Journal of Behavioral and Experimental Economics 103 (2023) 101987

Contents lists available at ScienceDirect

Journal of Behavioral and Experimental Economics

journal homepage: www.elsevier.com/locate/jbee

Conditioning competitive behaviour in experimental Bertrand markets through contextual frames[☆]

Francisca Jiménez-Jiménez [a], Javier Rodero-Cosano [b,*]

[a] Departamento de Economía. Universidad de Jaén, Spain
[b] Departamento de Teoría e Historia Económica. Universidad de Málaga., Plaza del Ejido s/n. 29013 Málaga, Spain

ARTICLE INFO

JEL classification:
code
D03
D22
L13

Keywords:
Framing effects
Bertrand competition
Laboratory experiments
Contextual frame

ABSTRACT

Explaining framing effects is one of the main challenges faced by decision theories. This research experimentally examines how different contextual frames influence competitive behaviour in a Bertrand duopoly game (repeatedly played under a stranger matching), unexplored so far. The design comprises four frames: one abstract (a beauty-contest framing), two meaningful (the standard Bertrand framing and an access-to-river framing) and one evocative (a take-from-fund framing). Our findings show that, at first, the evocative frame differentiates from the rest mostly in market prices. While the evocative frame induces subjects to behave closer to the theoretical predictions initially, the others need some repetitions until convergence is achieved. Differences across frames eventually vanish at the end. During the transition, in the Bertrand frame, a quicker decay in prices is observed due to the behavioural reactions to historical market prices. Lastly, irrespectively of frames, behavioural reactions to immediate past information allow to explain strategic interaction in the long-run: a force-balance situation which is consistent with the related literature on price floors in Bertrand games.

1. Introduction

Nowadays, an ongoing debate in social sciences concerns how psychological factors shape economic relationships. In this paper, we are interested in one of the most widely studied features in psychology, but fairly less pervasive in economics: the framing of decision problems. Since the classical Asian Disease Problem (Kahneman and Tversky 2000, Tversky and Kahneman 1981) experimental evidence has consistently shown that description of situations in positive/negative terms provokes behavioural biases in individual decisions. This kind of framing is classified as valence framing and has been thoroughly studied in the literature.[1]

The present research deviates from the mainstream in two aspects. First, we focus on a context framing or label framing, where the same decision problem is described with different narratives or stories. Second, in all cases, we implement a decision environment defined by a Bertrand duopoly competition that is repeatedly played under a stranger matching (i.e. all contexts are isomorphic in game theoretical terms). Our main purpose is to examine the sensitivity of players' decisions to different contextual frames and to arrange their pro- or anti-competitive effects, immediately and in the long run.

Contextual frames are found to significantly influence behaviour in individual decision making tasks, mainly in situations where people face problems they are unfamiliar with. In those cases, psychologists have shown that people tend to use heuristic shortcuts when lacking enough time and willingness to analyse deeply the problem in question (see the seminal work of Liberman et al. 2004). However, in some cases, there exists a mismatch between the intention imprinted by frame and the (out-of-lab) direct experience of the experimental subjects, which may lead to some unexpected null framing effects (see Abbink and Hennig-Schmidt 2006, Brandts and Schwieren 2007). In this paper, we also explore such dissonances.

Alekseev et al. (2017) distinguish between three types of contextual frames in terms of intentions. First, "abstract" frames where the language used in the experimental instructions is neutral and not related to any experience outside of the lab, such as players, choices, or numbers. Second, "meaningful" frames which employ language and terms that

☆ This research was funded by the Spanish Ministry of Science RTI2018-097620-B-I00, PID2021-127736NB-I00 and Junta de Andalucía projects, Spain P18-FR-3840 and UMA18-FEDERJA-243. Funding for open access charge: Universidad de Málaga/CBUA, Spain.

* Corresponding author.
E-mail addresses: jimenezf@ujaen.es (F. Jiménez-Jiménez), jrodero@uma.es (J. Rodero-Cosano).

[1] Although valence framing was initially analysed in individual risky decisions, it has been also studied in other contexts, see the surveys by Levin et al. (1998) and Kühberger (1998). See Druckman (2001) for a critical appraisal of de-contextualised framing effects.

https://doi.org/10.1016/j.socec.2023.101987
Received 20 July 2022; Received in revised form 29 January 2023; Accepted 30 January 2023
Available online 3 February 2023

can be related to a real-life situation, such as firms, prices, or market. Last, the third type of frame, which the authors call "evocative", includes terms that are not only related to a real-life situation, but also can evoke strong emotions like friends, foes, etc. Following this approach, we have designed four frames: (i) The Beauty contest frame (BCH, hereafter), which describes the strategic context in an *abstract* way as a guessing game; (ii) the Bertrand frame (BE, hereafter) which posits the environment in a *meaningful* context as a price competition in a product market; (ii) the River access frame (RIV, hereafter) which represents the game in a *meaningful* context as a competition for the access to a natural resource (a river); and (iv) the Take the fund frame (TF, hereafter) which explains the competition context in *evocative* terms as a common monetary fund to be assigned to the student who decides to take the lowest amount.

As Liberman et al. (2004) posit, if framing effects depended on social interpretation of context according to subjects' own experiences, it would be expected that such framing effects faded away when subjects gain experience on the incentive scheme with game repetition and information feedback. For this reason, we also analyse how subjects adapt/shape their behaviour over time.

Economists have thus far paid relatively little attention to the effects of frames in strategic settings. The rationality paradigm under which decision making is typically modelled focuses just on the game structure, beliefs and preferences to explain choice behaviour. Preferences are usually assumed to be exogenous to the context, stable over time and only dependent on outcomes. Beliefs about others' behaviour are assumed to be formed according to equilibrium conditions and rationally updated.

Nevertheless, recent economic research provides support for the importance of frames in games. In one-shot settings, experimental studies show that frames carefully designed to activate specific heuristic rules influence choices through (first or second order) beliefs (Dufwenberg et al. 2011). Evidence is less clear in repeated games: while the initial framing effects persist along time in social dilemmas (Gerlach et al. 2017), in other settings like the trust game the effects get reduced (Burnham et al. 2000). In asset markets, contextual frames can induce subjects different reference points which tend to vanish with repetition (Masiliunas and Nax 2020, Stefan 2016).[2]

To our knowledge, the present research is the first to examine how different contextual frames influence strategic behaviour in a competition game. Experimental work on the standard Bertrand competition has established a regular choice pattern: a relatively slow price convergence path towards equilibrium when there are just two firms (see, for example, Bruttel 2009, Dufwenberg and Gneezy 2000, Dufwenberg et al. 2007). Strategic complementarity is the main reason behind this slow convergence (in contrast with Nash predictions). The complementarity of strategies together with the discontinuity in the payoff function generate two opposing and simultaneous forces which drive competitive behaviour in this game: payoff dominance (bigger choices lead to higher payoffs) and the winning rule (smaller choices increase the chance of winning the game and of avoiding zero payoffs).

Based on previous research, the contextual frames are expected to influence competitive behaviour in the beginning, but we anticipate that such cross-frame differences will vanish in the long run. Furthermore, we posit that, during the transition, frames will also induce differential choice dynamics by standing out the salience of one of the two opposing forces.

[2] Some examples of valence framing experiments are Andreoni (1995) or Cox (2015) in public goods (see also Cox and Stoddard 2015), List (2007), Bardsley (2008) or Brañas-Garza (2007) in dictator games. Examples of contextual framing are Liberman et al. (2004) or Engel and Rand (2014) in prisoner's dilemmas, Abbink and Hennig-Schmidt (2006), Barr and Serra (2009) or Banerjee (2016) in bribery experiments. The mentioned Dufwenberg et al. (2011) simultaneously investigate the influence of valence and label framing dimensions on beliefs in a one-shot public goods experiment.

Our experimental findings show initial differences between the evocative frame and the other three, being significant in market prices but not in choices. With experience, behaviour converges across frames. Interestingly, we find different behavioural patterns during the transition. The dynamic framing effects are explained on the basis on two elements of prior experience: history and immediate past. The influence of history-based information (market prices and competitors' actions) allows to identify the predominant competitive force in each frame during the transition: payoff dominance versus winning rule. While behaviour observed in BE is more consistent with the winning rule (market prices) as the main driving force, in BCH and RIV behaviour is more significantly affected by payoff dominance (competitors' actions). In TF, the effects of both opposing forces cancel each other out. Lastly, behavioural reactions to immediate past information allow to explain strategic interaction in the long-run: a force-balance situation which is consistent with the related literature on price floors in Bertrand games.

2. The experimental design

The incentive structure is a Bertrand competition model with unitary demand and zero marginal cost. In every round, two firms have to choose simultaneously a price (with at most two decimal places) in the interval $[0, 100]$, both bounds included. The winner is the firm who chooses the lowest price. The winner's profits are given by the chosen price, the loser gets nothing. If both firms set the same price, profits are shared equally.

As subjects can choose up to two decimals, the game has 3 symmetric equilibria: $\{0, 0\}$, $\{0.01, 0.01\}$ and $\{0.02, 0.02\}$. From the viewpoint of payoff saliency in the lab, differences between them are insignificant. Hence, we will assume that the game has a unique Nash equilibrium given by $\{0, 0\}$, which gives a null payoff to players. This incentive structure is different from others used in experiments with similar games that generate positive payoffs in equilibrium through the implementation of price floors (for example, Dufwenberg and Gneezy 2000 or Dufwenberg et al. 2007).

