The dominance of reputation in continuous time: Experimental insights from a market entry game

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Abstract

I construct a continuous-time market entry game to experimentally investigate whether continuous-time interaction increases the incumbent's reputation compared to discrete-time interaction. In the model, entrants can build capacity up to a certain threshold in order to enter the market, while the incumbent can deter entry to influence the entrant's decision. In continuous time, players can adjust their actions at any moment, whereas in discrete time, actions are limited to a few simultaneous moves. In the experiment, both games are repeated five times in a row with a fixed incumbent and changing entrants. Through the transmission of distinct information among subsequent entrants, the incumbent is able to build reputation throughout the game. In continuous time, the incumbent achieves a significantly higher reputation. Moreover, when considering reputation in a round-based view, it becomes evident that reputation reaches a high level already in the first round, whereas in discrete time, it takes about three rounds to develop. These insights can be attributed to enhanced information transfer in continuous time. Through frequent and endogenous action changes, the incumbent is able to send more and clearer entry-deterring signals.

JEL-Codes: C72, C91, L10

Keywords: continuous-time game, reputation building, market entry, Chain Store Game, entry deterrence, laboratory experiment

1. Introduction

The emergence of the internet has fundamentally changed the possibilities of building reputation. Strategic interactions like the adjustments of prices between firms or individuals can be easily exchanged. Price wars and thus reputation formation is developed faster, as price changes are easy, quick and reversible (Rao et al., 2000). An illustrative example is the dynamic pricing used by companies, particularly in the context of online products. In this setting, prices quickly adjust to price changes of competitors (Hwang & Kim, 2006, p. 145). Established e-commerce incumbents, such as the globally operating online retailer Amazon, use dynamic price adjustments to their advantage by frequently altering their prices. The aim of Amazon is to hinder the market entry of potential entrants through continuous price undercutting (L. Chen et al., 2016).

The base of this research is the observation that also during market entries reputation building has a real-time aspect. In manufacturing industries, market entries take several years through building the necessary capacity (e.g. Cooke, 2020). During that time, interactions can evolve already during capacity building and the order of interaction is not exogenously prescribed. Observations from market entries reveal that incumbents can apply certain entry-deterring mechanisms to prevent potential or ongoing market entries. Examples of such mechanisms include advertising expenditures to build consumer loyalty (Bunch & Smiley, 1992), limit pricing to make competition unprofitable for potential entrants (Kadiyali, 1996), or filling available product niches (Smiley, 1988). During market entry, multiple of those deterring signals by the incumbent and adaptations by the entrant are transferred—a classical example of strategic interactions in continuous time.

Game-theoretical models of deterrence mechanisms in market entry have traditionally been formulated in discrete time, using either simultaneous moves (Salop, 1979; Trockel, 1986) or sequential moves (Kreps & Wilson, 1982a; Milgrom & Roberts, 1982; Neven, 1989; Selten, 1978), where the entrant acts as the first mover. Consequently, the deterring mechanism for one market entry was either executed as a reaction to a market entry or in parallel with the entrant's decision, limiting the incumbent to one specific order of moves and to one single move per game. Empirical investigations used this rigid type of modelling reputation effects, conducting the market entry game for multiple rounds with one incumbent and different entrants.

Yet, those games completely disregard the interaction dynamics within rounds as only one signal by the incumbent after each market entry can be transferred. Traditional discrete-time models fail to account for the real-time dynamics of capacity building and reputation formation that unfold within entry. This violation appears to be a massive suppression when modelling reputation effects of the incumbent. Based on this observation, there is a pressing need to adopt a continuous-time framework that more accurately reflects the strategic interactions and reputation mechanisms at play during market entries.

In this paper, I concentrate on the influence of continuous-time interaction on the incumbent's reputation compared to interaction in discrete time. Experiments of the original Chain Store Game (CSG)[1] and its variations to model the extent of reputation were all conducted in discrete time (Duman, 2020; Jung et al., 1994; Sundali & Rapoport, 1997; Sundali et al., 2000). Results reveal that the incumbent did execute deterring signals with the intention to prevent market entries. However, there were still high market entry rates throughout the game observed, demonstrating the ineffectiveness of reputation building. As the interactions in reality occur in continuous time rather than in discrete time, the timing mechanism could play a decisive role in reputation effects. The previously modeled discrete-time, round-based market entry games could therefore underestimate the impact of reputation.

My primary focus is to test in a structured laboratory experiment if reputation in continuous time is on a higher level than in discrete time. Additionally, I want to find out the differences in reputation evolvement throughout the rounds and precisely look at the reputation-building and end-game effects.

To this end, I developed an empirically testable, two-player ('Entrant' and 'Incumbent'), continuous-time market entry game that is based on literature. In this game, the Entrant must build a certain capacity in order to enter the market. Building capacity takes time, during which the Incumbent can choose to deter or accommodate the Entrant's investment. Alongside the continuous-time game, an analog discrete-time game was conducted, featuring exogenously-determined, simultaneous action choices with a grid time of 60 seconds. To isolate the treatment effect and only measure the impact of reputation, two one-round baseline games—one in continuous time and one in discrete time—without the ability of reputation building were conducted.

I found a positive and significant effect, indicating that the overall level of reputation is higher in continuous time compared to discrete time. When comparing the in-round reputation levels, it becomes clear that the difference in the reputation levels does not remain constant throughout the rounds. In continuous time, reputation remains relatively stable with only minor fluctuations, whereas in discrete time, reputation building requires time to unfold its effect. In addition, while reputation descriptively declined towards the end, this trend could not be statistically confirmed.

My paper is based on two main fields in literature: (i) Literature on destructive market entry games and (ii) literature on interaction in continuous time.

The literature of destructive market entry games[2] empirically analyze the effect of reputa-

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[1] An explanation of the CSG is provided below.

[2] Market entry games can be distinguished based on conflict behavior: the destructive, bilateral interaction between one Entrant and one Incumbent and the constructive conflict behavior of N different Entrants. The latter represents a *Greenfield Investment*, i.e., a market in which no (dominant) company operates yet and that must be created by new market-entering companies. Many researchers drew on the adaptive learning model of Roth & Erev (1995) and extended it to the situation of market entry by multiple Entrants (Duffy & Hopkins, 2005; Erev & Rapoport, 1998; Rapoport et al., 1998, 2000; Sundali et al.,

tion building[3] through entry deterrence. One of the most prominent market entry models and inspiration of the continuous-time market entry game is the CSG from Selten (1978). The CSG is a two-player extensive form game with an Entrant, who has the decision to enter the market, and an Incumbent who can either play cooperatively or aggressively as soon as the Entrant enters. Figure 1 shows the one-stage game, which is played consecutively for 20 rounds, with the same Incumbent facing 20 different potential Entrants. All Entrants observe the interaction between prior Entrants and the Incumbent to better assess the behavior of the Incumbent. By backward induction of the one-stage game, it becomes clear that the threat to play aggressively is not credible because as soon as the Entrant enters the market the Incumbent will play cooperatively for a higher payoff. However, if the game is played multiple times, the Incumbent can adopt an aggressive behavior in the early rounds with the objective to build up a reputation for toughness and prevent later Entrants from entering the market of the Incumbent. The so-called *deterrence theory* allows the Incumbent to have much higher profits in the long term than always playing cooperatively.

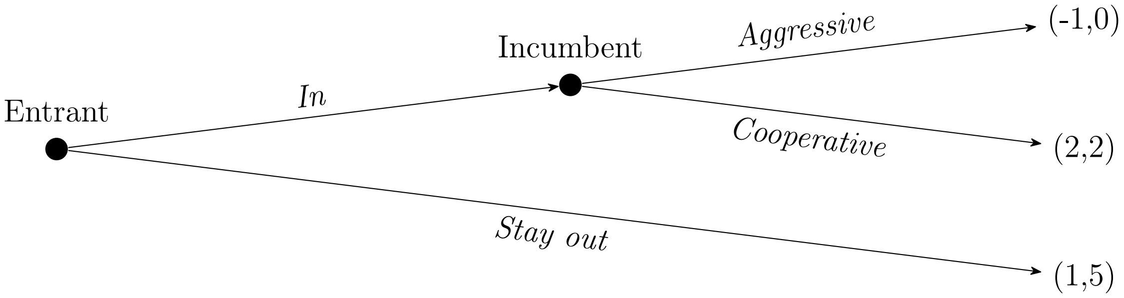

Figure 1. The One-Stage Chain Store Game from Selten (1978).

Based on the CSG, empirical investigations that test the evidence of the deterrence theory were conducted by Jung et al. (1994), Sundali & Rapoport (1997), and Rapoport et al. (2000) for the original CSG; Camerer & Weigelt (1988), Neral & Ochs (1992), and Jung et al. (1994) with incomplete information[4]; and Duman (2020) with imperfect information[5].

1995).

[3] Robert (1985) provides a well-known definition of reputation. He describes reputation as a characteristic or attribute that is ascribed to one person (or firm, industry, etc.) by another (e.g., an Incumbent has a reputation for deterring market entry). However, this characterization is typically based on empirical evidence (e.g. the Incumbent has been observed in the past to deter the market entry of new Entrants) which is then used to predict future behavior (e.g. the Incumbent is expected to continue deterring market entry in the future).

[4] In the original CSG, the Entrant has complete information about the Incumbent's cost structure. Kreps & Wilson (1982b) and Milgrom & Roberts (1982) relax this assumption by introducing incomplete information into the model. In their modification, the CSG distinguishes between two types of Incumbents with different payoffs, based on a fixed probability $p \in [0, 1]$. With probability p, the Entrant faces a strong Incumbent, whose dominant strategy is to fight the Entrant. Conversely, with probability $1 - p$, the Entrant encounters a weak Incumbent, whose subgame perfect strategy is to tolerate the Entrant. In experiments, weak Incumbents try to mimic strong Incumbents to deter entries (Jung et al., 1994).

[5] In the modification of Trockel (1986), the game structure is preserved by first transforming the CSG into its normal form and then back into an extensive form with the order reversed. In this model, the Incumbent acts as the first mover and the Entrant as the second mover, with the Entrant being unable to observe the Incumbent's action.

Particularly relevant to my paper is the observation that (i) all experiments were conducted in discrete time and (ii) despite the presence of entry deterrence, market entry remains high, and additional mechanisms like frequent repetitions of the game (more than 30 in Jung et al., 1994), more rounds within the game (Sundali et al., 2000) or incomplete information (Jung et al., 1994) are necessary to enhance reputation. Sundali & Rapoport (1997) highlight the relative failure of the Incumbent to deter most Entrants and discuss adaptions in the experimental design to increase reputation. This research assumes that incorporating continuous time into models of real-world interactions leads to an increase in reputation, even without the aforementioned mechanisms.

Furthermore, this paper contributes to the literature on games in continuous time. Unlike time-discrete games, which are divided into discrete periods with repeated interactions, in continuous time, the game moves in real time, allowing players to adjust actions endogenously at any moment during the game. While theoretical work began quite early (Bergin & MacLeod, 1993; Simon & Stinchcombe, 1989), experimental investigations remain relatively recent due to the high demands imposed by information technology (continuous communication with the server and updating flow payoffs in real time). Experimental investigations mainly focused on cooperation behavior in continuous time compared to discrete time. In continuous-time settings, cooperation levels were higher in prisoner's dilemma games (Friedman & Oprea, 2012)—especially with deterministic horizon (Bigoni et al., 2015), in long-horizon Cournot games (Friedman et al., 2015)[6], in public good games, especially when a rich communication protocol was added (Oprea et al., 2014) and in minimum-effort games when information on the effort level chosen by each group member was provided (Leng et al., 2018). However, Zhao (2020) conducted a battle of sexes game in continuous time, which resulted in worse outcomes compared to discrete time due to the complex equilibrium path requiring alternation between Nash equilibria. Consequently, there is no general validity to the claim that continuous time inherently increases cooperation, and it depends on the specific game whether continuous time is favorable (Zhao, 2021).

The enumerated experiments have in common to be viewed by subjects not as a competitive situation, but as a mutual problem with potential benefits for both conflicting parties. In contrast, the destructive continuous time market entry game is not about mutual cooperation but rather about individual deterrence of the Entrant. A coordination cannot take place due to the lack of alignment in common goals. To the best of my knowledge, no research has previously conceptualized and empirically investigated a destructive market entry game with continuous-time interaction. The research in this field is still unknown and my paper aims to close this research gap.

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[6] The experiment by Friedman et al. (2015) consists of 1,200 rounds, each lasting 4 seconds. The authors note that it is not only continuous time which fosters collusion but also about the frequency of feedback on decisions, i.e., the number of rounds.

This study provides the following contributions and implications. First, the research underlines the importance of designing experiments that closely mirror real-world conditions. By modeling a market entry game in continuous time, a more realistic representation of market entry dynamics evolves. Second, by comparing data from continuous time and discrete time, the study emphasizes the importance of considering time as a critical factor in reputation building. Reputation levels are higher and more stable in continuous-time settings, revealing that reputation building is more effective than previously assumed. Third, the results offer new insights into how immediate responses of companies affects strategic behavior and outcomes when entering or defending markets. Rapid deterrence on actions of Entrants provide a fast and easily interpretable signal.

The remainder of the paper is structured as follows: In Section 2, I introduce and analyze the continuous-time market entry game. In Section 3, I describe the experimental design, derive the hypotheses, and explain how I measure reputation and test my hypotheses. The results are presented in Section 4, and they are discussed in Section 5. Section 6 concludes the paper. The appendices contain instructions for the subjects and supplementary data analysis.

