Jordi Brandts · Antonio Cabrales
Gary Charness

Forward induction and entry deterrence: an experiment

Abstract The Dixit (Econ J 90:95–106, 1980) hypothesis that incumbents use investment in capacity to deter potential entrants has found little empirical support. Bagwell and Ramey (J Econ 27:660–680, 1996) propose a model where, in the unique game-theoretic prediction based on forward induction or iterated elimination of weakly-dominated strategies, the incumbent does not have the strategic advantage. We conduct an experiment with games inspired by these models. In the Dixit-style game, the incumbent monopolizes the market most of the time even without the investment in capacity. In our Bagwell-and-Ramey-style game, the incumbent also tends to keep the market, in contrast to the predictions of an entrant advantage. Nevertheless, we fin strong evidence that forward induction affects the behavior of most participants. The results of our games suggest that players perceive that the firs mover has an advantage without having to pre-commit capacity. In our Bagwell–Ramey game, evolution and learning do not drive out this

Financial support by the Spanish *Ministerio de Ciencia and Tecnología* (SEC2002-01352 and SEJ2006-11665-C02-01) and the Barcelona Economic Program of CREA and excellent research assistance by David Rodríguez are gratefully acknowledged. The authors thank Aurora García Gallego and Armin Schmutzler for helpful comments.

J. Brandts
Institut d'Anàlisi Econòmica, CSIC, Campus UAB, 08193 Bellaterra, Spain
E-mail: jordi.brandts@uab.es

A. Cabrales
Department of Economics, Universidad Carlos III de Madrid, c/ Madrid 126, 28903 Getafe, Spain
E-mail: antonio.cabrales@gmail.com

G. Charness (✉)
Department of Economics, 2127 North Hall, University of California, Santa Barbara, CA 93106-9210, USA
E-mail: charness@econ.ucsb.edu
Tel.: +1-805-8932412
Fax: +1-805-8938830

perception. We back these claims with data analysis and a theoretical framework for dynamics.

Keywords Entry · Capacity investment · Experiment · Forward induction · Equilibrium selection · First-mover advantage

JEL Classificatio Numbers C70 · C91 · D42 · L11 · L12

1 Introduction

Theoretical industrial organization has argued, formally since Dixit (1980) and intuitively since Bain (1956) and Modigliani (1958), that investment in capacity can be used to deter entry into markets. This issue has received considerable attention in the literature, as one of the leading instances of the importance of commitment in sequential games. Discussions of Dixit (1980) appear in virtually all the teaching manuals in the area (see e.g. Tirole 1989; Basu 1993; Martin 1993; Vives 1999). Despite this, there is little empirical evidence that incumbent firm actually invest in capacity to deter entry. Bagwell and Ramey (1996) provide a theoretical rationalization of this fact. The specifi model they put forward involves a different sequence of moves of the incumbent and the entrant than the one proposed by Dixit, as well as a partially-recoverable capacity or entry cost and the use of forward induction to select among several equilibria. The main result is that forward induction rules out the equilibria where the incumbent invests in capacity; as a result, the incumbent does not retain the whole market.[1]

We conduct experiments to test the extent to which this explanation is satisfactory and, more generally, to shed light on the strategic interaction between incumbents and entrants. Our work is an instance of the kind of interplay between theory and data that experiments make possible. The empirical validity of the Bagwell-Ramey prediction hinges on the extent to which participants in a laboratory follow the logic of forward induction.[2]

In this respect, the results from previous experimental studies on forward induction – reviewed in Sect. 3 – are mixed. We use two stylized games inspired by the game in Dixit (1980) and the game in Bagwell and Ramey (1996), hereafter B–R. In our Dixit entry game, only the incumbent may pre-commit. In this environment we fin a substantial rate of entry deterrence through pre-commitment, with the incumbent generally reaping the monopoly profit In our B–R game, an incumbent and a potential entrant make decisions in three stages. First, the incumbent may partially pre-commit to a given level of capacity. Then the entrant has the same choice, having observed the incumbent's choice. In the third stage both firm simultaneously decide whether to compete in the market, by then paying (the rest of) the capacity cost.

In our context, an entrant who pre-commits production must be signaling that she intends to become the monopolist, as pre-committing and then not producing is a dominated strategy. The entrant could have avoided pre-committing so as

[1] For a discussion of the Bagwell-Ramey model see also Vives (1999).

[2] For other examples of experimental work on theroretical industrial organization issues see Davis and Wilson (2000), Rustichini and Villamil (2000) and Abrams et al. (2000).

not to lose the pre-committed cost; in anticipation of this, the incumbent does not pre-commit. Thus, in this game the possibility of partial pre-commitment together with the logic of forward induction takes away the advantage that the incumbent has in the standard entry-deterrence model.