The game is played for 12 rounds under a random matching mechanism which allows subjects to gain experience with the incentive structure, but it prevents implicit collusion and reputation building (Dufwenberg and Gneezy 2000). The sessions consisted of 12 or 20 participants, being randomly re-paired every round.

Another design feature which inhibits collusion and favours undercutting strategies is the use of two decimals in the choice space, which should reinforce the pro-competitive bias (Huck et al. 2000). A player has to reduce the price just by 0.01 with respect to their opponent's choice to reap full profits.

After each round, subjects receive full feedback of their group: both players' choices, the winning number, individual payoffs, and the average and $2/3$ of the average in the case of the BCH treatment (see below). Subjects do not obtain information about the other groups in the session.

2.1. Frames and research hypotheses

Following to Alekseev et al. (2017), we design four contextual frames: one abstract, one evocative and two meaningful. These frames differ only in the wording of the instructions. To isolate potential meaningful framing effects, two alternative frames are considered: a standard Bertrand competition frame and another frame described as an economic decision problem of location (see below).[3]

[3] The experiment was not pre-registered. See the Supplementary Material for a translation of the original experimental instructions.

Table 1
Frames of the game.

Frame	Type	Context	Players	Strategy
BCH	Neutral	Guessing game	Students (implicit)	Number
BE	Meaningful	Market competition	Firms	Price
RIV	Meaningful	Access to river	Producers	Distance
TF	Evocative	Taking money from a fund	Students (implicit)	Money

BCH Beauty contest framing with a winning number hint, that is, signalling lower numbers.
The wording is similar to a Beauty Contest. Subjects have to choose a number in the above interval. The winner will be the person who chooses the closest number to 2/3 of the average. Then, the winner will always be the person who chooses the lowest number as there are only two players. We provide subjects with this information (as a hint) to make this treatment comparable to the other three, as the winning rule is explicitly included in the instructions. The main difference with the standard Beauty Contest is that payoffs are variable: that is, the winner's payoff is equal to the chosen number instead of a fixed prize as in a beauty contest game.[4]

BE Bertrand framing.
Firms are set up in a price competition described with a market framing. This frame is directly comparable with price competition experiments and, hence, taken as the baseline.

RIV River access framing.
Producers have to choose the plot distance from a water source. The closest producer will have exclusive access but the land quality is increasing with the distance to the water. The winners' payoffs are equal to their distance choice.

TF Taking money from a fund framing.
Participants have to choose how much money they want to take from a money fund (endowed with 100 non-accumulative points in each round). The person who chooses the lowest amount will get a prize equal to his/her withdrawal.

Table 1 summarises the main characteristics of frames.

Notice that the instructions of BE, RIV and TF are loaded in terms of labels used for players (firms, producers, students), strategies (prices, distance to the river, money taken from a fund) and competitive rules (the lowest price, the nearest land, the lowest amount of money), as compared to the BCH treatment which uses a neutral labelling.

We next present the research hypotheses. The hypotheses are structured in three groups: first-round behaviour, last-round behaviour, and the dynamics of behaviour over time.

Abstract frames can be hard to understand initially by most experimental subjects. For example, experimental studies on Beauty Contest reveal the inability of participants apprehending the strategic features of the game in one-shot decisions when it is presented in abstract terms, even using a simplified version game (Chou et al. 2009). Likewise, Jiménez-Jiménez and Rodero-Cosano (2015) use a Beauty Contest context to describe a Bertrand competition game in an abstract way. With priming manipulations towards lower or higher numbers, the authors find that, initially, choices differ considerably between treatments although all of them are well above equilibrium. Yet, the priming effects dissipate by the end of the experiment.

Literature on Bertrand competition (see, for instance, Bruttel 2009, Dufwenberg and Gneezy 2000, Dufwenberg et al. 2007) shows that experimental subjects acting as firms set market prices above equilibrium as an attempt to collude and achieve positive profits. Furthermore, a meaningful frame that is closely related to the economic situation to be represented (with terms such as firms, prices, market, etc.) may influence players' beliefs about the other players' actions, and beliefs affect motivations and, thereby, strategic behaviour (Dufwenberg et al. 2011). In this regard, a market frame may be used as a collusion device to influence on actual behaviour in games of strategic complements as ours (Masiliunas and Nax 2020). Therefore, it would be expected to find relatively low competition in our BE frame, at least initially. With respect to our second meaningful frame, RIV, we put forward the same predictions as for the BE frame since it uses also economic terms but adapted to a different competitive context. As far as we know, there is no previous research on competition using a frame with a wording similar to the RIV one.

Regarding the TF frame, we posit that the exposure of subjects to a decision problem which they have no direct experience with plays a crucial role in determining the actual behaviour. We believe that out of the three non-neutral frames designed in our experiment (BE, RIV and TF), the TF frame is the closest one to the prior experience of the participating students (who has not ever allocated a common money pool among friends?). The close connection of lab situation with the out-of-lab real-life experience may facilitate the immediate recognition of the strategic environment, and influence their mental representation of it.

Based on previous research, we expect frames to exert their influence differently on initial choices. In particular, initial choices are expected to deviate upwards from the equilibrium in all frames, although we anticipate a lower framing effect (lower choices) in the TF treatment (the evocative frame) than in the other three treatments: BE, RIV (the two meaningful frames) and BCH (the abstract frame).

Hypothesis 1a. In the first round, choices will be higher in the meaningful frames (BE and RIV) and the abstract frame (BCH) than in the evocative frame (TF).

Regarding the distribution of choices, it is difficult to expect a uniform distribution over the whole interval $[0, 100]$. More reasonably, given the pro-competitive design, choices should be located around (but no exactly over) some prominent numbers. Following Fatas et al. (2014), those prominent numbers should be discrete subdivisions of the strategic space; in our case intervals of tens: $0, 10, 20, 30, 40, 50, \dots, 100$. Notice that three of them are specially salient: (i) 0 is the equilibrium prediction and the lower bound of the interval; (ii) 50 is the strategy corresponding to a I(0) rationality player (someone who, for instance, has not apprehended the experimental instructions) and the midpoint of the interval; (iii) 100 is the most efficient cooperative choice and the upper bound of the interval. Another two numbers, 10 and 20, can be also germane since they are the closest to the equilibrium prediction, and fairly similar to the long-term average prices found in the experimental literature.[5]

Those prominent numbers will exert a notable influence on individual choice behaviour in all treatments but we expect significant differences in the distribution of choices between frames. Specifically, we posit as follows: (i) a higher proportion of choices around 50 in the abstract frame (BCH) than in the other frames (BE, RIV and TF); (ii) a higher proportion of choices above 50 in the two meaningful frames (BE and RIV) and, (iii) a higher proportion of choices below 50 (around 0, 10, 20) in the evocative frame (TF).

[4] This treatment is identical to the Priming Competition treatment in Jiménez-Jiménez and Rodero-Cosano (2015); we use the data of that paper for the current study. Grosskopf and Nagel (2008) introduce the two-person beauty contest game from which this frame is derived.

[5] Notice that, as the strategic setting is not a coordination game, we do not have properly focal points *à la* Schelling (1960).

Hypothesis 1b. In the first round, the distribution of choices will differ across frames. In particular, choices will be more concentrated on the interval midpoint (50) in the abstract frame (BCH). However, choices will be more frequent above the midpoint in the meaningful frames (BE, RIV) and below the midpoint in the evocative frame (TF).

At the end of the experiment, it would be reasonable to expect that the size of framing effects diminish as people adjust their choices according to their experiences. If subjects actually adjust their decisions following the competition rules of a Bertrand duopoly (rather than being anchored in a particular frame), we should observe a decreasing trend in choices in all frames. The literature on Bertrand competition shows that, in stranger matchings, bids exhibit a downward-sloping movement towards the Nash equilibrium, zero in our case (see Bruttel 2009, Dufwenberg and Gneezy 2000, Dufwenberg et al. 2007). Indeed, Bruttel (2009) finds that, after ten periods, bids decrease by approximately one-third (see her LOW treatment, which is the comparable one with ours). Then, we posit that differences in choices eventually fade away across frames after some repetitions of the game. Moreover, based on previous research, we state that the distribution of choices will show a higher frequency of numbers close to the zero equilibrium in the last round, although above it.

Hypothesis 2a. The framing effects are temporary. In the last round, choice behaviour will converge across different frames.

Hypothesis 2b. In the last round, choices will be more concentrated around the lowest prominent points above 0 (10 and 20).

Lastly, we focus on the evolution of choice behaviour along the experiment. Based on the basic incentive scheme (i.e. a Bertrand competition game without communication and played for 12 rounds under a stranger matching) and previous research, a general decay in choices can be anticipated. However, spirals up and down are typically observed along the decreasing trend towards the equilibrium (Bruttel 2009). Such cyclical movements can be explained by the existence of the two opposing forces, payoff dominance and the winning rule.[6]

However, when frames are also expected to influence choice dynamics, additional mechanisms should be considered. There are two basic mechanisms through which frames can influence behaviour: preferences and beliefs (Ellingsen et al. 2012). In our setting, the mechanism based on preferences should hardly matter. Thus, the impact of frames should transmit mainly through a beliefs-based channel.