2. The Continuous Market Entry Game

In the market entry game, two players interact with each other: An incumbent, representing a monopoly and an entrant, representing a prospective competitor. The entrant is a company that is not yet established in the market but can make investments to enter the incumbent's market. The set of player indices is given by $j = \{Entrant, Incumbent\}$. The total duration of the market entry game is $d_{12} = 300$ seconds and it consists of two consecutive phases. Phase 1 is the main phase with continuous-time interaction, whereas Phase 2 represents a static state without interaction possibilities. In Phase 1, both players j have two pure actions S^j each, resulting in the action sets:

$$S^{Entrant} = \{s_1^{Entrant} = 1 \text{ (Invest)}, s_2^{Entrant} = 0 \text{ (Not Invest)}\}$$

for the Entrant and

$$S^{Incumbent} = \{s_1^{Incumbent} = 1 \text{ (Tolerate Investment)}, s_2^{Incumbent} = 0 \text{ (Fight Investment)}\}$$

for the Incumbent. In summary, the possible actions for each player j are:

$$S^j = (s_1^j, s_2^j).$$

The action space S for both players, i.e., the set of all possible action combinations, is the Cartesian product of the action sets of both players. By combining the action sets of both players, four different action combinations can be derived:

$$S = S^{Entrant} \times S^{Incumbent}$$

The payoff for Player j in Phase 1, given time t in a specific action combination s, is defined as:

$$u^j_{1,t}(s) = u^j_{1,t}(s^{Entrant}_t, s^{Incumbent}_t) \text{ with } s^{Entrant}_t \in S^{Entrant}_t \text{ and } s^{Incumbent}_t \in S^{Incumbent}_t.$$

In Table 1, the payoff matrix of Phase 1 is displayed. The numbers represent the payoff for t = 1 second, i.e. $u^j_{1,1}(s)$.

Table 1. Phase 1 of the Market Entry Game (Payoff for t = 1 second).

	Incumbent	
Entrant	Tolerate Investment	Fight Investment
Invest	-5 , 3	-9 , 1
Not Invest	0 , 3	0 , 2

Before the start of Phase 1, both players must choose an action $s^{Entrant} \in S^{Entrant}$ and $s^{Incumbent} \in S^{Incumbent}$ with which they wish to begin Phase 1. The duration of Phase 1 is a maximum of $d_1 = 180$ seconds. During phase 1, both players can adjust their actions at any time and as often as desired. The Incumbent can either tolerate the investment or try to deter the Entrant from entering the market by fighting the investment. In doing so, not only does the payoff of the Entrant shrink, but the Incumbent also suffers from fighting the investment. The Entrant has the opportunity to build the capacity required to enter the Incumbent's market. This is realized by requiring the Entrant to choose the action *Invest* for a total of 60 seconds within phase 1, i.e. interruptions in capacity building are possible. If the Entrant enters the market, Phase 1 ends prematurely, which consequently lengthens the time in Phase 2.

Phase 2 is determined from Phase 1 without interaction possibilities between the Entrant and the Incumbent and represents a static state with two possible cases: A complete capacity building by the Entrant, resulting in market share with the Incumbent (length of $d_2 \geq 120$) or an incomplete capacity building by the Entrant, resulting not to enter the market, in which the Incumbent maintains a monopoly position (length of $d_2 = 120$). The payoff for Player j in Phase 2 per second is dependent on the completeness of the capacity investment m^e with

$$m^e = \begin{cases} 1 & \text{if Capacity building complete} \\ 0 & \text{if Capacity building incomplete} \end{cases}$$

and defined as $u^j_{2,t}(m^e)$. The payoffs for t=1 second, i.e. $u^j_{2,1}(m^e)$ are displayed in Table

2. The length of Phase 2 equals the length of the whole game subtracted by the length of Phase 1, i.e. $d_2 = d_{12} - d_1$.

Table 2. Phase 2 of the Market Entry Game (Payoff for t = 1 second) .

Capacity building complete	**Capacity building incomplete**
2 , 2	0 , 3

To provide a better understanding of the payoff composition of both phases, Table 3 shows four exemplary total payoffs. These payoffs are realized if the initial action choices of both players are not changed during Phase 1, resulting in four pure strategies.

The payoff matrix shows strong similarities with the CSG from Selten (1978). From a game-theoretical perspective, the Entrant would likely invest if the Incumbent tolerates, gaining a payoff of 180. As the Incumbent has a dominant strategy of *Always Tolerate*, the strategy combination (*Always Invest*, *Always Tolerate*)[7] represents a Nash equilibrium. From a behavioral standpoint, the incentive to fight the Entrant arises from a higher payoff if the Entrant never invests (900 and 720 compared to 660 and 540). Hence, the Incumbent is incentivized to fight the investment in a repeated game analog to the CSG.

Table 3. Total Payoffs of the Market Entry Game when the Strategies Remain Unchanged.

	Incumbent	
Entrant	Always Tolerate	Always Fight
Always Invest	180 , 660	-60 , 540
Never Invest	0 , 900	0 , 720

In the following, an analysis of the continuous-time market entry game is conducted to enhance the understanding of the possible and desired game outcomes from the players' perspectives. Generally, in a one-shot game, when a specific action combination s is played, a payoff combination $\pi(s)$ results. The set of all possible payoff combinations is defined as the payoff space $P = \{\pi(s)|s \in S\}$. While the calculation of the payoff space P in a single-repetition Prisoner's Dilemma with pure strategies results in just four points (see e.g. Crandall & Goodrich, 2005), determining the payoff space in a continuous-time market entry game is far more complex due to the infinite number of decision points of action choices.

A simplification, as proposed by Bergin & MacLeod (1993), involves transforming continuous-time games into a finite sequence of decision points, effectively modeling the game

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[7] In the following, the payoff combination (*Always Invest, Always Tolerate*) for the Entrant is explained: In Phase 1, the Entrant plays the action *Invest* and the Incumbent plays the action *Investment Tolerate*. Since the Entrant builds up the capacity directly after one minute, the length of phase 1 is one minute and the payoff in Phase 1 is $-5 * 60s = -300$. The length of Phase 2 is determined by the length of Phase 1 and is 240 seconds. The Entrant therefore receives a payoff of $240s * 2 = 480$ in phase 2. The total payoff for the Entrant thus results in $-300 + 480 = 180$.

on a discrete-time grid. Thereby, a *strategy* corresponds to a sequence of multiple action choices chosen throughout phase 1, where an action refers to a player's choice at a specific point in time. As the time grid becomes finer, i.e., with increasing continuity, the number of available actions rises, causing the set of all possible strategy combinations to grow exponentially.

For example, assuming a decision frequency of one second, where each player can change their action at most once per second, the number of possible strategy combinations grows to $4^{180} = 2.35 \times 10^{108}$, making it highly challenging to solve efficiently using polynomial-time algorithms. To overcome this, a method for determining the payoff space involves identifying boundary points, where one player's action remains fixed while the other player's action varies. This gives a selection of the most reasonable boundary points. While the payoff for player j in round 1, given a specific action combination s for t seconds was defined as $u^j_{1,t}(s)$, the overall payoff (from phase 1 and phase 2) for player j is defined as π_j.

Figure 2 shows the approximated payoff space of the continuous-time market entry game with the following boundary points:

- *Always Invest*: The Entrant chooses the action *Invest* from the beginning and the Incumbent varies his action. When the duration of the action *Tolerate* increases, both payoffs increase equally until the strategy combination (*Always Invest, Always Tolerate*) is reached with a payoff of *(180, 660)*.
- *Never Invest*: If the Entrant sticks to his strategy of always playing the action *Not Invest* throughout Phase 1, the payoffs correspond to the red vertical line. The Entrant's payoff remains 0, while the Incumbent can increase his payoff by progressively increase the action *Tolerate*.
- *Always Tolerate*: Due to the tipping point of an (in)complete investment (see Table 2), a discontinuity exists. The diagonal line occurs when the Entrant completes capacity building but interrupts it temporarily or starts it later. Market entry occurs later, allowing the Incumbent to spend more time in a monopoly position in Phase 1 (resulting in higher payoff), while the Entrant has a shorter period of market sharing in Phase 2 (resulting in lower payoff). The horizontal green line corresponds to maintaining the Incumbent's monopoly position, where the Entrant does not begin capacity building (payoff of 0) until nearly complete capacity building (payoff asymptotically approaches -300).
- *Always Fight*: The lower horizontal line represents complete investment, varying based on how long the Entrant took to build capacity. The diagonal line represents incomplete capacity building, ranging from maximum sunk cost (payoff asymptotically approaches -560 for the Entrant) to no investment started (payoff of 0).
- *Maximum Sunk Costs*: Finally, the purple line depicts the scenario where the Entrant builds maximum sunk costs and the Incumbent varies his strategy. The horizontal purple line represents the situation where the Entrant builds up capacity

under the action *Fight Investment* and the Incumbent varies the duration of *Tolerate Investment* when the Entrant does not build up capacity. The diagonal line shows the varying proportion of *Tolerate Investment* when the Entrant is building up capacity.

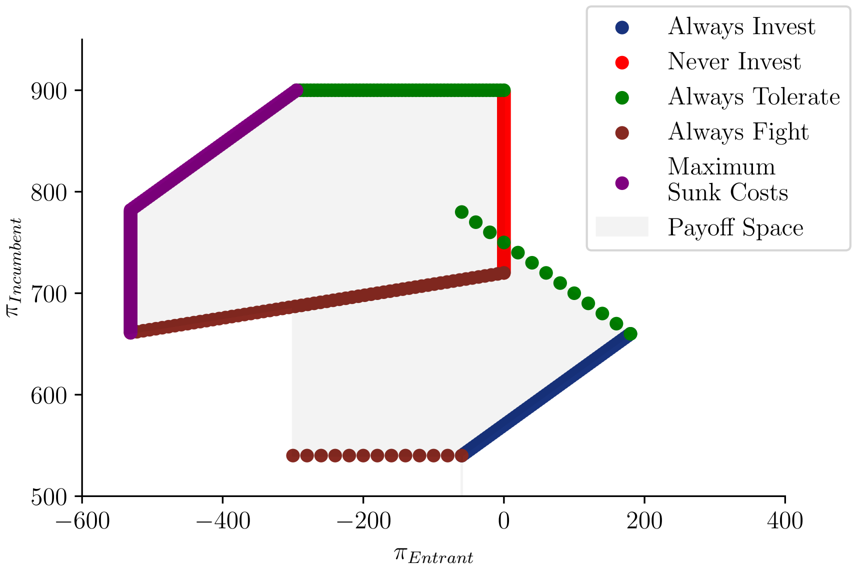


Figure 2. Determination of the Payoff Space of the Continuous-time Market Entry Game.

From the set of all boundary points, a boundary is created, and thus the overall payoff space in the market entry game can be defined. For the market entry game, it holds that $\#P = \infty$, thereby making any type of discretization a proper subset of the payoff space of the continuous-time market entry game.

The objective of this work is to compare the reputation effect in the continuous-time market entry game with an analogous discrete-time game. In discrete time, the order of moves is exogenously determined. Both players make simultaneous action choices. The discretization interval is equivalent to 60 seconds of the continuous-time game. Due to the 60 seconds discretization, the Entrant can enter the market in Phase 1 in just one move and a maximum of three moves is possible. The visualisation of the resulting payoff space of the discrete-time game compared to the continuous-time game is displayed in Figure 3.

The corresponding Python code to generate the payoff space in discrete time and approximate the payoff space in continuous time is displayed in the appendix in Section A.1. The Pareto set for both games can be derived directly from the payoff space. For the continuous-time market entry game, the Pareto set is defined as $\{(0, 750)+t\cdot(180, -90)|t \in [0, 1], (0, 900)\}$ and in discrete time it is $\{(180, 660), (60, 720), (0, 900)\}$.

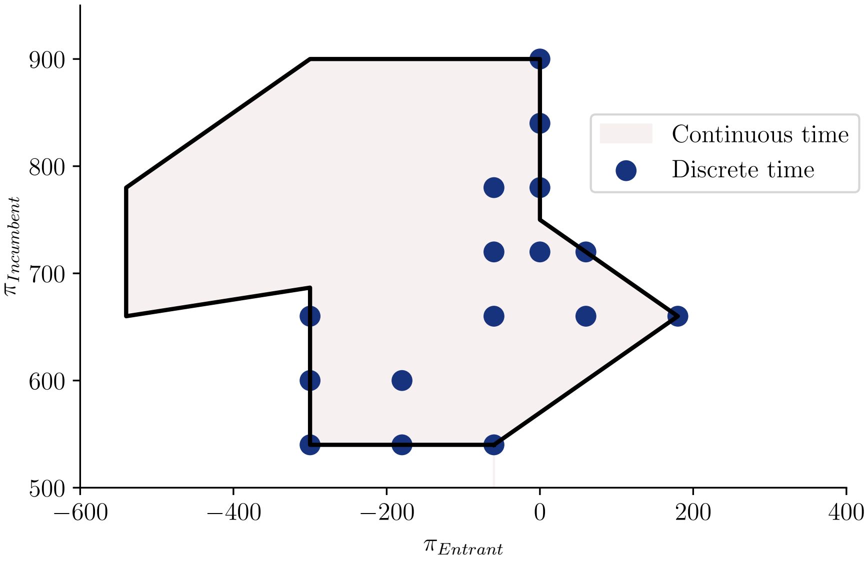


Figure 3. Payoff Space of the Continuous- and Discrete-time Market Entry Game.