We fin that the full B–R prediction does not hold in our laboratory data. We fin that there is only limited pre-commitment by either the incumbent or the entrant, and, contrary to the prediction, the incumbent becomes the monopolist three times as frequently as the potential entrant. An explanation of the tilt towards the incumbent may be found in a commonly-held belief by many players that the firs mover has a strategic advantage, and thus should become the monopolist in the post-commitment game. Nevertheless, we also fin evidence that the choice of whether or not to participate in the market is significantl affected by the pre-installation decisions made, so that there is some appreciation of the notion of forward induction.

The quite moderate level of pre-commitment in our B–R design data is indeed suggestive, as it is consistent with the fiel evidence. However, in what sense is it consistent with the more frequent use of pre-commitment in the Dixit treatment? Perhaps the world is more like the B–R environment, involving pre-commitment by both firm and partially recoverable costs; nevertheless, behavior in the Dixit treatment may help us to understand behavior in the B–R environment. The preconception of the first-m ver advantage may be the starting point in both cases: in Dixit the pre-commitment signal is a rather clear one and, hence, is used more frequently; it may be perceived as the way to drive home the point of the incumbent's first-m ver advantage. In contrast, in B–R the meaning of the combined signals may seem open to interpretation, and so pre-commitment is used less frequently.

The perceived first-m ver advantage is only part of our explanation of the results. Even if players were boundedly rational, one might expect that the opportunity to play the game repeatedly could lead players to avoid dominated strategies, at least after enough time of play. An initial perception of a first-m ver advantage would then vanish over time. It is, however, well known that learning or evolution does not always lead to limiting outcomes that respect the iterated deletion of weakly-dominated strategies.[3] We provide some results that explain why the initial pattern of play is not driven out. We show theoretically that our game has outcomes that do not satisfy the iterated-deletion logic, but are asymptotically present under dynamics where better-performing strategies grow faster than worse-performing ones.

2 Implementation

2.1 The Dixit game

In our Dixit game, there are two firm that can produce a homogeneous good with constant, and equal, marginal cost. Production requires some initial investment; the total cost of this is F. The game has two stages: In the firs stage, the incumbent makes an observable capacity pre-installation decision: whether or not to irrecoverably sink a fraction $a < 1$ of the fi ed cost of production F. In the second stage,

[3] See, e.g., Fudenberg and Levine (1998), Samuelson (1997), Vega-Redondo (1996).

No pre-installation

		Entrant	
		Out	**In**
Incumbent	**Out**	0, 0	0, 1
	In	1, 0	-F, -F

Incumbent Pre-installs

		Entrant	
		Out	**In**
Incumbent	**Out**	-aF, 0	-aF, 1
	In	1, 0	-F, -F

Fig. 1 Subgames in Dixit sessions

the two firm simultaneously make a decision on whether to compete in the market. This decision involves paying whatever portion remains of the full fi ed cost; thus, even if the incumbent has not pre-committed, it can still pay F in the second stage. The second-stage competition is in prices; as a result, if both firm decide to actually pay the full capacity cost, the resulting price will be equal to the marginal cost. If only one of them chooses to pay the whole cost, then the outcome will be the monopoly outcome.

This process is illustrated in the two subgames shown in Fig. 1, with monopoly profit normalized to 1. We label the action where a player does not (does) pay the whole investment cost in the third stage as “Out” (“In”). Earnings from Bertrand competition in the market are zero so that if both firm enter the market they both earn -F. Inaction leads to zero profits

In both subgames, the action pairs (Out,In) and (In,Out) are the only (pure-strategy) Nash equilibria.[4] Given this, there are a variety of pure-strategy subgame-perfect Nash equilibria in this game. However, some of the outcomes are *not* possible under subgame-perfection with pure strategies. The incumbent can guarantee itself zero profit by not pre-committing and then choosing Out in all subgames; thus, the incumbent cannot obtain -aF in equilibrium. Also, since the action pairs (Out,Out) and (In,In) are not pure-strategy equilibria in any subgame, the profi pairs (0,0) and (-F, -F) cannot occur as part of a pure-strategy subgame-perfect Nash equilibrium.

But either of the two profi pairs (1,0) and (0,1) is consistent with subgame perfection. Intuitively, if both firm believe that the incumbent will be the winner in the second stage, this leads to a Nash equilibrium where the incumbent is a monopolist in the second stage and the entrant chooses to not pre-commit and stays out of the market. The reverse happens if the firm believe that the entrant will ‘win’ after all first-stag outcomes.