The best response function in the Bertrand model is a one-on-one correspondence between beliefs and choices: players should choose a number slightly lower than their beliefs about the other player's action. Consequently, if subjects understand the basic game incentives underlying the frames, higher choices should be associated with beliefs that the other player will also select high choices.[7]

Therefore, we establish that adaptive choice behaviour is mainly the result of a beliefs' updating process affected by three main elements: initial conditions, feedback information and pure game repetition. Frames are expected to influence both initial conditions, as posited in Hypotheses 1a and 1b, and how subjects interpret information they receive after each round (partners' actions and individual payoffs). Yet, as frames are just clothes over the same incentive scheme, the initial and dynamic framing effects should dissipate along time, as predicted by Hypothesis 2a. Of course, if neither frames nor feedback information influence beliefs, the evolution of choices should be explained away just by the dynamic predictions of game theory: a pattern of systematic undercutting that converges towards the equilibrium.

It is worth mentioning that feedback information should only be relevant when subjects present some behavioural biases (as the competitor changes from round to round and session sizes are large enough). But, absent any alternative mechanism of beliefs formation (like the sequential choice in Dijkstra 2015), it would be reasonable to think that subjects will use past information to guess about their current opponents' actions. Moreover, following Bruttel (2009) who finds a strong influence of past information on competitive behaviour, we expect that subjects will use feedback information for making their current decisions.

In particular, we consider two key elements of feedback information: one related to a player's history and another related to his/her immediate past. The history-based information reflects the prior accumulated experience of a player along the session, while the immediate past captures his/her experience in the earlier round. Our expectations are established such that the further choices are above the Nash equilibrium, the more important the history effect will be. These expectations are based on the assumption that while payoff dominance pushes choices upwards, the winning rule pushes them downwards. In this regard, having a prior history further above the equilibrium could be consistent with players guided by payoff dominance as the predominant force (and, hence, players posit their beliefs about their current competitor's action on what their peers chose in the past). By contrast, being close to (or adjusting quickly towards) the equilibrium could indicate that winning the game is the predominant force (and players' beliefs about their current competitor's action are based on the winning numbers of their prior history). Therefore, given our expected framing effects on initial choices, we anticipate that the effect of history-based information will be more relevant in BE, RIV and BCH compared to TF.

Regarding immediate feedback information, we posit that its effect will be the same in all frames. Using a simple directional learning model, the immediate reactions of subjects to previous outcomes may capture the impact of the two forces: those players who lose in a round will react by decreasing their choices in the next round (to increase their chance of winning), while those players being winners in a round will react by increasing their choices in the next round (to get a higher payoff). A more sophisticated behavioural model is the impulse balance theory, an ex-post rationality learning model where the probability of playing an action (impulse) is reinforced according to the profit it might have been obtained given the feedback from the previous round (opponent's choice). In the case of a Bertrand competition, regardless of frame, if a higher (lower) price in the last round might have been better, the price tends to be increased (decreased) in the current round. The strength of the impulse will be greater the closer it is to the other's choice, as higher prices bestow higher profits.[8]

Hypothesis 3. Frames will impact on choices through information based on history. The effect of history will be more prominent in BE, RIV and BCH than in TF. The effect of immediate feedback will be equally relevant in all frames.

[6] While payoff dominance pushes choices upwards, the winning rule pushes them downwards. Under random matching, the counterbalance of these two forces may lead to a cyclical behaviour until choices converge towards the point where both forces equilibrate each other.

[7] Being more specific, assuming a continuous strategy space, if $F(x)$ and $f(x)$ are the distribution and density functions of beliefs about the other' strategy over the decision space, the optimal choice, x^* is given by the condition $x^* = \frac{1-F(x^*)}{f(x^*)}$. It can be easy to prove using stochastic dominance arguments that if $F(x)$ shift rightwards, x^* increases.

[8] The directional learning model was originally proposed by Selten and Buchta (1999) and further refined by Selten and Chmura (2008). Bruttel (2009) adapts it to a Bertrand competition model. Regarding the impulse balance theory, Ockenfels and Selten (2005) propose this behavioural model to explain data from sealed-bid first-price auctions with private values.

Table 2
Experimental setup.

Treatment	20 subjects sessions	12 subjects sessions	Total of sessions	Total of subjects
BCH	2	3	5	76
BE	2	3	5	76
RIV	3	3	6	96
TF	0	5	5	60

Table 3
Summary of descriptive measures by treatment.

Treatment	Average choice	St. Dev. choice	Median choice	Average market price	St. Dev. market price
BCH	27.7	19.2	21.0	18.8	9.2
BE	25.1	17.1	20.0	18.6	9.8
RIV	28.7	19.5	22.5	20.6	11.0
TF	22.4	20.0	18.0	14.3	11.8

2.2. Material and methods

All the treatments were conducted in the LINEEX lab of the University of Valencia (Spain). The software used was Ztree (Fischbacher, 2007).

The experiment took along about 25 min and the average accumulated earnings were 11.7 euros. The points gained by each participant along the 12 rounds of the experiment were added up and converted into money using an exchange rate of 1 point = 0.05 euros. The individual earnings were rounded up to tenths of Euro to facilitate payments. Each treatment consisted of five or six sessions with 12 or 20 participants each (308 in total). See Table 2 for more details.[9]

3. Results

Table 3 and Figs. 1 and 2 present a general description of the main experimental results by treatment. Table 3 shows some descriptive statistics regarding choices (average, standard deviation and median) and market prices (average and standard deviation) in each treatment. Figs. 1 and 2 display dynamics of choices and market prices, respectively.[10]

Looking at Table 3 and Figs. 1 and 2, two results stand out. First, choices and market prices start initially at fairly high levels in three of the treatments (BCH, BE and RIV) and smoothly converge towards (but never reduce down to) equilibrium; on the contrary, in TF, choices and market prices are lower (on average) from the start (as will be shown in the next Section 3.1). Second, although such differences are initially the greatest, all treatments eventually end more alike at the end.

To better understand the framing effects and test research hypotheses, we next examine behavioural patterns in more detail.

3.1. First-round results

Table 4 shows the average and standard deviations of choices in the first round by treatment. It also displays the results of pairwise non-parametric tests where p-values are corrected using the Benjamini–Hochberg adjustment for multiple hypotheses testing (Benjamini and Hochberg 1995), as implemented in Dinno (2014). These tests are run using 60 (TF), 76 (BCH and BE) and 96 (RIV) independent observations at the individual level, as subjects receive feedback just *after* the first round.

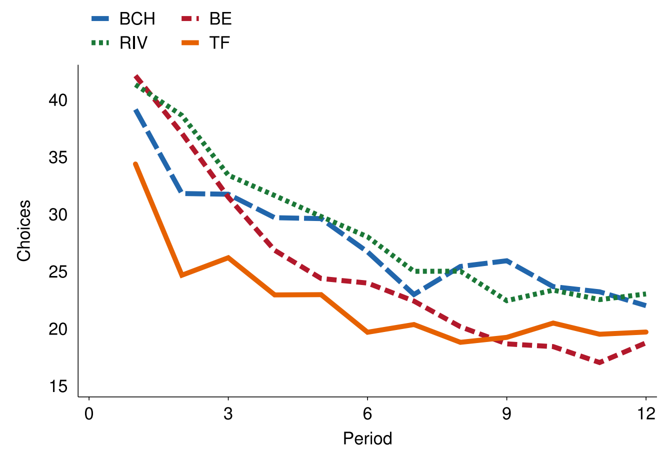

Fig. 1. Time path of average choices.

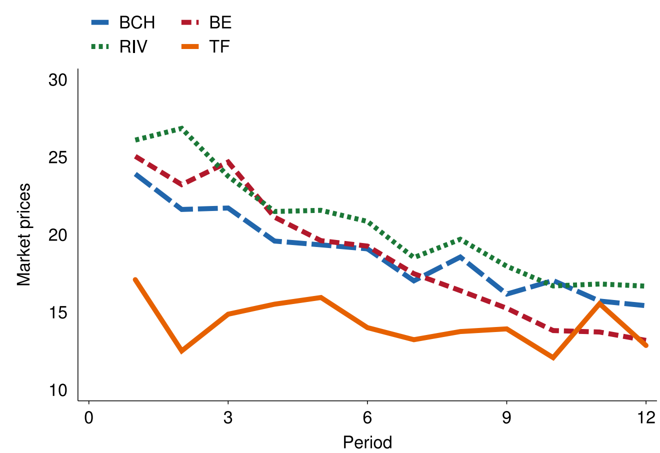

Fig. 2. Time path of average market prices.