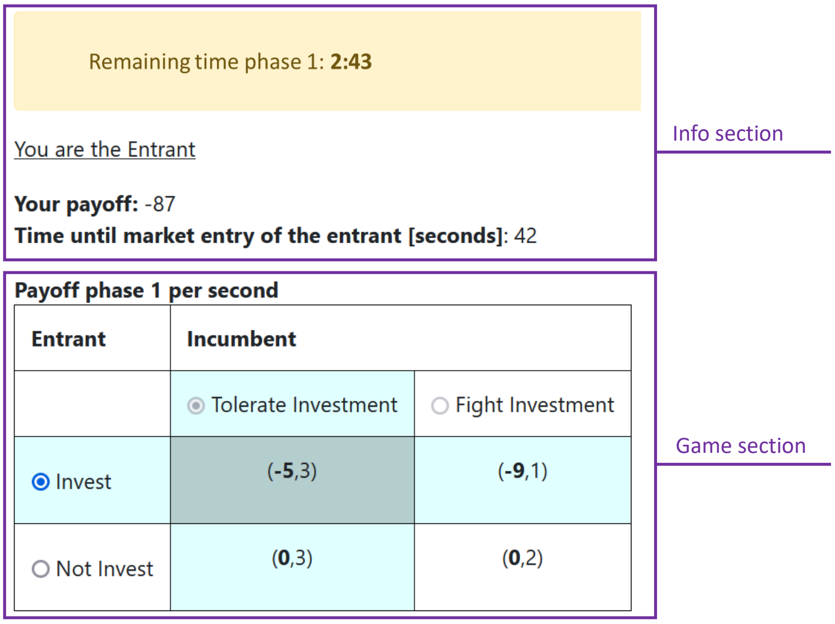
3. Experimental Design and Hypotheses

In the following subsections, I first describe the experimental setup of the continuous-time market entry game. Next, I provide details about the experimental design, including the treatments, matchings, sessions, history table, participants, as well as the payment structure. Finally, I outline the hypotheses and explain the empirical strategy used to test them.

3.1 User Interface

The laboratory experiment was implemented with the web-based platform oTree (D. L. Chen et al., 2016) as necessary features of the market entry game could be implemented. In particular, the continuous client-server architecture with the oTree *Live pages* module, the data storage with timestamps, and the reputation-induced experimental design were effectively utilized.

Figure 4 shows the user interface of the continuous-time treatment for the Entrant, which is separated into two sections. The top of the screen represents the info section, which displays relevant game data, i.e., the remaining time in Phase 1, the accumulated flow payoff as well as the time until market entry. The game section, where the interaction between the players takes place, is located below the info section. The quickly recognizable color coding is inspired by Friedman & Oprea (2012), where the current action is light-shaded in turquoise and the action combination is doubly shaded in dark turquoise. The possibility of continuous action changes is ensured by radio buttons to prevent multiple selections of actions. To ensure that endogenous turn sequences are implemented without delay, attention to a technically smooth and fluid game interface has been given. Action changes are transmitted to the server in real time and visualized immediately for the counterpart on the screen.


Remaining time phase 1: **2:43**

You are the Entrant

Your payoff: -87
Time until market entry of the entrant [seconds]: 42

Payoff phase 1 per second

Entrant	**Incumbent**	
	● Tolerate Investment	○ Fight Investment
● Invest	(**-5**,3)	(**-9**,1)
○ Not Invest	(**0**,3)	(**0**,2)

Figure 4. Screenshot of the continuous-time market entry game (Entrant's Perspective).

The discrete-time game was designed directly on the continuous-time game, with an analog info and game section. Although the game mechanism is different, only mandatory processes and game data[8] are adjusted to minimize unintended behavioral changes. In the discrete-time game, the action decision is made individually and independently of each other. For the announcement of the game result, a message box is displayed showing the player's action, the opponent's action and the resulting payoff. An example of the user interface of the time discrete game is displayed in the appendix in Figure A1.

3.2 Treatments

The two outlined games serve as corresponding treatments in the experiment, namely the continuous market entry game with reputation (**C-Rep**) and the discrete market entry game with reputation (**D-Rep**). Additionally, two further baseline treatments are necessary, namely the continuous market entry game without reputation (**C-NoRep**) and the discrete market entry game without reputation (**D-NoRep**).

3.3 Matchings and Sessions

Whereas the treatment blocks with and without reputation are realized in a between-subject design, the continuous and discrete treatments within each block are conducted

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[8] In the info field, the counter for the remaining time for Phase 1 is replaced by three game rounds. In addition, the message "Time until market entry of the Entrant" is replaced by "Investments until market entry". The payoff matrix is changed from "per second" to "per 60 seconds". As a result, all payoff entries in discrete time are multiplied by 60, so that players know that an action choice has the corresponding multiplier to the continuous-time game.

with a within-subject design. The reason to separate C-Rep and D-Rep from C-NoRep and D-NoRep are potential interaction effects caused by the treatments with reputation.[9] The order of treatments with reputation as well as without reputation are determined using a counterbalanced measures design. In each session, each of which includes 20 participants, individuals are assigned to two groups of ten participants each. One group first plays treatment C-Rep, followed by D-Rep, while the other group starts with treatment D-Rep and then plays treatment C-Rep. This arrangement ensures that the two possible treatment sequences are played with the same frequency.

C-Rep and D-Rep are played five times in a row, keeping the Incumbent fixed and changing the Entrants per round, i.e., an Incumbent interacts with five different Entrants in sequential order, resulting in a perfect stranger matching. With five rounds per game and the use of a perfect stranger matching, a number of ten participants per session, namely five Entrants and five Incumbents is required. The two baseline treatments C-NoRep and D-NoRep are played for one round and through stranger matching for both players, reputation building is inhibited. The purpose of the baseline treatments is to isolate the inherent effects of continuous and discrete time, i.e., to filter out baseline effects and only measure the relative differences attributable to reputation effects. Overall, 20 sessions were conducted, split into ten sessions for treatments without and ten sessions for treatments with reputation building. This results in observations from 100 subjects for each treatment. The sessions with C-NoRep and D-NoRep were conducted in December 2022[10] and the sessions with C-Rep and D-Rep were conducted in October 2023.

3.4 History Table

To enable reputation building of the Incumbent, information transfer between rounds is mandatory. The Entrant receives before and during the interaction relevant game data of past Entrants with the Incumbent. The history table for the Entrant in round 4 with exemplary data is displayed in Table 4.

The distinct game data variables within the history table were selected carefully, as too few variables would not represent the behavior of the Incumbent and too many variables could dilute the relevance of important variables and lead to a cognitive overload of the participants. Repeated tests with potential participants identified the most relevant variables: the payoff of the Entrant, whether the Entrant entered the market, the proportion of the action *Fight Investment* throughout the entire game, and the proportion of the action *Fight Investment* during the first 60 seconds. One might assume that the last

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[9] An alternative would be to have the participants play treatments without reputation exclusively in the first step and only afterward play treatments with reputation. This structure also leads to various problems, particularly a lack of randomization in the order of treatments, making it impossible to validly control for learning effects.

[10] During the session, additional treatments were conducted, measuring the conflict behavior and other discrete sequential time environments. Those treatments are disregarded and only C-NoRep and D-NoRep are used to serve as a baseline treatment

two columns are redundant. However, pre-tests revealed that establishing a reputation early in the interaction is crucial. Once a reputation is established, Incumbents tend to select the action *Tolerate* at the end of each round to maximize their payoff.This tactical approach reduces the proportion of *Fight Investment* over the entire game, potentially causing misinterpretation by Entrants. The Incumbent was also provided with a history table to better track their behavior across rounds. The Incumbent's history table is shown in the appendix in Table A1.

Table 4. An Exemplary History Table of an Entrant.

Game Data of past Entrants with the Incumbent				
Round	Payoff Entrant	Did Entrant enter market?	Proportion *Fight Investment* whole game	Proportion *Fight Investment* first 60s
1	-49	✓	77%	95%
2	-77	✓	89%	98%
3	0	✗	53%	53%
4	-	-	-	-

3.5 Participants and Payment

Students from different faculties of the Karlsruhe Institute of Technology were recruited using the online recruitment systems hroot (Bock et al., 2014) and ORSEE[11] (Greiner, 2004). All sessions were conducted at the Karlsruhe Decision & Design Lab (KD^{2}Lab). Upon arrival, participants received written and analog digital instructions on the screen. After they had read the instructions, participants completed a general and a reputation-specific questionnaire as a comprehension check as well as one practice round. Self-reported measures after the game and discussions with participants after the experiment indicate that they fully understood the rules of the game. All sessions lasted 60 to 75 minutes.

For the payment, participants received €5 as a fixed amount and €8-11 as an individual amount, depending on the performance in the market entry game. A payoff of 1250 points in the market entry game equals €1. As Entrants would have earned much less money than the Incumbents, they received an additional 700 points per game, resulting in the same payoff on average as the Incumbent. Overall, participants earned on average €14.26.

3.6 Hypotheses

My main focus is to study the effect of continuous-time interactions on reputation. To the best of my knowledge, no research has combined reputation and continuous-time environments. However, I base my hypotheses on the results and arguments of existing

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[11] Due to a system migration of the recruitment system at the KD^{2}Lab, hroot was used for sessions with C-NoRep and D-NoRep and ORSEE for sessions with C-Rep and D-Rep.

research regarding reputation in market entry games and continuous-time interactions. Based on the empirical results of the CSG by Selten (1978) and the modifications under incomplete and imperfect information, it becomes evident that Selten's deterrence theory is only partially fulfilled. Despite entry deterrence in the initial periods, studies by Jung et al. (1994), Sundali & Rapoport (1997), and Duman (2020) report high market entry rates of Entrants throughout the game. Even though the Incumbent intends to build a reputation under the discrete game format with complete information, the intended reputation from the Incumbent is not achieved. While previous research has attempted to improve reputation building through incomplete information, further approaches may lie in a continuous-time game format.

In two-player (social dilemma) games, consensus for a faster and stronger cooperation rate with continuous interaction exists. However, the results from continuous-time games cannot be transmitted directly to my hypotheses formulation as these games differ in one distinct dimension: The (social dilemma) conflict faced by the actors is analyzed in terms of coordination possibilities as it has the potential to be viewed as a common problem with mutual benefits for the conflicting parties. In contrast, my market entry game is a scenario with a destructive and competitive conflict, as a potential market entry threatens the monopoly position of the Incumbent. Only one player's objective can be optimally achieved: either the Incumbent maintains a monopoly position, or the market Entrant enters the market without opposition. Even though the existing literature focuses on coordination instead of reputation, the responsible mechanism discovered in the existing literature—namely the rapid interaction between the participants can transmit more signals—remains the same and is taken into account for my hypothesis formulation. As a consequence, I believe that the credibility of the Incumbent rises and therefore, he establishes an overall higher reputation. The first and main hypothesis is:

> **Hypothesis 1**: In C-Rep, reputation is overall at a higher level than in D-Rep.

Besides the comparison of the overall reputation level, the other two hypotheses focus on the development of reputation. The aim of that is to further investigate the behavior within rounds and to identify the root cause of potential reputation differences between C-Rep and D-Rep. Reputation is an attribute ascribed to one by another and primarily an empirical statement (Robert, 1985), which is based on the assessment of past behavior (Camerer & Weigelt, 1988). Therefore, the evolution of reputation needs time. In the empirical investigation of the CSG by Jung et al. (1994), this behavior is shown in the development of the market entry rate over time. While the market entry level starts high in the first rounds, it shrinks over time due to aggressive play by the Incumbent. This is a clear indicator that, in my market entry game, reputation also needs several rounds in discrete time to build up. Therefore, the second hypothesis is:

> **Hypothesis 2**: In D-Rep, reputation in the third round is higher than reputation in the first round.

The relevance of Hypothesis 2 is based on two components. First, it legitimizes that the same pattern observed in the empirical investigations of the CSG exists in D-Rep. Second, it descriptively contrasts the speed of reputation development in D-Rep with that in C-Rep.

Besides the process of reputation building, the reputation level in the final rounds is another focus of my investigation. In empirical investigations of the CSG, Jung et al. (1994), Sundali & Rapoport (1997), and Duman (2020) identify end-game effects as the entry rates rise and aggressive play diminishes towards the end. In contrast, Friedman & Oprea (2012) and Bigoni et al. (2015) showed that in continuous-time games, end-game effects lose their force when players can react quickly. In continuous-time environments, players have less incentive to preempt the opponent long before the end of the game, as the one-sided advantage is punished immediately. Therefore, end-game effects only emerge at the very end of the game. My third hypothesis is formulated based on this observation:

> **Hypothesis 3**: In D-Rep, reputation shrinks between the third and the fifth round.

3.7 Measuring reputation

Reputation is known as an intangible asset or resource (Kolesnikova et al., 2014) which cannot be directly controlled or measured (Anokhina, 2014). As in other laboratory experiments that measure reputation in a market entry game, quantitative measurable variables to approximate reputation are needed. The following indicators are included based on literature and pre-tests:

- ↑ **Payoff Incumbent**: The amount of the Incumbent's payoff. A higher payoff indicates a higher reputation.
- ↓ **Market Entry (%)**: The number of market entries by the Entrant compared to all potential entries. A lower share of market entries indicates a higher reputation.
- ↑ **Not Invest (%)**: The share the Entrant chooses *Not Invest*. A lower share of *Not Invest* indicates a higher reputation.
- ↓ **War of Attrition (WoA) (%)**: The share of action combination *(Invest, Fight Investment)* compared to all other action combinations. A lower share of WoA represents a higher reputation.[12]

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[12] WoA might not seem intuitive to use as an indicator for reputation at first glance. The proportion of the strategy combination *(Invest, Fight Investment)* represents the destructive state in the game where both parties suffer. The higher this proportion, the more it becomes evident that the Incumbent is still in the process of building up reputation through fighting market entries. This indicator is particularly important in the early rounds. Solely using the action choice *Fight Investment* by the Incumbent would be insufficient, as it would only represent the intention to build up a reputation, not the effect of reputation building.