Matters change under certain refine equilibrium notions of subgame perfection, which select a unique equilibrium from the set. The forward-induction argument pertains to the incumbent’s pre-installation decision: The incumbent can guarantee himself a payoff of 0, independently of what the entrant does, by not pre-installing and then choosing Out. Any strategy under which a player pre-installs and then chooses Out is weakly dominated, as it would yield a lower payoff. When the entrant observes a pre-commitment by the incumbent, he must conclude that the incumbent will play In, and so responds optimally with Out. As a consequence, the incumbent will always (optimally) pre-commit, and then play In. Therefore, by forward induction, only the outcome (In,Out) is plausible.

The corresponding reduced-normal form is shown in Table 1; it further illustrates the selection rationale presented above. The reasoning we present holds for all positive values of a and F. We chose $a = 1/2$ and $F = 1$, transforming the

[4] We will examine mixed strategies in detail in Sect. 5.

Table 1 The Dixit game in reduced-normal form

	OO	**O**I	**I**O	**I**I
NO	60,60	60,60	60,120	60,120
NI	120,60	120,60	0,0	0,0
PO	30,60	30,120	30,60	30,120
PI	120,60	0,0	120,60	0,0

payoffs by adding 1 to each payoff and then multiplying every payoff by 60. The incumbent (entrant) is the row (column) player. P (N) denotes pre-installation (no pre-installation). The letters O and I stand for Out and In.

We can also solve the game using the iterated deletion of weakly-dominated strategies. Note that strategy **P**O, the incumbent pre-committing and then choosing Out, is strictly dominated by strategy **N**O. With **P**O eliminated, the entrant has two weakly-dominated strategies: **O**I (by **O**O), and **I**I (by **I**O). Once these have been eliminated, strategies **N**O and **N**I are weakly dominated by **P**I. This strategy corresponds to the incumbent pre-installing and then choosing In. So the prediction is again that the incumbent will pre-commit and keep the market.

2.2 The B–R game

In our B–R game there are also two firm that can produce a homogeneous good with constant, and equal, marginal cost. In the firs and second stages, the incumbent and the entrant make sequential and observable capacity pre-installation decisions. After observing the incumbent's choice in the firs stage, the entrant then chooses between the same two options. In the third stage, the two firm simultaneously make a decision on whether to compete in the market. Thus, even if a fir has not pre-committed, it can still pay F in the third stage.

There are four possible pre-commitment combinations; Fig. 2 presents the four possible subgames for our B–R sessions using a general payoff representation with monopoly profit normalized to 1. As for the Dixit game, earnings from Bertrand competition in the market are zero so that if both firm enter the market they both earn -F and inaction leads to zero profits

In our B–R game, forward induction gives the second mover an advantage. The argument goes as follows: At the time of pre-commitment an entrant can guarantee

No Pre-installation

		Entrant	
		Out	**In**
Incumbent	**Out**	0, 0	0, 1
	In	1, 0	-F, -F

Entrant pre-installs

		Entrant	
		Out	**In**
Incumbent	**Out**	0, -aF	0, 1
	In	1, -aF	-F, -F

Incumbent pre-installs

		Entrant	
		Out	**In**
Incumbent	**Out**	-aF, 0	-aF, 1
	In	1, 0	-F, -F

Both pre-install

		Entrant	
		Out	**In**
Incumbent	**Out**	-aF, -aF	-aF, 1
	In	1, -aF	-F, -F

Fig. 2 Subgames in Bagwell–Ramey sessions

himself a payoff of 0 by not committing and then choosing Out. Thus, any strategy under which a player pre-commits and then chooses Out is 'irrational', as it yields a lower payoff.[5] Thus, according to the forward-induction logic, since the entrant does not play 'irrational' strategies, when the incumbent observes a pre-commitment by the entrant, he must conclude that the entrant intends to become the monopolist and will play In, and so the incumbent will respond optimally with Out. As a consequence, the entrant will always (optimally) pre-commit, and then play In.

In contrast, pre-commitment does not have the same signaling value for the incumbent firm An incumbent that pre-committed could, mistakenly, have believed that the entrant was not going to pre-commit (thus, expecting to become the monopolist). So, when faced with the unambiguous subsequent pre-commitment choice of the entrant, the incumbent should yield and leave the monopoly profit to the entrant. An incumbent who has not pre-committed has an even stronger reason to yield in front of a pre-committed entrant. In anticipation of all this, the incumbent does not pre-commit and leaves the market to the entrant. Therefore, by forward induction, only the outcome (Out,In) is plausible.

