not affect prosocial behavior, might its effect on the same be instigated by previous outcomes? In other words, is it the evolution or history of the game so far, and not the embedded incentives in economic games, that triggers the innate aggressiveness of players? Answers to these questions can be inferred from the results reported in Table 3 and Table 4.

Using indicators of experience in the immediately preceding round (Table 3), in M3-b and M3-c we see that both estimates of *aggressive* are negative and estimates of its interaction with experience of being duped in the previous round ($duped_{t-1}$) are positive; however, both are not significant. In M3-a, *aggressive* is positive, but possibly because the model is underspecified (i.e., no interaction with $duped_{t-1}$).

In Table 4, we allow for longer period of reckoning of undesirable experience, which is captured by the total number of being duped in previous rounds. For the results that used the pooled sample, *aggressive* is consistently positive in M4-a, M4-b and M4-c models, and significant in the last two models. Further, the estimates for the interactions of *aggressive* and the number of times duped are all negative and highly significant. These results indicate that innate aggression is manifested in lower marginal contributions when players experience bad outcomes in previous rounds.

Qualitatively similar results are obtained with the PG sample. As shown in M4-b and M4-c of the PG sample, *aggressive* is positive and its interactions with number of times duped in the past are negative. In contrast, the results based on the TG sample, neither *aggressive* nor its interactions with the same variables is significant.

TABLE 3. Regression results: aggression and game experience in the immediately preceding round

Dep, var. = contribution	M3-a	M3-b	M3-c
aggressive	0.0108	-0.0121	-0.0257
	(0.0257)	(0.0288)	(0.0313)
(with $payoff_{t-1}$) x (no $contribution_{t-1}$) [a]	-0.130***	-0.130***	-0.122***
	(0.0221)	(0.0222)	(0.0193)
(no $payoff_{t-1}$) x (with $contribution_{t-1}$) [a]	0.118***	0.104***	0.0974***
	(0.0330)	(0.0363)	(0.0358)
(no $payoff_{t-1}$) x (no $contribution_{t-1}$) [a]	-0.181***	-0.180***	-0.174***
	(0.0225)	(0.0226)	(0.0212)
($duped_{t-1}$) x (aggressive) [b]		0.0863	0.0863
		(0.0834)	(0.0849)

Dep, var. = contribution	M3-a	M3-b	M3-c
Constant	0.241***	0.222***	0.181
	(0.0317)	(0.0363)	(0.146)
Game features [c]	Yes	Yes	Yes
Covariates [d]	No	No	Yes
N	1,208	1,208	1,208
R-squared	0.291	0.293	0.321
F-statistic	18.36	21.93	15.28

Figures in parentheses are robust standard errors adjusted for clustering.

[a] We included all combinations of immediate game experience based on the amount of payoff received and contribution made in the previous round. "with payoff$_{t-1}$" is the case when variable zeropayoff$_{t-1}$=0; "no payoff$_{t-1}$" is the case when variable zeropayoff$_{t-1}$=1; "with contribution$_{t-1}$" is the case when variable zerocontrib$_{t-1}$=0; and "no contribution$_{t-1}$" is the case when variable zerocontrib$_{t-1}$=1. The base case is (with payoff$_{t-1}$) × (with contribution$_{t-1}$).

[b] We included all possible combinations of immediate game experience and aggressive in a separate regression and arrived at similar results; hence, we only included and presented in this paper the extreme case. We define duped$_{t-1}$ as a game experience of receiving payoff of zero and contributing a non-zero resource in the previous round.

[c] Game features include variables treatment, pg1ctrl, pg1treat, pg2ctrl, pg2treat, pg3ctrl, pg3treat, tgctrl, and tgtreat.