3.8 Empirical Strategy

My empirical strategy is as follows: First, I divide the data into two datasets, each characterized by a different level of detail. The first dataset contains the average values of all rounds for each Incumbent, enabling a comparison of overall reputation levels between C-Rep and D-Rep. Recall that the data collected of both treatments with reputation, D-Rep and C-Rep, is done in a within-subject design. Therefore, to accurately test Hypothesis 1, I estimate a panel-regression where i indexes subjects and g indexes the game number within each session. D-Rep serves as the reference category and C-Rep as a dummy variable. To address potential confounding factors, four control variables are incorporated[13]. Separate regressions are conducted for each of the four indicators, resulting in the following regression equation:

$$\begin{aligned}\text{Dep.Var}_{i,g} = \beta_0 + \beta_1 \cdot \text{C-Rep}_{i,g} + \beta_2 \cdot \text{Game no.}_{i,g} + \beta_3 \cdot \text{Age}_i \\ + \beta_4 \cdot \text{Game Theory skills}_i + \beta_5 \cdot \text{Female}_i + u_i + \epsilon_{i,g}\end{aligned}$$

Baseline differences between discrete- and continuous time can exist independently of the reputation factor. To accurately isolate the effect of reputation, it is necessary to include the other two treatments, D-NoRep and C-NoRep, for comparison. Therefore, the following Mann-Whitney U test is performed:

$$\begin{aligned}\text{H}_0 : (\text{Dep.Variable}_{C-Rep} - \text{Dep.Variable}_{D-Rep}) \\ = (\text{Dep.Variable}_{C-NoRep} - \text{Dep.Variable}_{D-NoRep})\end{aligned}$$

In contrast to Hypothesis 1, which aims for differences within treatments, Hypotheses 2 and 3 focus on round-based effects within the treatment D-Rep. For this analysis, the more detailed second dataset is used, representing the average values for each game round. To test for reputation building, the average value of the first round is compared to the third round and for end-game effects, the average value of the third round is compared to the last round. The variable *First Round* serves as the reference category, while two additional dummy variables, *Third Round* and *Fifth Round*, are incorporated. In this panel-regression, i indexes subjects and r indexes the round number within each game. With the control variables keeping the same, the following panel-regression is estimated:

$$\begin{aligned}\text{Dep.Var}_{i,r} = \beta_0 + \beta_1 \cdot \text{Third Round}_{i,r} + \beta_2 \cdot \text{Fifth Round}_{i,r} + \beta_3 \cdot \text{Age}_i \\ + \beta_4 \cdot \text{Game Theory skills}_i + \beta_5 \cdot \text{Female}_i + u_i + \epsilon_{i,r}\end{aligned}$$

---

[13] The control variable *Game no.* denotes the sequence of the treatments and controls for learning effects between treatments. The variable *Age* controls for differences in age and has four ranges: 1 if $18 \leq \text{age} \leq 21$, 2 if $22 \leq \text{age} \leq 25$, 3 if $26 \leq \text{age} \leq 29$, 4 if $\text{age} \geq 30$. *Game Theory skills* are assessed on a Likert scale from 1 (very poor) to 5 (very good), and *Female* is a binary variable, coded as 1 for female participants. For further Information regarding the control variables, I refer to the closing questionnaire, illustrated in Appendix B.4.

The following Wald test can be conducted to compare the coefficients between the third and fifth rounds:

$$H_0 : \beta_{\text{Third Round}} = \beta_{\text{Fifth Round}}$$

This approach allows for isolating the specific effects of reputation building and end-game strategies within treatment D-Rep.

4. Experimental Results

In the following, I first analyze the variables across the rounds and afterward examine the variables within rounds.

4.1 Across Rounds

I start with descriptive information on all four indicators for all treatments. Table 5 summarizes the data in numerical form.

Table 5. Mean, Median and Standard Deviation (SD) of all four Treatments.

		C-Rep	**D-Rep**	**C-NoRep**	**D-NoRep**
↑ Payoff Incumbent	Mean	681.0	645.6	655.7	660.0
	Median	677.6	648.0	652.0	660.0
	SD	39.0	36.3	78.5	70.4
↓ Market Entry (%)	Mean	70.0	86.0	89.8	93.9
	Median	80.0	100.0	100.0	100.0
	SD	21.9	18.6	30.6	24.2
↑ Not Invest (%)	Mean	37.2	22.5	29.2	15.3
	Median	38.1	20.0	16.7	0.0
	SD	21.2	19.9	33.2	30.4
↓ WoA (%)	Mean	22.9	30.7	18.9	16.3
	Median	24.1	30.0	11.1	0.0
	SD	12.7	21.8	22.7	37.3
# Observations		250	250	49	49

Recall, that in the case of *Payoff Incumbent* and *Not Invest (%)*, higher values indicate a stronger reputation, while for *Market entries (%)* and *WoA (%)*, lower values indicate a stronger reputation. Several patterns are worth pointing out.

At first, in the C-Rep treatment, the Incumbent achieves the highest average payoff of 681.0, outperforming all other treatments. Surprisingly, the Incumbent has the lowest payoff in D-Rep, suffering more in discrete time with reputation than in both treatments without reputation. Also, in C-Rep, compared to D-Rep, a lower share of *Market Entry*, a higher share of *Not Invest*, and a lower share of *WoA* are observable. This relationship suggests that the average reputation level across all rounds is higher in the C-Rep treatment than in the D-Rep treatment.

Second, as the indicator *WoA* represents the level of attrition in the game, it becomes clear that treatments with reputation building exhibit higher attrition than those without. This reflects the Incumbent's expected effort to build a reputation for toughness, rather than simply tolerating all Entrants.

Third, potential baseline effects for the indicator *Not Invest* are observable. The Entrants strategy of *Not Invest* is in the C-Rep treatment with 37.2% the highest compared to the other treatments. However, the Entrant has at the baseline treatment C-NoRep already without reputation a much higher rate of not investing in the market compared to the other baseline treatment D-NoRep.This suggests that the high rate of *Not Invest* is primarily influenced by the continuous-time mechanism rather than by reputation.

Fourth, in the D-NoRep treatment, a conflict-free market entry process in a discrete-time, single-round game can be observed. Both, the *Not Invest (%)* and *WoA (%)* indicators not only record the lowest mean values but also show a median value of 0%. Additionally, very high market entry rates (93.9%) are observed, resulting in a payoff of 660 for the Incumbent, which aligns with the ideal strategies of *Always Invest* for the Entrant and *Always Tolerate* for the Incumbent (see Table 4). This reveals that the Incumbent has neither built up nor attempted to build any reputation in the D-Rep treatment.

A panel-regression analysis of the treatments C-Rep and D-Rep across all indicators is displayed in Table 6 and supports the initial impression that C-Rep generally has a higher reputation. The coefficient for C-Rep indicates that its overall effect on *Payoff Incumbent* and *Not Invest* is positive and significant, while its effect on *Market Entry* and *WoA* is negative and significant. This suggests that C-Rep has a higher reputation impact on these indicators compared to D-Rep.

Additionally, using the Mann-Whitney U test to control for baseline effects and isolate the relative difference attributable to reputation effects, it is found that the three indicators *Payoff Incumbent*, *Market Entry*, and *WoA* exhibit strong significance. Although the indicator *Not Invest* is not statistically significant, the z-value remains positive, indicating a trend towards a higher reputation.

> **Result 1:** Continuous interaction leads to a higher reputation relative to discrete time.

4.2 Within Rounds

Following the analysis of overall reputation effects across rounds, I will conduct a detailed examination of the round-based effects of the treatments with reputation.
As already shown in Table 6, all indicators demonstrate that C-Rep has a higher reputation compared to D-Rep. The progression over the rounds reveals where and to what

Table 6. Panel-Regression (Random Effects) of the Treatments C-Rep and D-Rep with the Four Indicators as Dependent Variables.

Dependent Var.:	**Payoff Inc**	**Market Entry (%)**	**Not Invest (%)**	**WoA (%)**
D-Rep (Ref.)	-	-	-	-
C-Rep	35.432 ***	-16.000 ***	14.728 ***	-7.730 **
	(8.170)	(4.098)	(3.942)	(3.483)
Game no.	2.080	1.600	-1.245	4.161
	(8.170)	(4.098)	(3.942)	(3.483)
Age	-3.310	-2.923	0.237	2.843
	(10.160)	(6.004)	(6.185)	(3.866)
Game Theory skills	9.959	-3.184	1.904	-5.957
	(8.392)	(5.361)	(5.256)	(4.176)
Female	12.527	7.156	-10.405	-15.047 *
	(14.005)	(8.391)	(9.947)	(7.710)
Constant	619.401 ***	90.862 ***	23.679 ***	52.585 ***
	(27.274)	(15.986)	(15.415)	(13.035)
No. Observations	100	100	100	100
No. Groups	50	50	50	50
R^2_{within}	0.289	0.249	0.232	0.1201
$R^2_{between}$	0.048	0.035	0.040	0.1074
$R^2_{overall}$	0.202	0.154	0.137	0.1136
Significance ($Prob > \chi^2$)	0.001 ***	0.002 ***	0.003 ***	0.130
Mann-Whitney U test[1]	3.202 ***	-2.629 ***	0.365	-2.983 ***

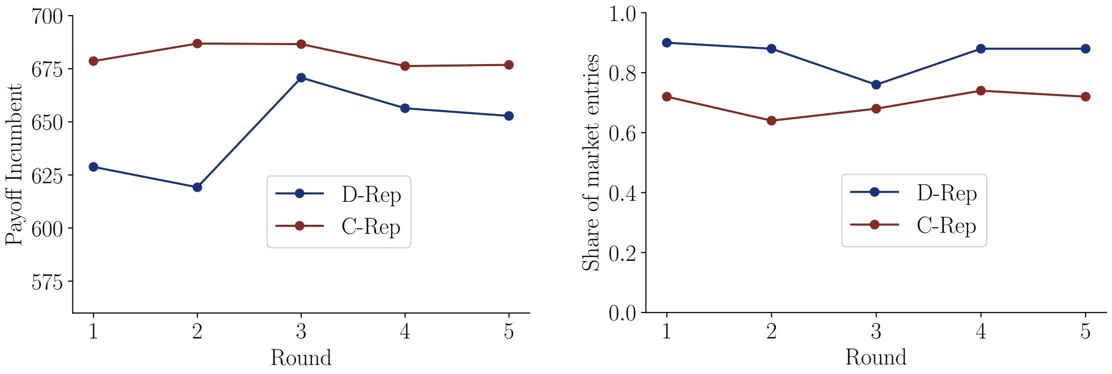
Note: Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[1] H_0: (Dep.Variable$_{C-Rep}$ - Dep.Variable$_{D-Rep}$) = (Dep.Variable$_{C-NoRep}$) - (Dep.Variable$_{D-NoRep}$) to be tested for all four dependent variables to filter out baseline effects and only get the relative difference attributable to reputation effects. z-value and significance-level for all indicators listed.

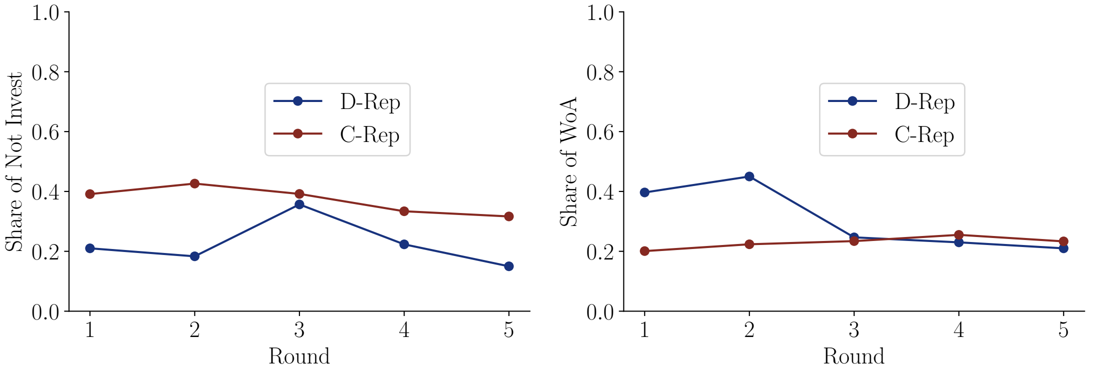
extent deviations between the treatments exist. Figure 5 shows the round-based view of D-Rep in blue and C-Rep in red for all indicators. It becomes evident, that the difference between D-Rep and C-Rep is not constant over the rounds but fluctuates in certain patterns.

In the first two rounds, the highest gap between the two treatments can be observed. While all indicators at the C-Rep treatment suggest, that the Incumbent already has in the first round a relatively high level of reputation, in D-Rep, reputation is low at the beginning and needs certain rounds to build over time. A very high gap in the early rounds represents (besides the indicator *Not Invest*) the indicator *WoA*, where C-Rep is twice as high as D-Rep. This indicates that in D-Rep the Incumbent needs to fight substantially more market entries to build up reputation. In the third round, the reputation level at D-Rep increases for all indicators, while the reputation in C-Rep remains constant and fluctuates only slightly over time, resulting in the convergence of the two graphs. Towards the end, the indicators suggest that, except for the indicator *WoA*, reputation is declining in D-Rep, leading to a wider gap between the two treatments. This provides descriptive evidence of end-game effects in D-Rep.