As expected, in the first round, the two meaningful frames (BE and RIV) and the neutral frame (BCH) induce subjects to choose relatively high numbers (choices around 40 and market prices around 25, on average), while the evocative frame (TF) leads to lower outcomes (choices around 34 and market prices around 17, on average). Likewise, while BCH, BE and RIV show similar standard deviations, behaviour in TF shows a greater dispersion. The TF frame seems to be more noisy than the others although not significantly.[11]

However, these initial framing effects are significant just in market prices but not in choices. The results of Kruskal–Wallis rank tests lead to a rejection for equality of first-round market prices among treatments at 5% ($\chi^2 = 9.847, p = 0.019$) but not for equality of first-round choices ($\chi^2 = 5.261, p = 0.153$). As shown in Table 4, the *post hoc* pairwise Dunn's tests indicate that there are not significant differences in any pairwise comparison of choices with a false discovery rate (q) of 5%. Nevertheless, differences in market prices between the TF treatment and the other three treatments are significant at $q = 5\%$ in all pairwise comparisons (see the corrected p-values marked in bold in Table 4).[12]

[9] In the Supplementary Material subsection S1.1 we run some robustness tests to check for differences in behaviour between session sizes. No statistical differences can be found in the three treatments where we have 12- and 20-subject sessions.

[10] Although the "market price" term only applies to the BE frame, we are going to use it indistinctly in all treatments as a synonym for the minimum choice of each couple in any round.

[11] See Table S1 in the Supplementary Material for all the pairwise comparisons testing the equality of standard deviations.

[12] It is worth mentioning that the evocative treatment differs from the other three treatments when these are considered jointly. A Mann–Whitney test of equality of first-round choices confirms the existence of significant differences at 5% between TF and the pooled choices of the other three treatments ($z = 2.201$, $p = 0.027$). The same happens to occur with market prices, being significant at 1% ($z = 3.123$, $p = 0.001$).

Table 4
Summary of descriptive statistics and non-parametric tests for first-round outcomes.

Treatment	Average choice	Standard deviation	Dunn's Pairwise Comparisons of choices (Benjamini–Hochberg, $q = 0.05$)		
			BE	RIV	TF
BCH	39.1	26.7	$z = -0.652$ ($p = 0.771$)	$z = -0.410$ ($p = 0.817$)	$z = 1.504$ ($p = 0.264$)
BE	42.1	26.8		$z = 0.278$ ($p = 0.780$)	$z = 2.117$ ($p = 0.205$)
RIV	41.3	26.5			$z = 1.962$ ($p = 0.149$)
TF	34.4	30.1			
Treatment	**Market price**	**Standard deviation**	**Dunn's Pairwise Comparisons of market prices (Benjamini–Hochberg, $q = 0.05$)**		
			BE	RIV	TF
BCH	23.9	16.0	$z = -0.152$ ($p = 0.879$)	$z = -0.330$ ($p = 1.000$)	$z = 2.444$ (**p= 0.029**)
BE	25.1	16.0		$z = -0.169$ ($p = 1.000$)	$z = 2.586$ (**p= 0.029**)
RIV	26.1	17.0			$z = 2.873$ (**p= 0.024**)
TF	17.1	20.6			

Result 1. *In the first round, there are not significant differences in choices across frames. However, the evocative frame (TF) leads to statistically different market prices as compared to the meaningful and neutral frames (BCH, BE and RIV). The initial market prices are significantly lower in the TF treatment.*

To explore the source of noise found in the first round, we examine the distributions of choices across treatments. Fig. 3 shows the kernel estimation of the distribution of choices by treatment in the first round (using a triangular kernel). We want to emphasise three main features. First, there is a high concentration of choices around the middle of the interval (50) in all treatments but, against our expectations, the highest peak is reached in the BE treatment, rather than in the abstract one (BCH). Second, in all treatments, there is a "long" right tail, i.e. choices between 50 and 100, although without notable differences across treatments. Third, the main differences across treatments are located on the left tails of distributions, being the TF treatment clearly more skewed to the left. These observations are confirmed by Kolmogorov–Smirnov tests for equality of distribution functions in the sense that TF differs considerably from each other frames. The initial distribution of choices is more left-skewed in TF and, hence, more closely to the equilibrium prediction.[13]

Another behavioural aspect that framing can influence is the choice of prominent numbers. More precisely, we assert that a choice is around a prominent number if it is at a distance of 0.5 or closer to that number. In our analysis, we consider as prominent numbers those which are the most frequently chosen by subjects: 0, 10, 15, 20, 30, 40, 50, and 100. All but 15 were actually expected given that people tend to decide in tens interval.

Fig. 4 plots the distribution of prominent numbers by treatment. In the BCH and RIV treatments, the joint proportion of choices around prominent numbers is about 40%, while in BE and TF such a rate rises closely to 60%.[14] However, the TF and BE treatments lead to very different prominent numbers in subjects' minds: low numbers in TF and high numbers in BE.[15]

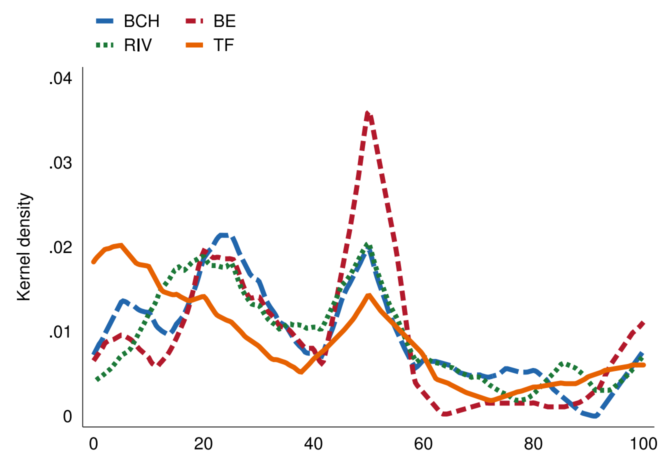

Fig. 3. Kernel distributions of choices in the first round.

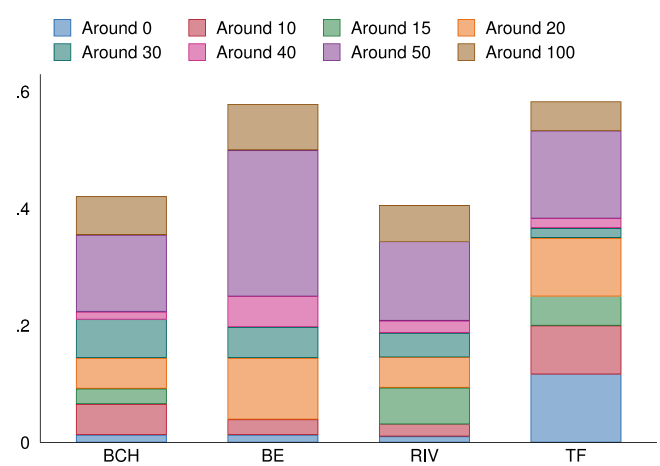

Fig. 4. Choices around some prominent numbers in the first round.

[13] The results of all possible pairwise tests are as follows: BCH–BE, $D = 0.1184, p = 0.654$; BCH–RIV, $D = 0.0877, p = 0.861$; BCH–TF, $D = 0.2202, p = 0.063$; BE–RIV, $D = 0.1064, p = 0.672$; BE–TF, $D = 0.2518, p = 0.023$; RIV–TF, $D = 0.2500, p = 0.016$. The comparison between TF and the other treatments considered jointly is also significantly different: $D = 0.2220, p = 0.014$.

[14] A test for the equality of proportions between these two pairs of treatments gives a $z = -2.9308$, one-sided $p < 0.01$.

[15] Low prominent numbers rates: 0.35 for TF and 0.145 for BE, $z = -2.8020$, one-sided $p < 0.01$. High prominent numbers rates: 0.233 for TF and 0.434 for BE, $z = 2.4459$, one-sided $p < 0.01$. See Table S2 in the Supplementary Material for further details.

Table 5
Summary of descriptive statistics and non-parametric tests for last-round outcomes.

Treatment	Average choice	Standard deviation	Dunn's Pairwise Comparisons of choices (Benjamini–Hochberg, $q = 0.05$)		
			BE	RIV	TF
BCH	22.0	17.6	$z = 0.255$ ($p = 0.959$)	$z = -0.302$ ($p = 1.000$)	$z = 0.306$ ($p = 1.000$)
BE	18.8	17.9		$z = -0.568$ ($p = 0.780$)	$z = 0.051$ ($p = 0.205$)
RIV	23.0	17.8			$z = 0.621$ ($p = 1.000$)
TF	19.7	20.0			
Treatment	**Market price**	**Standard deviation**	**Dunn's Pairwise Comparisons of market prices (Benjamini–Hochberg, $q = 0.05$)**		
			BE	RIV	TF
BCH	15.4	5.4	$z = 0.968$ ($p = 1.000$)	$z = 0.071$ ($p = 0.943$)	$z = 0.663$ ($p = 1.000$)
BE	13.2	6.2		$z = -0.940$ ($p = 1.000$)	$z = -0.306$ ($p = 0.911$)
RIV	16.7	7.4			$z = 0.621$ ($p = 0.802$)
TF	12.9	9.7			

Result 2. *At the beginning of play, prominent numbers are more often chosen in TF and BE than in BCH and RIV. In particular, the TF frame induce subjects to select prominent numbers which are more closely to the equilibrium prediction, while in BE subjects tend to select high prominent numbers.*

The previous results allow us to confirm just partly the Hypotheses 1a and 1b.

3.2. Long-term effects

As shown in Fig. 1, choices clearly decrease over time in all treatments until being closely undistinguishable at the end of the experiment.