*** p<0.01, ** p<0.05, * p<0.1

TABLE 4. Regression results: Aggression and number of times duped in the past

Dep. var. =	**Pooled**			**Public goods game**			**Trust game**		
contribution	**M4-a**	**M4-b**	**M4-c**	**M4-a**	**M4-b**	**M4-c**	**M4-a**	**M4-b**	**M4-c**
aggressive	0.00419	0.646***	0.671***	0.0111	0.666***	0.600***	-0.00973	0.0226	-0.00477
	(0.0334)	(0.141)	(0.151)	(0.0369)	(0.159)	(0.189)	(0.0990)	(0.154)	(0.160)
times duped [a]									
times duped$_{t-1}$ = 1	-0.0129	-0.0105	-0.0218	-0.00287	-0.00689	-0.0109	.	.	.
	(0.0234)	(0.0271)	(0.0294)	(0.0209)	(0.0246)	(0.0246)			
times duped$_{t-1}$ = 2	0.0407	0.0417	0.0469	-0.0453	-0.0327	-0.0238	0.104***	0.0892**	0.0940**
	(0.0314)	(0.0369)	(0.0371)	(0.0420)	(0.0492)	(0.0448)	(0.0382)	(0.0417)	(0.0415)
times duped$_{t-1}$ = 3	0.238***	0.229***	0.213***	0.0493	0.0278	0.00489	0.335***	0.321***	0.276***
	(0.0478)	(0.0554)	(0.0541)	(0.0770)	(0.0794)	(0.0843)	(0.0558)	(0.0614)	(0.0576)
times duped$_{t-1}$ = 4	0.416**	0.255*	0.181	0.359*	0.193	0.219	.	.	.
	(0.174)	(0.150)	(0.165)	(0.180)	(0.164)	(0.193)			
times duped$_{t-1}$ = 5	-0.0374	-0.0376	-0.143*	-0.136***	-0.139***	-0.135	.	.	.
	(0.0349)	(0.0359)	(0.0780)	(0.0324)	(0.0332)	(0.0841)			
(times duped$_{t-1}$ = 0) x (aggressive) [b]		-0.646***	-0.691***		-0.661***	-0.596***		.	.
		(0.149)	(0.159)		(0.166)	(0.196)			
(times duped$_{t-1}$ = 1) x (aggressive) [b]		-0.658***	-0.687***		-0.640***	-0.558***		-0.0787	-0.112
		(0.148)	(0.155)		(0.166)	(0.194)		(0.139)	(0.135)
(times duped$_{t-1}$ = 2) x (aggressive) [b]		-0.648***	-0.702***		-0.732***	-0.677***		0.0130	-0.0177
		(0.151)	(0.160)		(0.172)	(0.197)		(0.123)	(0.123)
(times duped$_{t-1}$ = 3) x (aggressive) [b]		-0.593***	-0.617***		-0.534*	-0.394		.	.
		(0.183)	(0.185)		(0.298)	(0.287)			

Dep. var. = contribution	Pooled			Public goods game			Trust game		
	M4-a	M4-b	M4-c	M4-a	M4-b	M4-c	M4-a	M4-b	M4-c
Constant	0.157***	0.799***	0.734***	0.123***	0.123***	-0.496***	0.302***	0.310***	1.299***
	(0.0353)	(0.144)	(0.201)	(0.0248)	(0.0249)	(0.158)	(0.0672)	(0.0681)	(0.425)
Game features[c]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariates[d]	No	No	Yes	No	No	Yes	No	No	Yes
N	1,208	1,208	1,208	854	854	854	354	354	354
R-squared	0.206	0.209	0.248	0.062	0.076	0.149	0.151	0.152	0.255
F-statistic	.	.	.	.	.	.	12.87	9.38	8.71

Figures in parentheses are robust standard errors adjusted for clustering.

[a] Interpretation is relative to the base case times duped$_{t-1}$ = 0.

[b] Interpretation of these interaction terms is relative to the base case (times duped$_{t-1}$) x (not-aggressive). Moreover, (times duped$_{t-1}$ = 4) x (aggressive) and (times duped$_{t-1}$ = 5) x (aggressive) are not reported because of collinearity and empty observations.

[c] Game features include variables treatment, pg1ctrl, pg1treat, pg2ctrl, pg2treat, pg3ctrl, pg3treat, tgctrl, and tgtreat.

[d] Covariates include variables age, female, rcatholic, rich, junior, openness, conscientiousness, extraversion, agreeableness, and neuroticism.

*** p<0.01, ** p<0.05, * p<0.1

7. Discussion

Based on the results of regressions in the previous section, we find that by itself, innate aggression does not determine prosocial behavior of players in either game; nor does it vary in specific subgames. Instead, we find an experience-specific effect of aggression on prosocial behavior. That is, we begin to unravel the effects of aggression on prosocial behavior only once we take into account each player's experience of unreciprocated generosity. Interestingly, we only observe this role of innate aggression in the PG and not in the TG, as shown by the results in Table 4.