To statistically verify whether the observations from Figure 5 are supported, I conducted a panel regression, as presented in Table 7. For all indicators, the variable *Third Round*



(a) ↑ Payoff Incumbent **(b)** ↓ Market Entry (%)



(c) ↑ Not Invest (%) **(d)** ↓ WoA (%)

Figure 5. Round-Based View of D-Rep and C-Rep for all Indicators.

indicates an increase in reputation and is statistically significant. This result supports Hypothesis 2, suggesting that in the D-Rep treatment, reputation requires time to develop, as it increases significantly from the first to the third round.

> **Result 2:** In discrete time, there is a significant positive correlation between the first round and the third round for all indicators of reputation, suggesting a process of reputation building over time.

A Wald test compares the coefficients for *Third Round* and *Fifth Round* to test for end-game effects. The F-value for the indicator *Not Invest* is 9.71 and highly significant ($p = 0.002$), verifying a higher level of investment by the Entrant in the last round compared to the third round. Despite the descriptive evidence of end-game effects, there is no statistical significance for the other three indicators, providing no support for the third hypothesis.

> **Result 3:** Three out of four indicators show no significant decrease in reputation between the third and fifth rounds, providing no statistical evidence of end-game effects in discrete time.

The corresponding regression table for Treatment C-Rep is presented in Appendix Table A2. None of the indicators reveal significant differences between the average values from

Table 7. Round-Based Panel-Regression (Random Effects) of the Treatment D-Rep to Test for Reputation Building and End-Game Effects.

Dep. Var.:	**Payoff Inc**	**Market Entry (%)**	**Not Invest (%)**	**WoA (%)**
First Round (Ref.)	-	-	-	-
Third Round	42.000 **	-14.000 **	14.666 *	-15.000 *
	(20.054)	(6.505)	(7.821)	(9.008)
Fifth Round	24.000	-2.000	-6.002	-18.666 **
	(19.496)	(6.810)	(7.311)	(8.768)
Age	-26.594	8.338	-7.088	13.375
	(14.324)	(7.058)	(7.631)	(6.925)
Game Theory skills	13.480	-1.023	-2.608	-11.212
	(14.033)	(7.109)	(7.410)	(7.061)
Female	25.997	-.406	-6.955	-24.103 *
	(28.020)	(9.986)	(10.582)	(14.243)
Constant	615.983 ***	84.215 ***	36.163 *	59.791 **
	(40.055)	(17.986)	(18.111)	(21.273)
No. Observations	150	150	150	150
No. Groups	50	50	50	50
R^2_{within}	0,046	0.048	0.083	0.052
$R^2_{between}$	0,109	0.028	0.060	0,150
$R^2_{overall}$	0,061	0.040	0.060	0.082
Wald $\chi^2(5)$	13.60	5.99	12.06 **	14.77 **
Wald test[1]	0.86	2.57	9.71 ***	0.21

Note: Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[1] H_0: $ThirdRound = FifthRound$.

the first to the third round, nor do the results of the Wald test indicate any significant effects. These findings align with the descriptive analysis, which suggests that the reputation level is established in the first round and remains consistently high throughout, with no evidence of end-game effects. Consequently, there is no statistical support for reputation building at the beginning or reputation decline at the end. A summary of the hypothesis results is provided in Appendix Section A3.

5. Discussion

The results of my study show that the time dimension matters in modeling reputation. I found a positive and significant effect indicating that the overall level of reputation is higher in continuous time compared to discrete time. Moreover, the difference in reputation levels does not remain constant throughout the rounds. While in continuous time, reputation remains relatively stable with only slight fluctuations, in discrete time, reputation building requires time to unfold its effect.

In the following, I discuss potential mechanisms that further explain my findings and explore why they occur. First, I focus on the underlying mechanisms that cause reputation to be higher when continuous time is enabled. Second, I address the end-game effects of C-Rep and D-Rep and explore potential reasons why no statistically significant end-game effects are observable in discrete time. Third, I discuss why high absolute market entry rates are still observable throughout both treatments with reputation. Lastly, I highlight opportunities for future research.

Building reputation in continuous time:

An appropriate orientation for underpinning my results are the continuous-time experiments conducted by Friedman & Oprea (2012) (prisoner's dilemma) and Oprea et al. (2014) (public-goods game). In these experiments, players used pulsing signals as a communication device to convey cooperation or promises. Once a mutually satisfying state was developed, quick reactions ensured stability in continuous time. Although the market entry game focuses on deterrence rather than cooperation, the frequency of pulsing signals plays a crucial role in building reputation.

To build up reputation in the market entry game, the Incumbent must send signals to the Entrant that clearly indicate that the market entry will be deterred once they start to build up capacity. Given the limitation to two possible actions, signaling can only become clearer through a high frequency of signal exchanges. In the market entry game, this exchange is represented by action changes. An analysis of action changes shows that, on average across all rounds, there were 0.3 action changes in discrete time compared to 13.3 action changes in continuous time. The considerably more frequent action changes in continuous time result in a higher quantity of information exchange during the game. The low rate of action changes in discrete time is explained by the discrete structure where a market entry is executed in one move. Therefore, an Entrant cannot adapt to an aggressive playstyle of the Incumbent during the round and reputation-enhancing signals of the Incumbent are conveyed only after the rounds via the history table. The omission of intra-round information exchange and the limitation to inter-round information exchange slow down the process of reputation building in discrete time. Besides the frequency of the signals, the quality of the signals in continuous time plays another decisive role.

Table 6 shows the dynamics of interaction in continuous time, based on data from 6672 action changes across all rounds in C-Rep[14]. Given a certain action combination, the outgoing arrows with their corresponding numerical values shows the likelihood that the Entrant switches action compared to the likelihood that the Incumbent switches action. In contrast to the dynamics in the Prisoner's Dilemma in Friedman & Oprea (2012), no convergence to a certain action combination is observed. Instead, there is an alternating behavior of action changes rotating clockwise. Specifically, the switch from the action combination *(Invest, Tolerate Investment)* to *(Invest, Fight Investment)* serves as the relevant reputation-enhancing signal. Fighting the investment as soon as the Entrant invests is an easily interpretable deterring signal by the Incumbent.

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[14] Since 100 games with five rounds each were conducted, the data was extracted from 500 subgames played in continuous time.

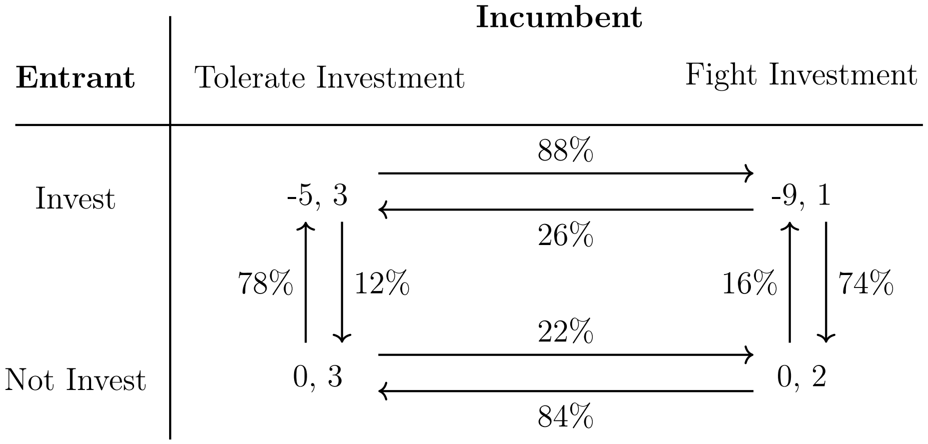

Figure 6. Dynamics of Interaction at the C-Rep treatment.

Analysis of game data reveals that, on average, this action change is executed 2.9 times per round. This likely explains the rapid reputation building in continuous time already within the first round. To summarize the number and quality of signals, the following result emerges:

> **Result 4:** The frequency and timing of action changes enable rapid and sustainable reputation building. In continuous time, signals can be transmitted and interpreted immediately, whereas in discrete time, information exchange is largely confined to transitions between rounds.

Dynamics of end-game effects:

In contrast to Hypothesis 1 (reputation level) and Hypothesis 2 (reputation building), there was descriptive but no statistical support for Hypothesis 3, stating that in discrete time reputation shrinks towards the end. Based on game theoretic reasoning by induction theory, in the last round, the Incumbent would have no incentive to build up further reputation through fighting the investment as no long run considerations come into perspective and consequently, Entrants would enter the market. In the market entry game, the subjects did not realize the unraveling argument of backward induction. Orienting on experimental investigations of the CSG, the number of rounds and the experiences of the subjects influence end-game effects. In the experiment by Sundali & Rapoport (1997), stronger end-game effects were visible when playing the CSG over 15 rounds instead of 10 rounds. In another CSG experiment, Jung et al. (1994) separated the data between inexperienced subjects and experienced subjects, who had participated in one prior experimental session. The data revealed, that experienced subjects identified the induction theory and had a substantially higher market entry rate in the last round compared to inexperienced subjects. Therefore, induction theory appears to be identified with experience. The reason for the weaker decline of reputation in D-Rep than expected could be therefore be attributed to the participants' lack of experience with game theoretic experiments and the limitation to five game rounds.

In contrast to descriptive results in discrete time, I do find support that in continuous time no end-game effects were notable. It seems that the unraveling argument of tolerating the Entrant in the last round loses its force[15]. Through the in-round reputation signals explained above, the reputation level remains high until the very end of the last round. This confirms the findings of Friedman & Oprea (2012) and Bigoni et al. (2015) that end-game effects diminish when players can react quickly.

High absolute market entry rate in C-Rep:

Although significantly lower values for the indicator Market Entry were observed in C-Rep compared to D-Rep (see Table 6), the market entry rate of 70% in C-Rep still appears relatively high in absolute terms. Further data analysis identifies one plausible explanation for this high market entry rate. Table 8 illustrates the impact of initial deterrence by the Incumbent—measured as the proportion of *Fight Investment* during the first 60 seconds of round 1[16]—on game dynamics in subsequent rounds (average of rounds 2–5)

Table 8. Impact of the Action *Fight Investment* in the First Round for the First 60 Seconds on Subsequent Market Dynamics.

	Action: Round 1, first 60s		Reaction: Round 2-5	
Treatment	Share *Fight Investment*	Share of Incumbents	*Market Entry* (Rounds 2-5)	*Payoff Incumbent* (Rounds 2-5)
D-Rep	>90%	46.00%	72.83%	661.32
C-Rep		16.00%	46.88%	722.97
D-Rep	<10%	54.00%	95.37%	641.11
C-Rep		26.00%	84.62%	626.79

The data is divided into two peripheral groups based on the level of initial deterrence. The first group are Incumbents who initially choose the action *Fight Investment* in the first round for more than 90%. This group represents aggressive Incumbents who strictly follow the goal of building a reputation of toughness and prevent future market entries. The second group are Incumbents with a share of an initial *Fight Investment* of below 10%. This group represents the contrasting scenario where Incumbents tolerate market entries in the first round and do not have the goal of building up a reputation.

Table 8 reveals the following three findings. At first,it shows that an initial deterrence rate of >90%, compared to <10%, is associated with lower subsequent *Market Entry* rates and higher payoffs for the Incumbent. The causal relationship between initial deterrence and reduced subsequent market dynamics holds true for both treatments, C-Rep and D-Rep. The deterring effectiveness, however, is in C-Rep higher. The *Market Entry* rate for

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[15] My statement that no end-game effects in continuous time are notable is supported by Figure 5 for descriptive evidence and Table A2 for statistical evidence.

[16] The first 60 seconds were measured instead of the entire round length, as they more strongly reflect initial deterrence. During the game, the Incumbent often switches to *Tolerate Investment* either when they perceive no chance of successfully deterring entry or when they assess the probability of the Entrant beginning to invest as low.

aggressive Incumbents is 72.83% in D-Rep and 46.88% in C-Rep compared to the *Market Entry* rate for tolerate Incumbents, which is 95.37% in D-Rep and 84.64% in C-Rep. This represents a difference for aggressive Incumbents of 37,74 percentage points in C-Rep, compared to 22.54 percentage points in D-Rep.[17]. Thus, it holds that in continuous time, the Incumbent's entry deterrence has a stronger effect.

Second, the aspect of the stronger effect of entry deterrence in continuous time is intensified in regard to the following fact: In D-Rep, participants are bound to the action for 60 seconds, resulting in an initial fighting share of either 0% or 100%. This means, that all 46.00% of aggressive Incumbents in D-Rep have a 100% initial fighting share, conveying a clear and strong signal of aggression to subsequent Entrants via the history table. Despite the strong initial aggression signal in D-Rep, the market entry rate in the subsequent rounds is 72.83% in D-Rep compared to 46.88% in C-Rep. This clearly underscores how superior the continuous-time game mechanism is in reputation building.

Third, Table 8 shows that the proportion of aggressive Incumbents is very low. In C-Rep, only 16% of the Incumbents were aggressive and initially deterred the Entrant while a notable proportion of 26% Incumbents followed a tolerant strategy. The low proportion of aggressive Incumbents seems to be the reason why the average market entry rate in C-Rep remains relatively high in absolute terms. Factors such as risk tolerance, long-term considerations, or preferences for fairness might have influenced their decisions[18]. On this basis, Incumbents can be categorized into three groups based on their initial aggressiveness: Those who followed the deterrence theory of Selten (1978) (16%), those who adopted a more selfless approach aiming for a tolerant solution for both players (26%), and those in between, who did neither fully deter nor fully tolerate the Entrant (58%). Despite the fact that Incumbents in C-Rep who engaged in higher initial fighting of investments achieved substantially higher payoffs (722.97 vs. 626.79), the individual incentive to commit to a tough behavior was lacking in the game.