To demonstrate that differences in choice behaviour across frames decrease over time, we performed a set of econometric models to test the duration of treatment effects. Hence, using the panel data technique with random effects and clusters at the session level, individual choices are regressed on treatment dummy variables and the *Period* variable (defined by different time spans). Taking TF as baseline, the results show that differences between BE and TF are statistically significant at 5% just until the 4th round inclusive ($\beta_{BE} = 7.324$, $p = 0.031$), while the differences between BCH and TF and between RIV and TF hold significant at 5% until the 9th round inclusive ($\beta_{BCH} = 5.977$, $p = 0.048$; $\beta_{RIV} = 7.336$, $p = 0.041$). When the time span is higher than nine rounds, differences across treatments are all insignificant at 5%.

The lack of cross-frame differences in the last round is confirmed by the results of Kruskal–Wallis rank tests (at the session level, 5–6 independent observations per treatment): $\chi^2 = 0.495$, $p = 0.9199$ for choices, and $\chi^2 = 1.368$, $p = 0.7131$ for market prices. As shown in Table 5, the *post hoc* Dunn's multiple comparison tests indicate that we cannot reject the null hypothesis of equality between frames in any pairwise comparison at $q = 5\%$.

The distributions of choices also converge across treatments: all standard deviations have similar values. Kernel and focal point analysis confirm this result (see Figs. 5 and 6). The distributions become more similar and the lowest focal points are predominantly used in all frames. Notice that, in the evocative frame, the main differences between first- and last-round choice behaviour concern the reduction in noise.

Result 3. *At the end of the experiment, there are no significant differences across treatments regarding individual choices, market prices and distributions of choices. Choices are primarily concentrated on the lowest prominent numbers above 0: 10 and 20.*

Thus, our findings support for the Hypotheses 2a and 2b.

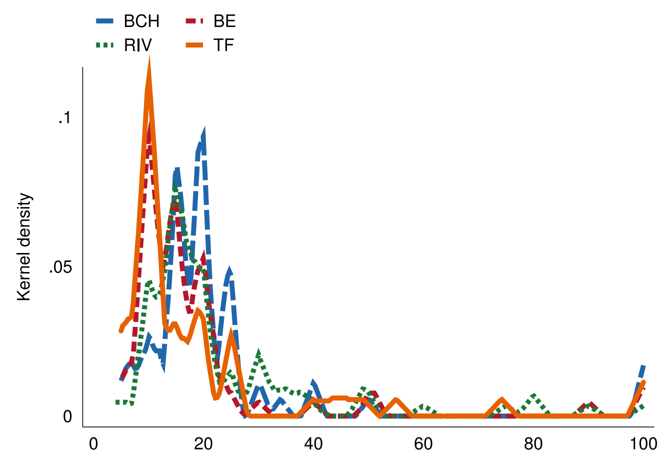

Fig. 5. Kernel distributions of choices by treatment at round 12.

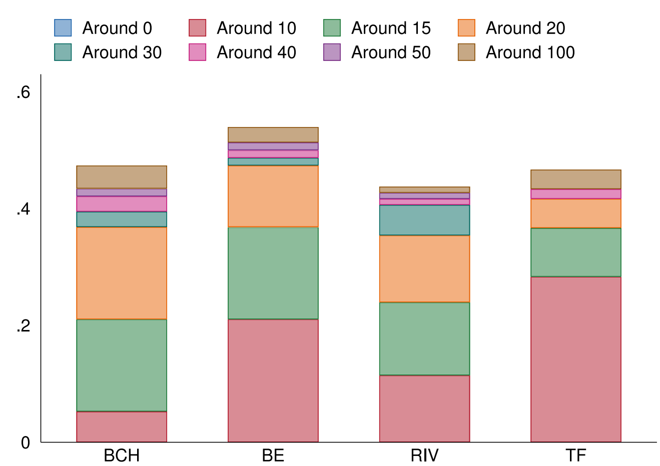

Fig. 6. Choices around some prominent numbers by treatment at round 12.

3.3. A behavioural model of dynamic framing effects

An interesting feature displayed in Fig. 1 deals with the different pace at which choice behaviour evolves in each treatment. In each round, players have to best respond to their beliefs about their current

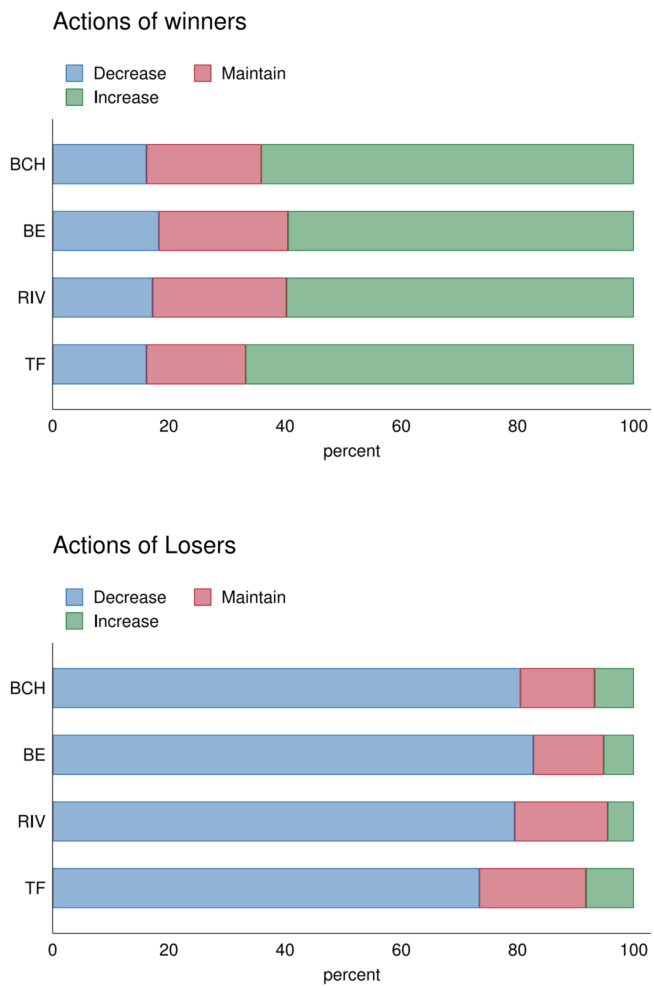

Fig. 7. Directional learning conditional on previous round results.

competitor's action. Given that strategies are complements, a player should consider that, while lower choices would be more likely to win the game for a given distribution of beliefs, higher numbers would lead to gain higher payoffs in case of winning. As we will show below, the relative impact of the two opposing forces on choice behaviour depends considerably on the game frame.

We start by analysing the individual immediate reactions to winning/losing experience. Fig. 7 illustrates how subjects change their choices after winning or losing in an earlier round.[16]

As expected, subjects react to their immediate experience in a similar way in all treatments: More than 60% of winners increase their choices, while nearly 80% of losers decrease their choices. In this regard, the previous round outcomes seem to affect current beliefs and, consequently, modify current choices in the direction predicted: choices are likely to decrease after losing and increase after winning, being individuals more sensitive to losses than to gains. This is consistent with the model of directional learning proposed by Selten and Buchta (1999). There seem to be not notable differences across treatments regarding the effects of immediate feedback.

To better understand the relationship between dynamics of choice and frame posited by Hypothesis 3, we propose two behavioural models. These models allow us to identify and measure the main drivers of behaviour in each treatment: history, immediate feedback and repetition of game. This approach is similar to that of Bruttel (2009).

Table 6 reports estimations for the change in individual choices ($\text{Choice}_t - \text{Choice}_{t-1}$) using panel data models with fixed effects and clustered at the session level when BE is taken as baseline. Two kinds of models are estimated. The first kind (*No Treat −1*) includes as regressors: (i) *Period*; (ii) *Past Market Prices*$_{t-2}$, the average market price across all previous markets in which the subject participated except for the last one; (iii) *Competitor*$_{t-1}$, the partner's choice whom the subject faced with in the previous round and, (iv) *Choice*$_{t-1}$ - *Competitor*$_{t-1}$, the difference between the own choice and the partner's choice in the previous round. Notice that this variable is positive if the subject chose a higher number than his/her opponent and, hence, lost the game. In the second kind of model (*No Treat −2*), we incorporate *Past Competitors*$_{t-2}$ instead of *Past Market Prices*$_{t-2}$ as a proxy of remembrances of historical interactions. Finally, to test differences across treatments in each kind of model, Table 6 also shows two models that include interaction terms between treatment dummies and explanatory variables (*Treat −1* and *Treat −2* in Table 6).[17]

Three main results are highlighted. First, *Period* is not significant when treatment interactions are included. Notice that neither of interaction coefficients between *Period* and treatment dummies is significant, which indicates the lack of differences across treatments. This result suggests that the decreasing trend observed in choice behaviour can be rather explained by the influence of the behavioural determinants included in our models. In this regard, the repetition of game would not be in itself a major driver of choice dynamics in a competition game.