To elaborate, once we have allowed aggression to vary with cumulative extreme game experience, we find aggression per se to be positively correlated with contribution. In other words, holding game experience and interactions with game experience fixed, aggressive players tend to contribute more than not-aggressive players. Furthermore, we find that while aggressive players tend to be more prosocial, they also adjust their contribution more intensely than not-aggressive players for the same history of being duped.

To show this further, we use the results in Table 4 to predict the contributions of aggressive and not-aggressive players by the number of times duped for both the PG sample and TG sample (Table 5). In predicting the contributions, we set the game features and covariates to their mean values. In the PG game, the predicted contribution is 14 percent for both the aggressive player and not-aggressive player who both have no previous episode of being duped. For those who had been duped only once, the predicted contributions are 16 percent and 12 percent for the aggressive player and not-aggressive player, respectively. If they have been duped twice or thrice in the past, the predicted contributions of aggressive players drop to zero, while the figure remains above ten percent for the not-aggressive player. Surprisingly, the predicted contribution of the aggressive player rebounds to 95 percent if she has been duped four times in the past.

TABLE 5. Predicted contributions of aggressive and not-aggressive players by number of times duped, in public goods game and trust games

	Public goods game		Trust game	
	Aggressive	Not-aggressive	Aggressive	Not-aggressive
times $duped_{t-1} = 0$ [a]	0.135***	0.1347***		
	(0.0291)	(0.0164)		
times $duped_{t-1} = 1$	0.1618***	0.1238***	0.2545***	0.2948***
	(0.0395)	(0.0225)	(0.0856)	(.0405)
times $duped_{t-1} = 2$	0.0301	0.1109**	0.4431***	0.3889***
	(0.0406)	(0.0420)	(0.1114)	(0.0432)
times $duped_{t-1} = 3$	0.3415	0.1396*	0.6427***	0.5708***
	(0.1974)	(0.0780)	(0.1437)	(0.0503)
times $duped_{t-1} = 4$ [b]	0.9503***	0.354*		
	(0.0417)	(0.1889)		
times $duped_{t-1} = 5$ [b, c]		-0.0004		
		(0.0738)		

Note: The predicted contributions are estimated with all other covariates set at mean values. Figures in parentheses are robust standard errors.
[a] It is not possible for trust game players to have never been duped because of its game design.
[b] No observations in the trust games because the maximum number rounds is four.
[c] No estimate for the aggressive player since there is no aggressive player that has been duped five times in the public goods game.
***$p<0.01$, **$p<0.05$, *$p<0.1$

The patterns of predicted contributions in the TG are likewise interesting. The predicted contribution goes up for both aggressive and not-aggressive players as they experience more times of being duped in the past. Aggressive players tend to contribute more than not-aggressive players if both were duped twice or thrice in the past. So unlike in the PG, in the TG aggressive players appear to become more generous to their partner-receivers who persistently do not reciprocate.

Interestingly, the direction of our estimates in the PG corroborates that of Dreher et al. [2016] who investigated the impact of administered testosterone on prosocial behavior in an ultimatum game. Thus, our study adds yet another piece of evidence supporting the claim that the digit ratio is a lifetime biomarker for fetal testosterone exposure.

Our results also point to an interesting role of innate aggression in the PG and TG. Contrary to expectations, aggressive players are not necessarily non-cooperative players. In most of our regression results, we find *aggressive* to be insignificant, and yet contributions are always strictly positive in every round of either the PG or TG. Moreover, aggressive players are not always more intense in "punishing" non-cooperative players than others who likewise experienced unfair outcomes. They do so only in PGs. In the TG, they are more intense in "rewarding" non-reciprocating partner-receiver, despite the number of times they have been short-changed by the latter. How then could we explain the apparent inconsistencies in the behavior of aggressive players?

One possible explanation is that aggressive players do not necessarily play to maximize payoffs, whether their own or of the whole society. According to Dreher et al. [2016], such individuals may be driven instead by dominance-seeking aggression. Cabral and de Almeida [2019] define dominance as a pattern of social interaction that allows for the control of both the behavior of perceived "lower-ranked" individuals and valuable resources. In lower animal species, plain aggression is sometimes enough to achieve dominance or high social status within a cluster of species. Arguably, human social interactions are more complex, which requires behavior other than plain aggressive behavior in achieving dominance [Dreher et al. 2016]. Dominance-seeking behavior may include prosocial behavior in neutral (neither prosocial nor non-prosocial) and prosocial environments, because an immediate or unexpected display of aggressive behavior may result in the individual's exclusion from a cluster, before dominance is achieved. In non-prosocial environments, dominance-seeking behavior includes reactive aggression, whereby an aggressive individual perceives non-prosocial behavior among his peers as a provocation or a threat to his dominance [Dreher et al. 2016].