> **Result 5**: Despite the reputational superiority of continuous time over discrete time, a high absolute market entry rate is observed. This is less a result of inefficiency in the continuous-time mechanism, but rather due to the low proportion of aggressive Incumbents.

Future research opportunities:

In the previous subsection, I explained one reason for the overall high market entry in C-Rep. Mechanisms can be employed to allow the Incumbent to better establish their reputation through signaling. One approach focuses on the medium through which the reputation is conveyed to subsequent Entrants. In the experiment, game data indicating

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[17] The difference for C-Rep is 84.62% - 46.88% = 37.74 percentage points. The difference for D-Rep is 95.37% - 72.83% = 22.54 percentage points.

[18] The instructions were written objectively to avoid any experimenter effect. No verbal motivation or extracurricular incentive was given to the Incumbent to adopt an aggressive playstyle.

reputational effects were only transported to subsequent Entrants through a history table (see Table 4). The game data did transmit average values to subsequent Entrants but not the dynamics taking place in continuous time. Instead of just providing the history table, in future studies it can be tested, how reputation develops, if the interaction between Entrant and Incumbent is directly observed by subsequent Entrants.

More empirical work investigating the intersection between continuous-time games and reputation[19] as well as continuous-time games and market entries[20] also remains.

6. Conclusion

Do continuous-time interactions generate a higher level of reputation in a destructive market entry game with capacity building? Inspired by Selten's Chain Store Game, my study presents a controlled experiment based on a self-constructed model to measure reputation dynamics in a real-life, continuous-time setting compared to a conventionally modeled discrete-time setting. The data reveal a significant positive correlation between continuous time and all indicators of reputation. After filtering out baseline effects, continuous interaction still led to a strong improvement in the reputation level relative to discrete time. Within-round data show that in discrete time, reputation requires a certain amount of time to build, whereas in continuous time, reputation is established within the first round and remains constant throughout the game. The reason for the faster and higher reputation in continuous time is primarily the greater frequency and quality of information transfers. The Incumbent can send more and clearer reputation-enhancing signals, and the Entrant can better adapt to the playstyle of the Incumbent. The findings of this study underscore the critical role that continuous-time interactions play in reputation building within market entry games. As reputation dynamics in real life occur in continuous time, the application of Selten's deterrence theory appears to be more effective than previously assumed. Future research should test reputation building when direct observation of interactions by future Entrants is incorporated. Additionally, further investigations into continuous-time interactions concerning reputation building and market entry are desirable.

---

[19] Transactions in e-commerce become not only faster, but also markets require a certain amount of trust (reputation in a positive sense). This can be modeled best by a continuous-time trust game (see Berg et al. (1995) for the conventional trust game). An experiment from Bolton et al. (2004) reveals that even with partner matching no more than 80% of the transactions were completed in discrete time. An empirical investigation could be helpful to test if the continuous-time mechanism can strengthen trust.

[20] Building on empirical research that examines tacit coordination in market entry games within time-discrete environments (e.g., Erev & Rapoport (1998), Rapoport et al. (1998, 2000) and Sundali et al. (1995)), future research should explore these dynamics in continuous-time settings to investigate whether continuous time fosters coordination in this type of market entry game.

References

Anokhina, K. (2014). Anokhina, Katherine. "Structure and classification of intangible assets in industrial enterprises. *Socio-economic research bulletin*, 4(55).

Berg, J., Dickhaut, J., & McCabe, K. (1995). Trust, Reciprocity, and Social History. *Games and Economic Behavior*, 10(1), 122–142. https://doi.org/10.1006/game.1995.1027

Bergin, J., & MacLeod, W. B. (1993). Continuous Time Repeated Games. *International Economic Review*, 34(1), 21. https://doi.org/10.2307/2526948

Bigoni, M., Casari, M., Skrzypacz, A., & Spagnolo, G. (2015). Time Horizon and Cooperation in Continuous Time. *Econometrica*, 83(2), 587–616. https://doi.org/10.3982/ECTA11380

Bock, O., Baetge, I., & Nicklisch, A. (2014). Hroot: Hamburg Registration and Organization Online Tool. *European Economic Review*, 71, 117–120. https://doi.org/10.1016/j.euroecorev.2014.07.003

Bolton, G. E., Katok, E., & Ockenfels, A. (2004). How Effective Are Electronic Reputation Mechanisms? An Experimental Investigation. *Management Science*, 50(11), 1587–1602. https://doi.org/10.1287/mnsc.1030.0199

Bunch, D. S., & Smiley, R. (1992). Who Deters Entry? Evidence on the Use of Strategic Entry Deterrents. *The Review of Economics and Statistics*, 74(3), 509–521. https://doi.org/10.2307/2109496

Camerer, C., & Weigelt, K. (1988). Experimental Tests of a Sequential Equilibrium Reputation Model. *Econometrica*, 56(1), 1. https://doi.org/10.2307/1911840

Chen, D. L., Schonger, M., & Wickens, C. (2016). oTree—An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9, 88–97. https://doi.org/10.1016/j.jbef.2015.12.001

Chen, L., Mislove, A., & Wilson, C. (2016). An Empirical Analysis of Algorithmic Pricing on Amazon Marketplace. *Proceedings of the 25th International Conference on World Wide Web*, 1339–1349. https://doi.org/10.1145/2872427.2883089

Cooke, P. (2020). Gigafactory Logistics in Space and Time: Tesla's Fourth Gigafactory and Its Rivals. *Sustainability*, 12(5), 2044. https://doi.org/10.3390/su12052044

Crandall, J. W., & Goodrich, M. A. (2005). Learning to compete, compromise, and cooperate in repeated general-sum games. *Proceedings of the 22nd International Conference on Machine Learning*, 161–168. https://doi.org/10.1145/1102351.1102372

Duffy, J., & Hopkins, E. (2005). Learning, information, and sorting in market entry games: Theory and evidence. *Games and Economic Behavior*, 51(1), 31–62. https://doi.org/10.1016/j.geb.2004.04.007

Duman, P. (2020). Does Informational Equivalence Preserve Strategic Behavior? Experimental Results on Trockel's Model of Selten's Chain Store Story. *Games*, 11(1), 9. https://doi.org/10.3390/g11010009

Erev, I., & Rapoport, A. (1998). Coordination, "Magic," and Reinforcement Learning in a Market Entry Game. *Games and Economic Behavior*, 23(2), 146–175. https://doi.org/10.1006/game.1997.0619

Friedman, D., Huck, S., Oprea, R., & Weidenholzer, S. (2015). From imitation to collusion: Long-run learning in a low-information environment. *Journal of Economic Theory*, 155, 185–205. https://doi.org/10.1016/j.jet.2014.10.006

Friedman, D., & Oprea, R. (2012). A Continuous Dilemma. *The American Economic Review*, 102, 337–363. https://doi.org/10.1257/aer.102

Greiner, B. (2004, January). *An Online Recruitment System for Economic Experiments* (Vol. 63).

Hwang, S. B., & Kim, S. (2006). Dynamic Pricing Algorithm for E-Commerce. In T. Sobh & K. Elleithy (Eds.), *Advances in Systems, Computing Sciences and Software Engineering* (pp. 149–155). Springer Netherlands. https://doi.org/10.1007/1-4020-5263-4_24

Jung, Y. J., Kagel, J. H., & Levin, D. (1994). On the Existence of Predatory Pricing: An Experimental Study of Reputation and Entry Deterrence in the Chain-Store Game. *The RAND Journal of Economics*, 25(1), 72. https://doi.org/10.2307/2555854

Kadiyali, V. (1996). Entry, Its Deterrence, and Its Accommodation: A Study of the U. S. Photographic Film Industry. *The RAND Journal of Economics*, 27(3), 452–478. https://doi.org/10.2307/2555839

Kolesnikova, J. S., Grunichev, A. S., Salyahov, E. F., & Zagidullina, V. M. (2014). Reputation as Part of Intangible Property, Intangible National Wealth and Intangible Heritage. *Asian Social Science*, 10(13), p271. https://doi.org/10.5539/ass.v10n13p271

Kreps, D. M., & Wilson, R. (1982a). Reputation and imperfect information. *Journal of Economic Theory*, 27(2), 253–279. https://doi.org/10.1016/0022-0531(82)90030-8

Kreps, D. M., & Wilson, R. (1982b). Sequential Equilibria. *Econometrica*, 50(4), 863. https://doi.org/10.2307/1912767

Leng, A., Friesen, L., Kalayci, K., & Man, P. (2018). A minimum effort coordination game experiment in continuous time. *Experimental Economics*, 21(3), 549–572. https://doi.org/10.1007/s10683-017-9550-3

Milgrom, P., & Roberts, J. (1982). Predation, reputation, and entry deterrence. *Journal of Economic Theory*, 27(2), 280–312. https://doi.org/10.1016/0022-0531(82)90031-x

Neral, J., & Ochs, J. (1992). The Sequential Equilibrium Theory of Reputation Building: A Further Test. *Econometrica*, 60(5), 1151. https://doi.org/10.2307/2951542

Neven, D. J. (1989). Strategic Entry Deterrence: Recent Developments in the Economics of Industry. *Journal of Economic Surveys*, 3(3), 213–233. https://doi.org/10.1111/j.1467-6419.1989.tb00068.x

Oprea, R., Charness, G., & Friedman, D. (2014). Continuous time and communication in a public-goods experiment. *Journal of Economic Behavior & Organization*, 108, 212–223. https://doi.org/10.1016/j.jebo.2014.09.012

Rao, A. R., Bergen, M. E., & Davis, S. (2000). How to Fight a Price War. *Harvard Business Review*, 78(2), 107–116.

Rapoport, A., Seale, D. A., Erev, I., & Sundali, J. A. (1998). Equilibrium Play in Large Group Market Entry Games. *Management Science*, 44(1), 119–141. https://doi.org/10.1287/mnsc.44.1.119

Rapoport, A., Seale, D. A., & Winter, E. (2000). An experimental study of coordination and learning in iterated two-market entry games. *Economic Theory*, 16(3), 661–687. https://doi.org/10.1007/PL00020947

Robert, W. (1985, January). Reputations in games and markets. In *Game-theoretic models of bargaining* (pp. 27–62). Cambridge University Press. https://doi.org/10.1017/CBO9780511528309.004

Roth, A. E., & Erev, I. (1995). Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. *Games and Economic Behavior*, 8(1), 164–212. https://doi.org/10.1016/s0899-8256(05)80020-x

Salop, S. C. (1979). Strategic entry deterrence.

Selten, R. (1978). The chain store paradox: Theory and Decision. (9(2)), 127–159. https://doi.org/10.4337/9781849805544.00021

Simon, L. K., & Stinchcombe, M. B. (1989). Extensive Form Games in Continuous Time: Pure Strategies. *Econometrica*, 57(5), 1171. https://doi.org/10.2307/1913627

Smiley, R. (1988). Empirical evidence on strategic entry deterrence. *International Journal of Industrial Organization*, 6(2), 167–180. https://doi.org/10.1016/S0167-7187(88)80023-7

Sundali, J., Israeli, A., & Janicki, T. (2000). Reputation and deterrence: Experimental evidence from the Chain Store Game. (6.1).

Sundali, J., & Rapoport, A. (1997, January). Induction vs. Deterrence in the Chain Store Game: How Many Potential Entrants are Needed to Deter Entry? In *Understanding Strategic Interaction* (pp. 403–417). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-60495-9_31

Sundali, J., Rapoport, A., & Seale, D. A. (1995). Coordination in Market Entry Games with Symmetric Players. *Organizational Behavior and Human Decision Processes*, 64(2), 203–218. https://doi.org/10.1006/obhd.1995.1100

Trockel, W. (1986). The chain-store paradox revisited. *Theory and Decision*, 21(2), 163–179. https://doi.org/10.1007/BF00127193

Zhao, S. (2020). Coordination Games in Continuous Time. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3470747

Zhao, S. (2021). Taking turns in continuous time. *Journal of Economic Behavior & Organization*, 191, 257–279. https://doi.org/10.1016/j.jebo.2021.09.001

A. Appendix

A.1 Python Code for Calculating the Payoff Space of the Continuous- and Discrete-Time Market Entry Game

Continuous-Time Approximation via Discrete-Time with 10-Second Discretization

```
import itertools

inc_coordinates_k = [] #List of payoff-coordinates of incumbent
ent_coordinates_k = [] #List of payoff-coordinates of entrant
payoffs_k = [[]] #List of payoff-space (combined coordinates
of incumbent and entrant)

# create a list of all possible strategies for entrant and incumbent,
i.e. all binary strings of length 19 with unique combinations of 0 and 1

entrant = list(itertools.product([0,1], repeat=18)) #1 = "Invest"
incumbent = list(itertools.product([0,1], repeat=18)) #1 = "Fight Investment"

# 1. Loop to display all possible strategies of the Entrant
for strat_ent in range(len(entrant)):
    kom_e = entrant[strat_ent]

    # 2. Loop to display all possible strategies of the Incumbent
    for strat_inc in range(len(incumbent)):
    kom_i = incumbent[strat_inc]

    # Set variables to default values
    ent_payoff = 0
    inc_payoff = 0
    entrant_in_counter = False
    general_counter = 18   #Grid 18
    entrant_in = 0
    incumbent_tolerate = 0

        # 3. Loop to calculate the payoff of all possible strategy combinations

        for combinatorics in range(len(kom_i)):
            strategy_e = kom_e[combinatorics]
```

```
    strategy_i = kom_i[combinatorics]

#Calculate the payoff

    if (entrant_in_counter == False and general_counter > 0):
        general_counter = general_counter - 1

        #("Invest","Tolerate Investment")
        if (strategy_e == 1 and strategy_i == 0):
            ent_payoff = ent_payoff - 5
            inc_payoff = inc_payoff + 3
            entrant_in_counter = True

        #("Invest","Fight Investment")
        elif (strategy_e == 1 and strategy_i == 1):
            ent_payoff = ent_payoff - 9
            inc_payoff = inc_payoff + 1
            entrant_in_counter = True

        #("Not Invest","Tolerate Investment")
        elif (strategy_e == 0 and strategy_i == 0):
            inc_payoff = inc_payoff + 3

        #("Not Invest","Fight Investment")
        elif (strategy_e == 0 and strategy_i == 1):
            inc_payoff = inc_payoff + 2


#Calculate final results

# Capacity building complete
if entrant_in_counter == True:
    inc_payoff = inc_payoff + (general_counter+2)*2
    ent_payoff = ent_payoff + (general_counter+2)*2

# Capacity building incomplete
elif entrant_in_counter == False:
    inc_payoff = inc_payoff + 2*3

#Multiply results by 60 and round the number
```

```
        ent_payoff = round(ent_payoff*10,2)
        inc_payoff = round(inc_payoff*10,2)

        #Append to List, if combination is unique
        if ([ent_payoff,inc_payoff] in payoffs_60) == False:
            payoffs_60.append([ent_payoff,inc_payoff])
            inc_coordinates_60.append(inc_payoff)
            ent_coordinates_60.append(ent_payoff)
```