Second, the previous round outcomes are relevant to explain the change in choices in all models, without significant differences across treatments except for the BE-BCH comparison. On the one hand, we find a significantly negative coefficient of *Choice*$_{t-1}$ - *Competitor*$_{t-1}$; roughly, for every point above (below) the partner's choice in the earlier round, a subject reduces (increase) his/her choice by about 0.8 points in the current round. On the other hand, the partner's previous choice *Competitor*$_{t-1}$ is also significant and negative: a competitor's high number reduces *the increase* in own choices. Notice that, although the coefficient of *Competitor*$_{t-1}$ is negative, its total effect on choice change has the expected positive sign in all models as this variable also appears in *Choice*$_{t-1}$-*Competitor*$_{t-1}$. This result is consistent with the strategic complementarity nature of the game, regardless of the frame. When treatment interactions are considered, the only significant differences at 5% are found between BE and BCH (see the coefficient of *BCH*Competitor*$_{t-1}$ in *Treat −2*). Therefore, our findings provide significant evidence of the importance of immediate feedback to shape choice behaviour in *all* frames: subjects do not only consider how far they were from their previous competitor's choice, but also the specific

[16] We just include winners and losers since ties rarely happen (see Table S3 in the Supplementary Material).

[17] Two kinds of models are thus estimated due to the high correlation between *Past Market Prices*$_{t-2}$ and *Past Competitors*$_{t-2}$ (about 0.64, significant at 1%). We use a Hausman specification test to distinguish between fixed and random effects in panel data models. In all our cases, the Hausman results indicate to reject the null hypothesis ($p < 0.001$ in the four models estimated in Table 6). Hence, we use fixed effects to appropriately model individual-level effects in our regressions. Likewise, we use the Hausman test to check for endogeneity of $\text{Choice}_{t-1} - \text{Competitor}_{t-1}$. As instrumental variable, we define a dummy to indicate whether the player won in the previous round or not. In all models, we cannot reject the null hypothesis of exogenous regressors ($p > 0.1$ in all cases). Lastly, we also checked for possible multicollinearity problems using the variance inflation factor (VIF) test. In the models without interaction terms, the VIF values were all below 2.4, much lower than the problematic value of 5 (mean VIF = 1.68 in *No Treat −1* and 1.71 in *No Treat −2*). In the models with interactions terms, we find some (structural) multicollinearity due to the correlation between the treatment interactions and the main effect terms (mean VIF = 14.77 in *Treat −1* and 15.86 in *Treat −2*).

Table 6
Behavioural factors and treatment interactions. Panel data estimations of choice variations (BE as base treatment).

VARIABLES	No Treat-1	Treat-1	No Treat-2	Treat-2
Period	−0.470***	−0.403	−0.291*	−0.295
	(0.143)	(0.443)	(0.140)	(0.340)
BCH*Period		−0.145		−0.119
		(0.517)		(0.435)
RIV*Period		−0.00737		−0.0248
		(0.485)		(0.393)
TF*Period		0.0693		0.241
		(0.510)		(0.436)
Past Market Prices$_{t-2}$	0.00540	−0.156***		
	(0.0848)	(0.0512)		
BCH*Past Market Prices$_{t-2}$		0.313**		
		(0.123)		
RIV*Past Market Prices$_{t-2}$		0.336***		
		(0.112)		
TF*Past Market Prices$_{t-2}$		−0.0899		
		(0.204)		
Past Competitors$_{t-2}$			0.167***	0.00246
			(0.0500)	(0.0849)
BCH*Past Competitors$_{t-2}$				0.212**
				(0.0946)
RIV*Past Competitors$_{t-2}$				0.189
				(0.115)
TF*Past Competitors$_{t-2}$				0.218
				(0.155)
Competitor$_{t-1}$	−0.558***	−0.449***	−0.582***	−0.444***
	(0.0488)	(0.0919)	(0.0516)	(0.0947)
BCH*Competitor$_{t-1}$		−0.197*		−0.215**
		(0.0978)		(0.101)
RIV*Competitor$_{t-1}$		−0.118		−0.152
		(0.125)		(0.127)
TF*Competitor$_{t-1}$		−0.125		−0.132
		(0.151)		(0.168)
Choice$_{t-1}$ - Competitor$_{t-1}$	−0.809***	−0.763***	−0.846***	−0.776***
	(0.0395)	(0.0683)	(0.0432)	(0.0870)
BCH*Choice$_{t-1}$ -Competitor$_{t-1}$		−0.149*		−0.162*
		(0.0766)		(0.0928)
RIV*Choice$_{t-1}$ -Competitor$_{t-1}$		−0.0148		−0.0398
		(0.0908)		(0.109)
TF*Choice$_{t-1}$ -Competitor$_{t-1}$		−0.0123		−0.0389
		(0.115)		(0.152)
Constant	16.39***	15.68***	10.42***	10.54***
	(2.458)	(2.416)	(1.984)	(1.769)
Observations	3,080	3,080	3,080	3,080
R^2	0.504	0.512	0.511	0.517
Number of subject	308	308	308	308

Dependent variable: *Choice$_t$-Choice$_{t-1}$*.
Robust standard errors in parentheses.
***p<0.01
**p<0.05
*p<0.1

value chosen by such a competitor. This is in line with the impulse balance theory (Ockenfels and Selten 2005).[18]

Third, we do find significant differences across frames regarding the history effects (measured by *Past Market Prices$_{t-2}$* and *Past Competitors$_{t-2}$*). In particular, regarding *Past Market Prices$_{t-2}$*, the *Treat −1* model shows significant differences between BE and BCH and between BE and RIV in the sense that the winning numbers impact more negatively on choice change in BE (see the significantly negative coefficient of *Past Market Prices$_{t-2}$* and the significantly positive coefficients of *BCH*Past Market Prices$_{t-2}$* and *RIV*Past Market Prices$_{t-2}$*). Regarding the effects of *Past Competitors$_{t-2}$* in *Treat −2*, estimations show that the impact of previous partners' choices is significantly higher in BCH than in BE as the coefficient of *BCH*Past Competitors$_{t-2}$* indicates. We do not find significant differences between BCH and RIV. Therefore, these results are consistent with the idea that in BE the most prominent force is the winning rule, while in the BCH and RIV treatments the strongest force seems to be the payoff dominance. Table S8 in the Supplementary Material, which shows estimations by treatment and model, confirms these findings. However, in the TF treatment both opposing forces (winning rule and payoff dominance) appear to be equally strong (see the coefficients of *Past Market Prices$_{t-2}$* and *Past Competitors$_{t-2}$* in the two last columns of Table S8).

All in all, our experiment helps to explain why choices hold on a relatively high level during longer time in BCH and RIV as compared to BE, and why choice dynamics are smoother in TF.[19]

[18] In the Supplementary Material, Figure S2, we use the first kind of models to predict individual reactions to immediate outcomes in three different rounds (3, 7 and 12) for each frame.

[19] We obtained the same results by treatment taking individual choice instead of choice variations as dependent variable (see Table S9 in the Supplementary Material). Also, we tested whether winners and losers differ in their choice behaviour. Table S10 presents estimations for choice variation when (*Choice$_{t-1}$* - *Competitor$_{t-1}$*) is divided into two separate explanatory

Result 4. *Immediate behavioural factors (previous round outcomes) significantly affect dynamics of choice, with no distinction across frames. However, the impact of history factors substantially depends on the game frame: (i) in BE, the history based on market prices has a significant negative impact on choices; (ii) in BCH and RIV, the history based on competitors' choices positively affects choices; (iii) in TF, the effects of the two opposing history factors are cancelled each other.*

Therefore, our experimental findings confirm Hypothesis 3.

4. Discussion

As far as we know, the present research is the first one studying how different contextual frames may determine initial choices and their adaptive dynamics in a Bertrand competition experiment. This paper has shown that, in competition experiments, frames can exert some initial effects on market prices and *subtle* (but disappearing) effects in the long run.

In our baseline BE frame, which is nearly identical to a standard Bertrand experiment, we have obtained that subjects behave slightly more competitive than usual: our average choices start at 42.1 and reach 18.8 in the 12th round while, for instance, Bruttel (2009) found average choices around 50 in the first round and close to 25 in the last 10th round (LOW10 treatment). We have not observed more than some anecdotal collusion attempts in any of our treatments but, as previously shown, some prominent numbers clearly attract choices.

Our design includes an abstract frame (BCH) to test whether decontextualised instructions may also trigger some mental interpretation in subjects' minds. After all, even abstract frames are frames, although abstract contexts have traditionally been viewed as a way to achieve experimental control. In a prisoner's dilemma, Engel and Rand (2014) find that a neutral description (i.e. in pure game-theoretical terms) makes subjects behave as cooperative as in a team frame of the game. In our case, in the beginning, the subjects facing the abstract frame behave similarly to those deciding in the two meaningful frames, BE and RIV. Moreover, although the winning rule hint introduced in the instructions of BCH could induce subjects to choose slightly lower numbers at the start (see Jiménez-Jiménez and Rodero-Cosano 2015), this treatment becomes indistinguishable from RIV over time. In line with Engel and Rand (2014) we have found that abstract frames can introduce *uncontrollable* references into subjects' perceptions of the economic problem they face.