The corresponding reduced-normal form is shown in Table 2. Once again, we chose $a = 1/2$ and $F = 1$, and we then transformed the payoffs by adding 1 to each payoff and then multiplying every payoff by 60. In this Table, the firs letter (**N** or **P**) of the three-letter groups in the leftmost column refer to whether the first-m ver pre-installed, while the next two letters (O or I) refer to whether the firs mover then competed the market if the entrant did or did not pre-install, respectively. The firs two letters of the four-letter groups in the top row refer to whether the second mover chose to pre-install, conditional on whether the firs mover pre-installed; the last two letters refer to whether the entrant then conditionally competed in the market.

The iterated deletion of weakly-dominated strategies leads us here to the same prediction as does forward induction, that the entrant wins the market with or without pre-committing, and the incumbent does not pre-commit. The interested reader can work through the procedure or can fin a detailed description in Brandts et al. (2005). It is worth mentioning that, even with just two rounds of deletion of dominated strategies, the entrant can guarantee his favorite outcome (Out,In), as all the equilibria in the game that remain after two rounds of deletion produce that outcome.

As we have seen, in our case the forward-induction rationality requirements imposed by Bagwell and Ramey are relatively mild. Players should avoid weakly-dominated strategies, and their opponents should be aware of this and take it into account when making their decisions.[6,7]

[5] More precisely, it is weakly dominated. In general, definition of rationality under payoff uncertainty will imply that players do not use weakly-dominated strategies; see, e.g. Dekel and Fudenberg (1990) or Börgers (1994).

[6] An alternative definitio by Van Damme (1989), p. 485) states that when: "player i chooses between an outside option or to play a game G of which a unique (viable) equilibrium e^* yields this player more than the outside option, only the outcome in which i chooses G and e^* is played is plausible." It is easy to see that this (stronger) notion yields the same result in this game.

[7] We should also note that there are a variety of subgame-perfect equilibria; in some of them the incumbent pre-commits. For example, suppose both agents expect (Out,In) in all of the second-stage subgames when the incumbent does not pre-commit, and they expect (In, Out) if the incumbent pre-commits. Then, it is optimal for the incumbent to pre-commit. Similarly one can construct subgame-perfect equilibria with the entrant pre-commiting, as well as with no agent pre-commiting.

Table 2 The Bagwell-Ramey game in reduced-normal form

	NNOO	**NN**OI	**NN**IO	**NN**II	**NP**OO	**NP**OI	**NP**IO	**NP**II	**PN**OO	**PN**OI	**PN**IO	**PN**II	**PP**OO	**PP**OI	**PP**IO	**PP**II
NOO	60,60	60,60	60,120	60,120	60,60	60,60	60,120	60,120	60,30	60,30	60,120	60,120	60,30	60,30	60,120	60,120
NOI	60,60	60,60	60,120	60,120	60,60	60,60	60,120	60,120	120,30	120,30	0,0	0,0	120,30	120,30	0,0	0,0
NIO	120,60	120,60	0,0	0,0	120,60	120,60	0,0	0,0	60,30	60,30	60,120	60,120	60,30	60,30	60,120	60,120
NII	120,60	120,60	0,0	0,0	120,60	120,60	0,0	0,0	120,30	120,30	0,0	0,0	120,30	120,30	0,0	0,0
POO	30,60	30,120	30,60	30,120	30,30	30,120	30,30	30,120	30,60	30,120	30,60	30,120	30,30	30,120	30,30	30,120
POI	30,60	30,120	30,60	30,120	120,30	0,0	120,30	0,0	30,60	30,120	30,60	30,120	120,30	0,0	120,30	0,0
PIO	120,60	0,0	120,60	0,0	30,30	30,120	30,30	30,120	120,60	0,0	120,60	0,0	30,30	30,120	30,30	30,120
PII	120,60	0,0	120,60	0,0	120,30	0,0	120,30	0,0	120,60	0,0	120,60	0,0	120,30	0,0	120,30	0,0

3 Previous experimental literature

One may think that most people will not be able to follow the kind of logic that forward induction involves. However, a number of experimental studies report results that are favorable to forward induction. Cooper et al. (1992) analyze experiments involving a choice between an outside option for one of the players and a 2×2 coordination game, with two Pareto-ranked equilibria. They analyze the case where forward induction and a simple dominance argument lead to the same prediction, and their results are consistent with this kind of forward-induction concept. Cooper et al. (1993) present results from an experimental game, where there is an outside option for one of the players and a symmetric Battle-of-the-Sexes game is played if this outside option is foregone. When forward induction coincides with simple dominance the results are again consistent with these notions. However, in a second treatment, an outside option that does not dominate one of the other choices in the Battle-of-the-Sexes affects play in the same manner as an outside option that does dominate.