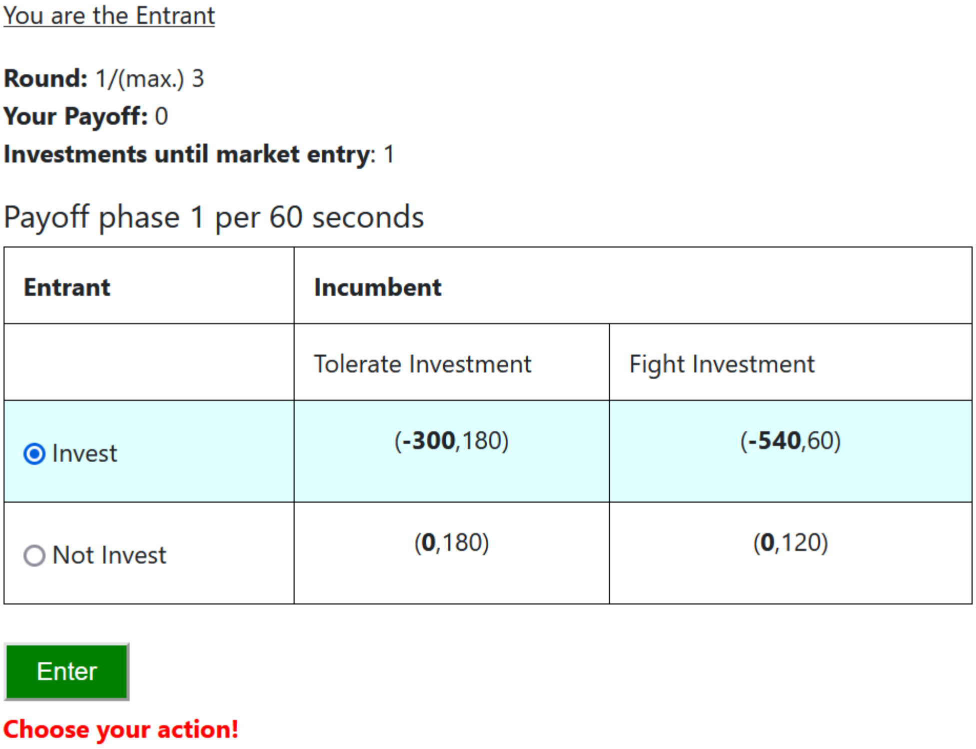
Discrete-Time with 60-Second Discretization

```
import itertools

inc_coordinates_k = [] #List of payoff-coordinates of incumbent
ent_coordinates_k = [] #List of payoff-coordinates of entrant
payoffs_k = [[]] #List of payoff-space (combined coordinates
of incumbent and entrant)

# create a list of all possible strategies for entrant and incumbent,
i.e. binary strings of length 3 with unique combinations of 0 and 1

entrant = list(itertools.product([0,1], repeat=3)) #1 = "Invest"
incumbent = list(itertools.product([0,1], repeat=3)) #1 = "Fight Investment"

# 1. Loop to display all possible strategies of the Entrant
for strat_ent in range(len(entrant)):
    kom_e = entrant[strat_ent]

    # 2. Loop to display all possible strategies of the Incumbent
    for strat_inc in range(len(incumbent)):
    kom_i = incumbent[strat_inc]

    # Set variables to default values
    ent_payoff = 0
    inc_payoff = 0
    entrant_in_counter = False
    general_counter = 3   #Grid 3
    entrant_in = 0
    incumbent_tolerate = 0

        # 3. Loop to calculate the payoff of all possible strategy combinations
```

```
for combinatorics in range(len(kom_i)):
    strategy_e = kom_e[combinatorics]
    strategy_i = kom_i[combinatorics]

#Calculate the payoff

    if (entrant_in_counter == False and general_counter > 0):
        general_counter = general_counter - 1

        #("Invest","Tolerate Investment")
        if (strategy_e == 1 and strategy_i == 0):
            ent_payoff = ent_payoff - 5
            inc_payoff = inc_payoff + 3
            entrant_in_counter = True

        #("Invest","Fight Investment")
        elif (strategy_e == 1 and strategy_i == 1):
            ent_payoff = ent_payoff - 9
            inc_payoff = inc_payoff + 1
            entrant_in_counter = True

        #("Not Invest","Tolerate Investment")
        elif (strategy_e == 0 and strategy_i == 0):
            inc_payoff = inc_payoff + 3

        #("Not Invest","Fight Investment")
        elif (strategy_e == 0 and strategy_i == 1):
            inc_payoff = inc_payoff + 2


#Calculate final results

# Capacity building complete
if entrant_in_counter == True:
    inc_payoff = inc_payoff + (general_counter+2)*2
    ent_payoff = ent_payoff + (general_counter+2)*2

# Capacity building incomplete
elif entrant_in_counter == False:
```

```
    inc_payoff = inc_payoff + 2*3

#Multiply results by 60 and round the number
ent_payoff = round(ent_payoff*60,2)
inc_payoff = round(inc_payoff*60,2)

#Append to List, if combination is unique
if ([ent_payoff,inc_payoff] in payoffs_60) == False:
    payoffs_60.append([ent_payoff,inc_payoff])
    inc_coordinates_60.append(inc_payoff)
    ent_coordinates_60.append(ent_payoff)
```

A.2 User Interface of the Discrete-Time Market Entry Game



You are the Entrant

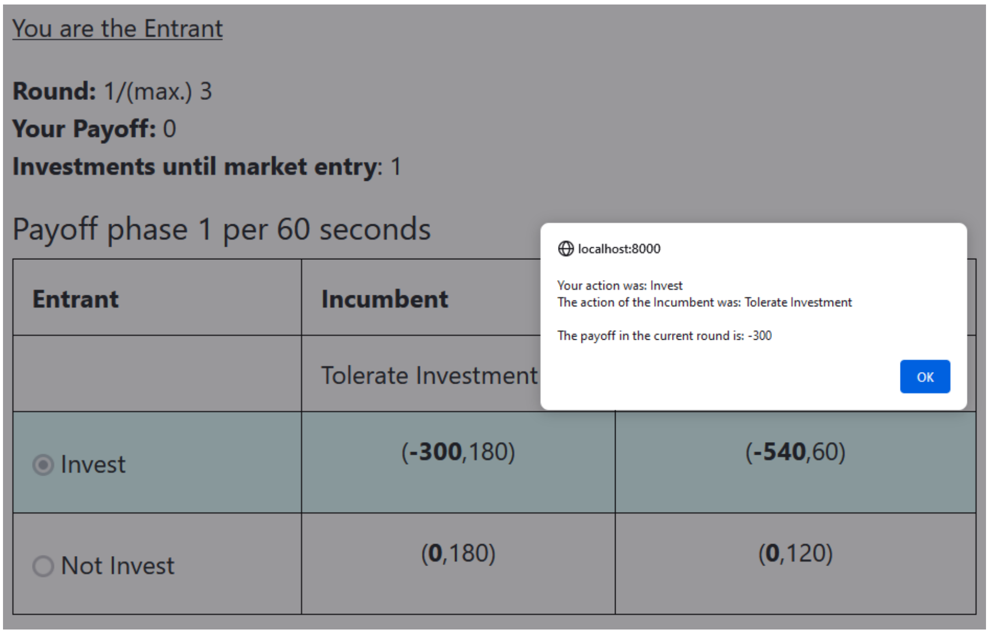
Round: 1/(max.) 3
Your Payoff: 0
Investments until market entry: 1

Payoff phase 1 per 60 seconds

Entrant	**Incumbent**	
	Tolerate Investment	Fight Investment
● Invest	(**-300**,180)	(**-540**,60)
○ Not Invest	(**0**,180)	(**0**,120)

Choose your action!

(a) Action Choice Without Knowledge of the Action Chosen by the Other Player.



You are the Entrant

Round: 1/(max.) 3
Your Payoff: 0
Investments until market entry: 1

Payoff phase 1 per 60 seconds

Entrant	**Incumbent**	
	Tolerate Investment	
● Invest	(**-300**,180)	(**-540**,60)
○ Not Invest	(**0**,180)	(**0**,120)

localhost:8000

Your action was: Invest
The action of the Incumbent was: Tolerate Investment

The payoff in the current round is: -300

(b) After Both Players Decided, the Results are Displayed.

Figure A1. User Interface of Phase 1 of the Time Discrete Market Entry Game.

A.3 History Table of the Incumbent

Table A1. An Exemplary History Table of an Incumbent.

Your Previous Game Data				
Round	Your Payoff	Did Entrant enter market?	Proportion *Fight Investment* whole game	Proportion *Fight Investment* first 60s
1	654	✓	77%	95%
2	612	✓	89%	98%
3	810	✗	53%	53%
4	-	-	-	-

A.4 Panel-Regression of the Treatment C-Rep

Table A2. Round-Based Panel-Regression (Random Effects) of the Treatment C-Rep to Test for Reputation Building and End-Game Effects.

Dep. Var.:	**Payoff Inc**	**Market Entry (%)**	**Not Invest (%)**	**WoA (%)**
First Round (Ref.)	-	-	-	-
Third Round	7.980	-4.000	0.054	3.334
	(23.014)	(9.172)	(7.652)	(6.223)
Fifth Round	-1.760	0.000	-7.468	3.244
	(21.567)	(8.719)	(7.618)	(6.334)
Age	-34.751	5.997	-4.239	8.163
	(18.034)	(9.067)	(9.135)	(5.657)
Game Theory Skills	4.358	-6.114	5.679	0.121
	(15.623)	(8.176)	(8.447)	(5.269)
Female	-3.219	8.905	-5.350	-8.756
	(37.178)	(18.202)	(19.426)	(11.094)
Constant	704.270 ***	76.308 ***	32.770	14.968
	(48.634)	(24.423)	(25.232)	(15.691)
No. Observations	150	150	150	150
No. Groups	50	50	50	50
R^2_{within}	0.002	0.003	0.014	0.004
$R^2_{between}$	0.075	0.040	0.026	0.054
$R^2_{overall}$	0.024	0.018	0.019	0.019
Wald $\chi^2(5)$	6.530	2.600	2.700	4.820
Wald test[1]	0.200	0.210	1.060	0.000

Note: Robust standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[1] H_0: $ThirdRound = FifthRound$.

A.5 Summary of Hypothesis Results

Table A3. Summary of Hypothesis Results.

	Hypothesis 1	Hypothesis 2	Hypothesis 3
Payoff Incumbent	✓***	✓**	✗
Market Entry (%)	✓***	✓*	✗
Not Invest (%)	✗	✓*	✓***
WoA (%)	✓***	✓*	✗
Result	✓	✓	✗

B. Instructions

B.1 General Instructions

In this experiment, two players interact with each other: One player represents a dominant company with a monopoly position (hereinafter referred to as the **Monopolist**[21]). The other player represents another company that can make investments to enter the Monopolist's market (hereinafter referred to as the **Entrant**).
The game lasts 300 seconds and consists of two consecutive phases.

Phase 1

Phase 1 consists of an interaction between the Entrant and the Monopolist. Both players have two strategies each.
Strategies of the Entrant:

- **Invest**: The Entrant invests in the market.
- **Not Invest**: The Entrant does not invest in the market.

Strategies of the Monopolist:

- **Tolerate Investment**: The Monopolist tolerates the Entrant's investment.
- **Fight Investment**: The Monopolist hinders the Entrant's investment.

Choosing a strategy pair results in a specific outcome with corresponding payoffs. These payoffs are depicted in the table below. The payoffs are per second (the total payoff is summed per second). The left number represents the Entrant's payoff, and the right number represents the Monopolist's payoff:

	Incumbent	
Entrant	○ Tolerate Investment	○ Fight Investment
○ Invest	-5 , 3	-9 , 1
○ Not Invest	0 , 3	0 , 2

Phase 1 lasts a maximum of 180 seconds. During Phase 1, the Entrant has time to invest and build up the necessary capacity to enter the Monopolist's market. However, the investment involves costs (see the payoff table) and time. The necessary time for the investment is 60 seconds.

If the Entrant's strategy in Phase 1 is 'Invest' for 60 seconds, Phase 1 ends early because the Entrant is now in the Monopolist's market. Consequently, the time in Phase 1 is shorter, and the time in Phase 2 is longer.

---

[21] In pre-tests, subjects reported that the term *Monopolist* would be more approachable than using the term *Incumbent*.