The rhetoric-based approach we implement to analyse the framing effects has also allowed to identify a frame, the evocative one (TF), in which market outcomes are closer to the Nash prediction since the start of the session. In this frame, some participants seem to immediately recognise the incentive scheme of the game. The winning choices start at a level very close to the Nash prediction and are practically kept at this low level during the whole experiment. In this regard, our findings are consistent with the idea that the direct experience of experimental subjects with the decision task could facilitate the recognition problem of the strategic setting in one-shot games (see, for example, Chou et al. 2009 in Beauty Contest Games).

As an alternative explanation, the TF frame may have invoked some (moral) social norm related to the adequacy of money withdrawing from a common pool. Previous research has suggested a necessary reinterpretation of actual behaviour in dictator games (Bardsley 2008, List 2007), public goods games (Cox 2015), asset markets (Sonnemann et al. 2013, Weber et al. 2000) and bribery games (Banerjee 2016). Morally-loaded evocative frames can have a strong immediate impact on behaviour (Chang et al. 2019 or Ellingsen et al. 2012). In a seminal paper, Liberman et al. (2004) find that a cooperative frame has higher cooperation rates, both initially and on average, than an uncooperative one in a prisoner's dilemma. See Columbus et al. (2020) and Mieth et al. (2021) for recent works about the role of social norms in social dilemmas.

Furthermore, theories of contextual frames as inductors of social norms generally assume that the mechanism through which frames may influence behaviour is the formation of first-order or second-order beliefs (Dufwenberg et al. 2011, Ellingsen et al. 2012). The models presented in Section 3.3 provide strong support for that link in all frames. Our experimental findings suggest that, in price competition experiments, frames may act as social norms. This is also consistent with the Masiliunas and Nax (2020)'s results. Further research would be desirable as markets tend to be socially networked.

During the convergence process across frames, past history helps explain competitive behaviour. Taking the relevant past information as a reference point, a more aggressive competitive behaviour is observed when the reference point is the market price as compared to the competitor's bid. Notice that players' current bids are nearly always below past competitors' bids or past market prices, which indicate that subjects are bidding under the loss domain (where risk seeking is predicted).

However, after a relatively low number of repetitions, competitive behaviour eventually converges across frames although stays far from the equilibrium prediction. This is consistent with most framed economic experiments where, even when initial framing effects exist, the incentive structure hidden behind the curtain of narratives is unveiled with repetition. Consequently, this research has shown that the specific contextual frame is less relevant when the aim is to test an incentive effect on strategic behaviour, as long as subjects are provided with enough time to understand the game and react according to their preferences and beliefs. This may suggest that it is not reliable to trust on initial reactions due to the psychological misconceptions induced by the frame.

Finally, another methodological implication of our results is that non-abstract contexts may offer advantages when a game-recognition problem may be present or a more "naturalistic" decision context is pursued/intended. In Bertrand competition, an evocative language has affected competitive behaviour in a desirable way in the sense that it helps subjects recognise the game structure faster. In this regard, an evocative context can be a useful tool for experimental design (Alekseev et al. 2017). For example, a researcher who desires to analyse treatment conditions that affect the level of competition, may first introduce a highly competitive baseline by using an evocative frame in the game. This is the approach followed by recent literature in political science (see Brutger et al. 2022 and references therein), information disclosure (Montero and Sheth 2021) or (un)ethical behaviour (Wang and Chen 2021). In this sense, evocative contexts may help gain external validity and generalise lab experimental results to field settings.

5. Concluding remarks

One puzzling paradox in Industrial Organisation is the systematic deviations between Nash predictions and experimental (and empirical) evidence in price competition settings. Researchers face harsh work when attempting to rationalise the formation of out-of-equilibrium beliefs implied by strategic complementarity. Variations in incentive settings have led to differences in those expectations and, then, in the initial level of bid, the rate of decay and the final level of bid. Instead, this research has focused on the role of contextual frames in a Bertrand competition game.

Our study has allowed to identify a frame, the evocative one, which induces a quicker recognition of the competition environment and a subsequent cycling move around the initial level, which is held until the end (but never reaches equilibrium). A force balance based on immediate past experience permits to explain its dynamics over time.

---

variables depending on its positive or negative sign. Estimations show similar reactions between winners and losers.

On the contrary, the meaningful and neutral frames induce subjects to select initial higher bids, and their rates of decay can be mainly explained by the type of information participants use from the past markets: competitors' bids or market prices. When market prices are taken as the relevant information, as in BE, the decay in bids is quicker and sharp.

Lastly, in our experiment, the incentive structure eventually prevails and the initial framing effects fade away after some repetitions. Moreover, we have obtained that the impact of immediate experience on choice change is independent of frame and winner/loser position. This evidence could be interpreted as if there was an underlying implicit price floor (high enough to ensure positive payoffs) so that, once competition reaches such a price floor, the resulting force balance would impede further convergence towards the equilibrium. Indeed, at the end of our experiment neither of the frames promotes competitive behaviour enough to reach the equilibrium.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.socec.2023.101987.

References

Abbink, K., & Hennig-Schmidt, H. (2006). Neutral versus loaded instructions in a bribery experiment. *Experimental Economics*, *9*(2), 103–121. http://dx.doi.org/10.1007/s10683-006-5385-z.

Alekseev, A., Charness, G., & Gneezy, U. (2017). Experimental methods: when and why contextual instructions are important. *Journal of Economic Behaviour and Organization*, *134*, 48–59. http://dx.doi.org/10.1016/j.jebo.2016.12.005, URL: https://www.sciencedirect.com/science/article/pii/S0167268116302876.

Andreoni, J. (1995). Warm-glow versus cold-prickle: the effects of positive and negative framing on cooperation in experiments. *Quarterly Journal of Economics*, *110*(1), 1–21, URL: http://www.jstor.org/stable/2118508.

Banerjee, R. (2016). On the interpretation of bribery in a laboratory corruption game: moral frames and social norms. *Experimental Economics*, *19*, 240–267. http://dx.doi.org/10.1007/s10683-015-9436-1.

Bardsley, N. (2008). Dictator game giving: altruism or artefact? *Experimental Economics*, *11*(2), 122–133. http://dx.doi.org/10.1007/s10683-007-9172-2.

Barr, A., & Serra, D. (2009). The effects of externalities and framing on bribery in a petty corruption experiment. *Experimental Economics*, *12*(4), 488–503. http://dx.doi.org/10.1007/s10683-009-9225-9.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B. Statistical Methodology*, *57*(1), 289–300. http://dx.doi.org/10.1111/j.2517-6161.1995.tb02031.x, arXiv:https://rss.onlinelibrary.wiley.com/doi/pdf/10.1111/j.2517-6161.1995.tb02031.x. URL: https://rss.onlinelibrary.wiley.com/doi/abs/10.1111/j.2517-6161.1995.tb02031.x.

Brañas-Garza, P. (2007). Promoting helping behavior with framing in dictator games. *Journal of Economic Psychology*, *28*(4), 477–486. http://dx.doi.org/10.1016/j.joep.2006.10.001, URL: https://www.sciencedirect.com/science/article/pii/S0167487006000900.

Brandts, J., & Schwieren, C. (2007). Frames and games. In S. H. Oda (Ed.), *Developments on experimental economics: new approaches to solving real-world problems* (pp. 175–180). Berlin, Heidelberg: Springer Berlin Heidelberg, http://dx.doi.org/10.1007/978-3-540-68660-6_16.

Brutger, R., Kertzer, J. D., Renshon, J., Tingley, D., & Weiss, C. M. (2022). Abstraction and detail in experimental design. *American Journal of Political Science*, 1–16. http://dx.doi.org/10.1111/ajps.12710, arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1111/ajps.12710. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/ajps.12710.

Bruttel, L. V. (2009). Group dynamics in experimental studies–The Bertrand Paradox revisited. *Journal of Economic Behaviour and Organization*, *69*(1), 51–63. http://dx.doi.org/10.1016/j.jebo.2008.10.002.

Burnham, T., McCabe, K., & Smith, V. L. (2000). Friend-or-foe intentionality priming in an extensive form trust game. *Journal of Economic Behaviour and Organization*, *43*(1), 57–73. http://dx.doi.org/10.1016/S0167-2681(00)00108-6, URL: https://www.sciencedirect.com/science/article/pii/S0167268100001086.

Chang, D., Chen, R., & Krupka, E. (2019). Rhetoric matters: a social norms explanation for the anomaly of framing. *Games and Economic Behavior*, *116*, 158–178. http://dx.doi.org/10.1016/j.geb.2019.04.011, URL: https://www.sciencedirect.com/science/article/pii/S0899825619300673.

Chou, E., Margaret, M., Nagel, R., & Plott, C. R. (2009). The control of game form recognition in experiments: understanding dominant strategy failures in a simple two person "guessing" game. *Experimental Economics*, *12*(2), 159–179, URL: https://link.springer.com/article/10.1007/s10683-008-9206-4.

Columbus, S., Münich, J., & Gerpott, F. H. (2020). Playing a different game: situation perception mediates framing effects on cooperative behaviour. *Journal of Experimental Social Psychology*, *90*, Article 104006. http://dx.doi.org/10.1016/j.jesp.2020.104006, URL: https://www.sciencedirect.com/science/article/pii/S0022103120302857.

Cox, C. A. (2015). Decomposing the effects of negative framing in linear public goods games. *Economics Letters*, *126*, 63–65. http://dx.doi.org/10.1016/j.econlet.2014.11.015, URL: https://www.sciencedirect.com/science/article/pii/S0165176514004340.