In the PG, both aggressive and not-aggressive players exhibit prosocial behavior initially. However, aggressive individuals contribute significantly more in the first round or in a neutral environment as shown in both preliminary observations (Figure 7a) and regression analyses. Since the contribution is made anonymously, one may argue that establishing dominance is not relevant in the first move when game experience is nil by definition. By the rules of the PG (the game driving the result of our pooled sample), however, the payoffs are awarded at the game's conclusion. Therefore, initial prosocial behavior is not made to establish dominance in the first round per se, but merely as a means for aggressive players to encourage cooperation from the team such that the team always reaches PPT and positive payoffs are gained. Thus, an aggressive player is perceived as dominant by others when he or she enables the team to achieve the maximum total payoffs throughout the game.

We argue that aggressive players exhibit reactive aggression not just to punish selfish team members but also to encourage a higher contribution from each player. Interestingly, we observe that this kind of punishment that elicits more cooperative behavior is only effective for players who were duped. Meaning, non-free-riders (duped players mostly) take responsibility for the team and compensate for both the punishment made by aggressive players and the free-riding behavior done by other members. However, this compensating behavior reaches a saturation point when the player is duped for the fifth and last time. By then, she reduces her contribution.

Therefore, an aggressive player's dominance-seeking behavior involves two actions: first, she contributes more initially; and second, she contributes less in order to motivate other players to contribute more (reactive aggression).

Since we do not observe reactive aggressions in players in the TG, our results seem not to conform with those in previous studies on dominance-seeking behavior. However, in the TG, the partner-receiver has established early and consistently that she will not reciprocate (i.e., cannot be "trusted" to give back to the partner-sender). Presumably the partner-sender has accepted this. Perhaps he also realized at once that if he withholds his contribution the partner-receiver will not change her decision and that resulting overall welfare will be lower than if he contributes and gets nothing back. By improving social welfare unilaterally and at personal cost to him, the aggressive partner-sender gets his reward in terms of improved social standing. However, we have no direct evidence of change of social standing or that players value such. What we have here is simply evidence of prosocial behavior of aggressive players that is consistent with the implied behavior of aggressive players motivated by dominance. Explicating the role of innate aggression – whether to elicit cooperation in other players or seek dominance over players – in economic games is a promising lead for further investigation.

8. Concluding remarks

To conclude, we are able to answer the questions on whether inherently aggressive individuals and inherently not aggressive ones differ in their prosocial behavior, and whether they differ in their initial, subsequent or overall prosocial behavior.

We find that indeed, individuals who are respectively predisposed and not so predisposed towards aggression behave differently. Using data from two classroom experiments involving college students, we find that aggressive individuals dtend to behave more prosocially when necessary to establish perceived dominance.Further, we find that aggressive individuals vary their initial and subsequent prosocial behavior based on reactive aggression when they are provoked or when their perceived dominance is threatened, perhaps to motivate other players to cooperate more. This, however, is only observed in the PG sample. In the TG sample, we observe an aggressive player to contribute more than a not-aggressive player with the same game experience (including being duped). This leads us to suggest that aggressive players may not be motivated by dominance as conventionally defined. Possibly, aggressive players who unilaterally improved overall social payoff at personal cost to them instead find reward enough in terms of elevated social status or social esteem. While our supporting evidence based on the TG sample is weak, we still think the results are worth exploring with more appropriate game setups.

Besides adding to the long line of literature that relates gestational testosterone exposure (proxied by the digit ratio) to aggressive behavior, this study also highlights the importance of experience in understanding the effect of innate aggression on prosocial behavior. To elaborate, aggressive individuals seemingly are provoked less by the incentives and constrains embedded in a collective action game than by their individual experiences as the game progresses. In line with the literature on path dependency of economic growth of countries, the policy implication of our findings is that the evolution of the collective action games, perhaps as much as their structures, matter for achieving efficient outcomes.

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