Important: The Entrant can pause the investment by choosing 'Not Invest', meaning the 'Invest' strategy does not have to be continuous for 60 seconds. It can be spread over Phase 1.

Phase 2

Phase 2 is a static state, meaning there is no interaction between the Entrant and the Monopolist.

If the Entrant has chosen the strategy 'Invest' for 60 seconds in Phase 1, the capacity building of the Entrant is complete. Phase 2 then results in a market division, and the payoffs per second are '2' for both the Entrant and the Monopolist (first column of the table).

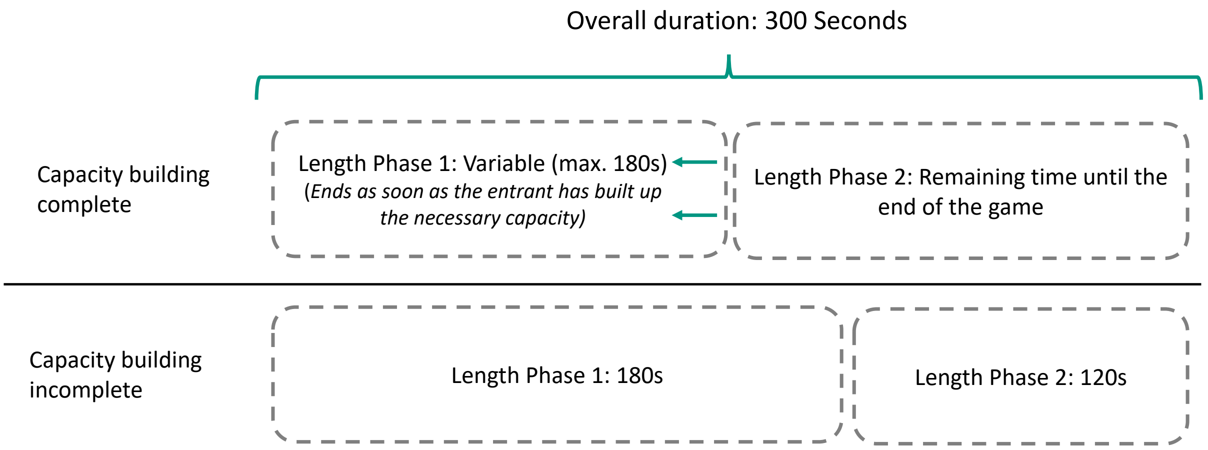
If the Entrant has not chosen the strategy 'Invest' at all or for less than 60 seconds in Phase 1, the Entrant's capacity building is incomplete, and they do not enter the Monopolist's market. In this case, the payoffs per second in Phase 2 are '0' for the Entrant and '3' for the Monopolist. Thus, depending on how the Entrant plays in Phase 1, the state in Phase 2 is determined (complete or incomplete capacity building).

Capacity building complete	**Capacity building incomplete**
2 , 2	0 , 3

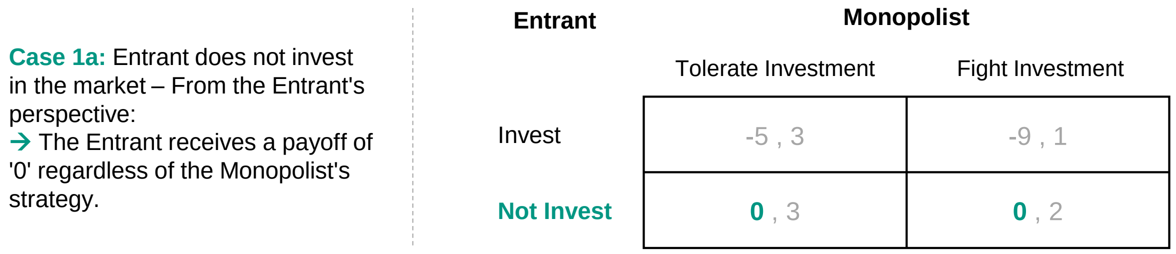
The table above shows the per-second payoffs for the Entrant (left number) and the Monopolist (right number). The total payoff from Phase 2 is calculated by multiplying the value from the table by the length (in seconds) of Phase 2.

For the Monopolist, it is advantageous if the Entrant does not enter the market (payoff of '3' instead of '2' per second in Phase 2). However, if the Monopolist tries to prevent market entry and makes it difficult for the Entrant to invest in Phase 1, it also reduces the Monopolist's own payoff (see the payoff table for Phase 1).

The length of Phase 2 depends on the length of Phase 1. The graphic below illustrates this situation:

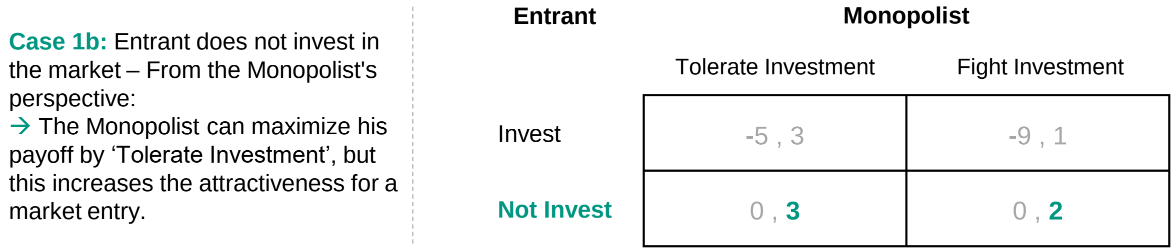


The payoff matrix of Phase 1 will be analyzed in more detail below:



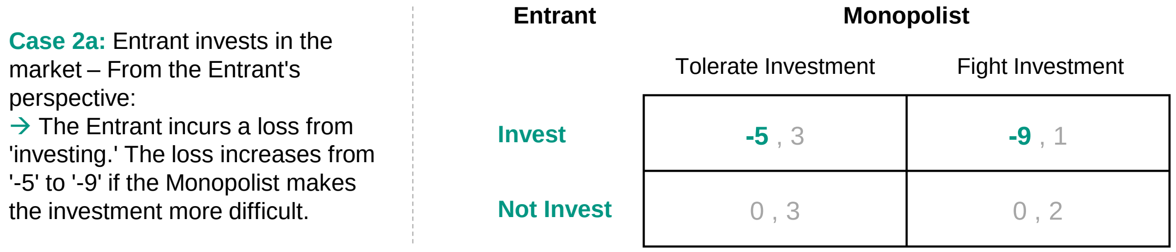
Case 1a: Entrant does not invest in the market – From the Entrant's perspective:
→ The Entrant receives a payoff of '0' regardless of the Monopolist's strategy.

Entrant	Monopolist	
	Tolerate Investment	Fight Investment
Invest	-5 , 3	-9 , 1
Not Invest	**0** , 3	**0** , 2



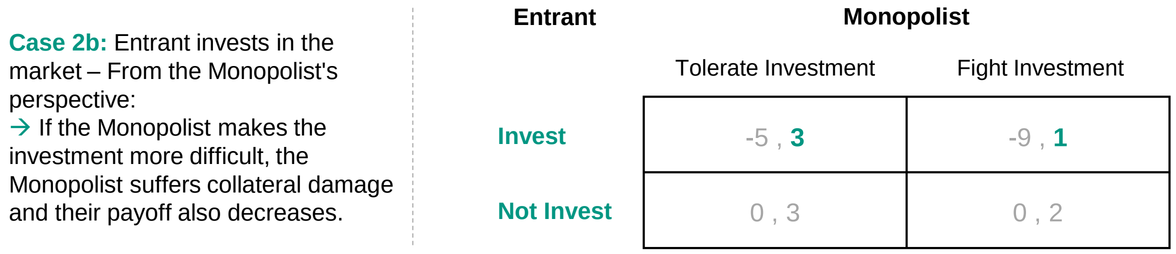
Case 1b: Entrant does not invest in the market – From the Monopolist's perspective:
→ The Monopolist can maximize his payoff by 'Tolerate Investment', but this increases the attractiveness for a market entry.

Entrant	Monopolist	
	Tolerate Investment	Fight Investment
Invest	-5 , 3	-9 , 1
Not Invest	0 , **3**	0 , **2**



Case 2a: Entrant invests in the market – From the Entrant's perspective:
→ The Entrant incurs a loss from 'investing.' The loss increases from '-5' to '-9' if the Monopolist makes the investment more difficult.

Entrant	Monopolist	
	Tolerate Investment	Fight Investment
Invest	**-5** , 3	**-9** , 1
Not Invest	0 , 3	0 , 2



Case 2b: Entrant invests in the market – From the Monopolist's perspective:
→ If the Monopolist makes the investment more difficult, the Monopolist suffers collateral damage and their payoff also decreases.

Entrant	Monopolist	
	Tolerate Investment	Fight Investment
Invest	-5 , **3**	-9 , **1**
Not Invest	0 , 3	0 , 2

The matrix below shows example results, aggregated after Phase 1 and Phase 2. Note that it is assumed here that the players maintain their initial strategies. Throughout the game, players can change their strategies at any time.

Example calculation of ('Always Invest', 'Always Tolerate') for the Entrant: In Phase 1, the Entrant plays the 'Invest' strategy, and the Monopolist plays the 'Tolerate Investment' strategy. Since the Entrant builds up capacity after 60 seconds, the length of Phase 1 is 60 seconds, and therefore their payoff in Phase 1 is: $-5 \times 60\ \text{s} = -300$.
The length of Phase 2 is then 240 seconds (300s - 60s), so the Entrant receives a payoff of: $240\ \text{s} \times 2 = 480$. The total payoff for the Entrant is thus $-300 + 480 = 180$.
If the Entrant always chooses the strategy 'Not Invest' in Phase 1, their final payoff is '0'. If the Entrant chooses the strategy 'Invest', their payoff depends on the Monopolist's strategy choice.

Game Procedure

- You will participate in two games in total: the presented continuous-time game and another game with the same basic structure. The exact specifics of the second game will be revealed immediately before it starts.
- Both games start with a practice round. Subsequently, you will play the game for five consecutive rounds.
- You will be assigned a player role (i.e., Monopolist or Entrant) at the beginning of the experiment. The player role does not change throughout the entire experiment.
- You will receive a variable payoff per game: 1250 payoff points in the game correspond to €1.00. Since the Entrant generally receives fewer points, they will receive an additional 700 points after each game.
- Before the game starts, you will need to answer some control questions.

B.2 Initial Understanding Test

1. How many seconds does a game last, i.e., Phase 1 + Phase 2 (number as answer)?
2. How long does Phase 1 last in seconds if the Entrant has not fully built up capacity in Phase 1 (number as answer)?
3. The Entrant took 100 seconds to build up capacity (–> 40s 'Not Investing', 60s 'Investing'). How long does Phase 2 last in seconds accordingly (number as answer)?
4. What is the total payoff of the Entrant if they never choose the 'Investing' strategy (number as answer)?
5. Can the total payoff of the Entrant also become negative (e.g., if the monopolist makes the investment more difficult)? That is, can it also be a disadvantage for the Entrant to invest in Phase 1?
   ○ Yes
   ○ No
6. Please choose 'Advantage for the Entrant' from the options below:
   ○ Advantage for the monopolist
   ○ Advantage for the Entrant
   ○ No advantage

B.3 Specific Reputation-Based Information

For Entrant

You will now play the game for five more rounds. Throughout all games, you will continue to take on the role of the Entrant. Your goal remains to maximize your payoff.

The following information is important for the five rounds:

There are five regions in a market, each with one specific monopolist. You will interact sequentially with a different monopolist in each region. Before interacting with a monopolist, you can view the game data of past Entrants with the monopolist using the table below. This will give you the opportunity to better assess the behavior of this monopolist (e.g., very aggressive vs. very benevolent).

Game Data of past Entrants with the Monopolist

Round	Payoff Entrant	Did Entrant enter market?	Proportion *Fight Investment* whole game	Proportion *Fight Investment* first 60s
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-

For Incumbent

You will now play the game for five more rounds. Throughout all games, you will continue to take on the role of the Incumbent. Your goal remains to maximize your payoff.

The following information is important for the five rounds:

You are a monopolist in one region and you will interact sequentially with five different Entrants. Your current opponent, the Entrant, will receive information about your previous game data with past Entrants before interacting with you. Since the current Entrant can see your previous game data and adjust their strategy accordingly, you have the opportunity to develop a strategy over multiple rounds.

Your Previous Game Data				
Round	Your Payoff	Did Entrant enter market?	Proportion *Fight Investment* whole game	Proportion *Fight Investment* first 60s
1	-	-	-	-
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-

B.4 Closing Questionnaire

For completing the survey, you will receive 4000 points or €3.20.

1. **What is your gender?**
   - ○ Male
   - ○ Female
   - ○ Prefer not to say

2. **How old are you?**
   - ○ <18
   - ○ 18-21
   - ○ 22-25
   - ○ 26-29
   - ○ >30

3. **What is your current level of education? (highest completed qualification)**
   - ○ Master/Diploma
   - ○ Bachelor
   - ○ Vocational Training
   - ○ High School Diploma
   - ○ None of the above

4. **In which field is/was your study?**
   - ○ Economics
   - ○ Engineering
   - ○ Natural Sciences
   - ○ Humanities
   - ○ Computer Science/Mathematics
   - ○ Other

5. **How would you rate your knowledge in the field of game theory?**
   - ○ Very good
   - ○ Good
   - ○ Basic
   - ○ Poor
   - ○ None

6. **How well did you understand the instructions and the gameplay?**
   - ○ Very well
   - ○ Well
   - ○ Basic
   - ○ Barely
   - ○ Not at all

7. **What was your strategy in your role?**

8. **To what extent did you change your strategy between the two games?**