Cox, C. A., & Stoddard, B. (2015). Framing and feedback in social dilemmas with partners and strangers. *Games*, *6*(4), 394–412. http://dx.doi.org/10.3390/g6040394, URL: https://www.mdpi.com/2073-4336/6/4/394.

Dijkstra, P. T. (2015). Price leadership and unequal market sharing: collusion in experimental markets. *International Journal of Industrial Organization*, *43*, 80–97. http://dx.doi.org/10.1016/j.ijindorg.2015.08.003, URL: https://www.sciencedirect.com/science/article/pii/S0167718715001010.

Dinno, A. (2014). Dunntest: Dunn's test of multiple comparisons using rank sums. Stata software package. URL: https://alexisdinno.com/stata/dunntest.html.

Druckman, J. N. (2001). Using credible advice to overcome framing effects. *The Journal of Law, Economics, and Organization*, *17*(1), 62–82. http://dx.doi.org/10.1093/jleo/17.1.62, arXiv:https://academic.oup.com/jleo/article-pdf/17/1/62/2537131/170062.pdf.

Dufwenberg, M., Gächter, S., & Hennig-Schmidt, H. (2011). The framing of games and the psychology of play. *Games and Economic Behavior*, *73*(2), 459–478. http://dx.doi.org/10.1016/j.geb.2011.02.003, URL: http://www.sciencedirect.com/science/article/pii/S0899825611000376.

Dufwenberg, M., & Gneezy, U. (2000). Price competition and market concentration: an experimental study. *International Journal of Industrial Organization*, *18*(1), 7–22. http://dx.doi.org/10.1016/S0167-7187(99)00031-4, URL: http://www.sciencedirect.com/science/article/B6V8P-3XXCYCV-1/2/57d028964dcce93705fd9934cf8b5f99.

Dufwenberg, M., Gneezy, U., Goeree, J., & Nagel, R. (2007). Price floors and competition. *Economic Theory*, *33*, 211–224. http://dx.doi.org/10.1016/S0167-7187(99)00031-4, URL: https://www.sciencedirect.com/science/article/pii/S0167718799000314.

Ellingsen, T., Johannesson, M., Mollerstrom, J., & Munkhammar, S. (2012). Social framing effects: preferences or beliefs? *Games and Economic Behavior*, *76*(1), 117–130. http://dx.doi.org/10.1016/j.geb.2012.05.007, URL: https://www.sciencedirect.com/science/article/pii/S0899825612000802.

Engel, C., & Rand, D. G. (2014). What does "clean" really mean? The implicit framing of decontextualized experiments. *Economics Letters*, *122*(3), 386–389. http://dx.doi.org/10.1016/j.econlet.2013.12.020, URL: https://www.sciencedirect.com/science/article/pii/S0165176513005594.

Fatas, E., Haruvy, E., & Morales, A. J. (2014). A psychological reexamination of the Bertrand Paradox. *Southern Economic Journal*, *80*(4), 948–967. http://dx.doi.org/10.4284/0038-4038-2012.264, URL: http://journal.southerneconomic.org/doi/abs/10.4284/0038-4038-2012.264.

Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178, URL: https://link.springer.com/article/10.1007/s10683-006-9159-4.

Gerlach, P., Jaeger, B., & Hertwig, R. (2017). Cooperation needs interpretation — A meta-analysis on context frames in social dilemma games. In *The social framework of individual decisions: 570 + 1 experiments in (Un)ethical behavior* (pp. 9–40). Humboldt-Universität zu Berlin, Doctoral dissertation.

Grosskopf, B., & Nagel, R. (2008). The two-person beauty contest. *Games and Economic Behavior*, *62*, 93–99. http://dx.doi.org/10.1016/j.geb.2007.03.004, URL: http://www.sciencedirect.com/science/article/B6WFW-4NHV71V-1/2/b20ce20840f79a2c5c3a68ae113b380c.

Huck, S., Normann, H., & Oechssler, J. (2000). Does information about competitors' actions increase or decrease competition in experimental oligopoly markets? *International Journal of Industrial Organization*, *18*(1), 39–57. http://dx.doi.org/10.1016/S0167-7187(99)00033-8, URL: http://www.sciencedirect.com/science/article/B6V8P-3XXCYCV-3/2/b839c7d5bc103f1bc7abac5b41d16487.

Jiménez-Jiménez, F., & Rodero-Cosano, J. (2015). The effect of priming in a Bertrand competition game: an experimental study. *Journal of Behavioral and Experimental Economics*, *58*, 94–100. http://dx.doi.org/10.1016/j.socec.2015.07.006, URL: https://www.sciencedirect.com/science/article/pii/S2214804315000968.

Kahneman, D., & Tversky, A. (2000). *Choices, values, and frames* (1st ed.). Cambridge University Press.

Kühberger, A. (1998). The influence of framing on risky decisions: a meta-analysis. *Organizational Behavior and Human Decision Processes*, *75*(1), 23–55. http://dx.doi.org/10.1006/obhd.1998.2781, URL: http://www.sciencedirect.com/science/article/pii/S0749597898927819.

Levin, I. P., Schneider, S. L., & Gaeth, G. J. (1998). All frames are not created equal: a typology and critical analysis of framing effects. *Organizational Behavior and Human Decision Processes*, *76*(2), 149–188. http://dx.doi.org/10.1006/obhd.1998.2804, URL: http://www.sciencedirect.com/science/article/B6WP2-45M2Y85-4/2/dd8cf0dd47293650634e7b9a9bc48712.

Liberman, V., Samuels, S. M., & Ross, L. (2004). The name of the game: predictive power of reputations versus situational labels in determining prisoner's dilemma game moves. *Personality and Social Psychology Bulletin*, *30*(9), 1175–1185. http://dx.doi.org/10.1177/0146167204264004, PMID: 15359020.

List, J. A. (2007). On the interpretation of giving in dictator games. *Journal of Political Economy*, *115*(3), 482–493, URL: http://www.jstor.org/stable/10.1086/519249.

Masiliunas, A., & Nax, H. H. (2020). Framing and repeated competition. *Games and Economic Behavior*, *124*, 604–619. http://dx.doi.org/10.1016/j.geb.2020.10.002, URL: https://www.sciencedirect.com/science/article/pii/S0899825620301433.

Mieth, L., Buchner, A., & Bell, R. (2021). Moral labels increase cooperation and costly punishment in a Prisoner's Dilemma game with punishment option. *Scientific Reports*, *11*(1), 10221. http://dx.doi.org/10.1038/s41598-021-89675-6.

Montero, M., & Sheth, J. D. (2021). Naivety about hidden information: an experimental investigation. *Journal of Economic Behaviour and Organization*, *192*, 92–116. http://dx.doi.org/10.1016/j.jebo.2021.09.032, URL: https://www.sciencedirect.com/science/article/pii/S0167268121004170.

Ockenfels, A., & Selten, R. (2005). Impulse balance equilibrium and feedback in first price auctions. *Games and Economic Behavior*, *51*(1), 155–170. http://dx.doi.org/10.1016/j.geb.2004.04.002, URL: https://www.sciencedirect.com/science/article/pii/S0899825604000703.

Schelling, T. (1960). *The strategy of conflict*. Harvard University Press.

Selten, R., & Buchta, J. (1999). Experimental sealed bid first price auctions with directly observed bid functions. In D. V. Budescu, I. Erev, & R. Zwick (Eds.), *Games and human behavior: essays in honor of amnon rapoport* (pp. 79–102). Lawrenz Associates.

Selten, R., & Chmura, T. (2008). Stationary concepts for experimental 2x2-games. *American Economic Review*, *98*(3), 938–966. http://dx.doi.org/10.1257/aer.98.3.938, URL: https://www.aeaweb.org/articles?id=10.1257/aer.98.3.938.

Sonnemann, U., Camerer, C. F., Fox, C. R., & Langer, T. (2013). How psychological framing affects economic market prices in the lab and field. *Proceedings of the National Academy of Sciences*, *110*(29), 11779–11784. http://dx.doi.org/10.1073/pnas.1206326110, URL: http://www.pnas.org/content/110/29/11779.

Stefan, M. (2016). On the impact of semantic framing in experimental asset markets. *Journal of Behavioral and Experimental Finance*, *9*, 81–87. http://dx.doi.org/10.1016/j.jbef.2015.11.006, URL: https://www.sciencedirect.com/science/article/pii/S2214635016000137.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, *211*(4481), 453–458. http://dx.doi.org/10.1126/science.7455683, URL: http://www.sciencemag.org/cgi/content/abstract/211/4481/453.

Wang, S., & Chen, T. (2021). When and why contexts predict unethical behavior: evidence from a laboratory bribery game. *Frontiers in Psychology*, *12*, http://dx.doi.org/10.3389/fpsyg.2021.675319, URL: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.675319.

Weber, M., Keppe, H.-J., & Meyer-Delius, G. (2000). The impact of endowment framing on market price - an experimental analysis. *Journal of Economic Behaviour and Organization*, *41*(2), 159–176. http://dx.doi.org/10.1016/S0167-2681(99)00092-X, URL: http://www.sciencedirect.com/science/article/pii/S016726819900092X.