Van Huyck et al. (1993) consider an experimental setting in which players participate in an auction for the right to play a coordination game. Their results exhibit two key features: The price in the auction is high enough for a forward induction argument (different from dominance here) to select the Pareto-efficien equilibrium, and subjects' play in the coordination game actually selects this equilibrium. Broseta et al. (2003) report evidence favorable to forward induction in an experiment in which subjects firs bid in an auction and subsequently play a game with several equilibria. The results presented in Brandts and Holt (1995) support forward induction in a very simple game where it is equivalent to the elimination of dominated strategies, but not in two more demanding environments.

There is also evidence that suggests that forward induction is not an important behavioral force. Schotter et al. (1994), Nagel (1995), Capra et al. (1999) and McKelvey and Palfrey (1992) study experimental games for which the application of iterated dominance selects one outcome and obtain results that are not consistent with the predictions of the iterated dominance argument. Balkenborg (1998) reports results from a game in which backward induction yields an outcome different from that resulting from forward induction arguments; less than 20% of all outcomes are consistent with the forward-induction outcome.

Overall, it seems that the jury is still out on the matter. We are still far from having delineated the circumstances under which forward induction is and is not consistent with people's behavior in the laboratory. Only a large accumulation of studies will make it possible to obtain a global view on the empirical usefulness of forward induction. Given this context, we feel it is useful to study the predictive validity of forward induction in an environment that is of interest in relation to an important issue in industrial organization.

4 Experimental design & results

4.1 The experiments

We conducted our sessions at Universitat Pompeu Fabra in Barcelona. Recruiting was accomplished via announcements posted in university buildings; participants included students in economics, business, law, political science, and the humanities. There were 12 (different) people in each of three Dixit sessions and six B–R sessions, or 108 participants in all. There were two separate groups of six in each session (although this was not mentioned); this separation ensures two completely-independent observations for each session, for the purpose of statistical tests.

A session consisted of 25 periods in which people were matched and randomly re-matched in pairs, within the six-person subgroups. People received their earnings over the 25 periods played in a session, with nominal payoffs re-normalized for experimental purposes. Average payoffs for the 2-h sessions were around 2,500 pesetas, including a show-up fee of 500 pesetas (at the time, $1 exchanged for approximately 180 pesetas).

We allowed participants' roles to change, re-drawing these each period. We felt that this scheme offered the best chance for people to experience each role and perhaps to understand the subtleties involving the strategic relations between the two firms We note that abstract terms were used, rather than labels such as "incumbent" and "entrant".[8]

Our games were played using the strategy-elicitation method. This means that the incumbent had to choose whether to pre-install or not and also whether to complete the investment or not for each of the entrant's possible pre-installation decisions in the second stage. Similarly, the entrant had to make a pre-installation decision for the incumbent's two possible pre-installation decisions, as well as a complete investment decision for the two possible resulting pre-installation decisions of the two players. Essentially, participants submit strategies for the reduced normal-form game, as they do not have to say what they would do at nodes that cannot be reached given their own strategies.[9]

In the Dixit sessions, the incumbent stated his choice concerning pre-installation, as well as his choice (In or Out) in the resulting subgame. The entrant stated a choice (In or Out) if the incumbent had pre-installed and also if the incumbent had not pre-installed. After the data for the period was matched up, each participant was informed of the payoff outcome for that period.

In the B–R sessions play proceeded as follows: Each incumbent stated whether he wished to pre-install, and also stated a choice (In or Out) for each of the two cases regarding possible pre-commitment by the entrant. Each entrant made choices without being informed of the paired incumbent's choices and stated whether she wished to pre-install if the incumbent had pre-installed and also whether she wished to pre-install if the incumbent had not pre-installed. Given her own pre-installation

[8] The full instructions can be found in the supplemental materials on the web.

[9] We acknowledge that the strategy method is controversial. For example, while Brandts and Charness (2000) fin that the strategy method does not affect behavior, Brandts and Charness (2003) fin that punishment levels are twice as high for responses to actual moves compared to contingent responses (although the treatment effect regarding deception is nevertheless present in both cases). The trade-off is between the quantity of data that can be gathered and potential problems with the quality of these data. Our concern here was that we would have very few observations at certain nodes with direct responses, so we elected to gather information about complete strategies. In principle, one should expect the strategy-elicitation method to evoke a more thoughtful response. However, since having one respond to all particular actions by the player with whom one is matched might well weaken the signaling value of pre-commitment and require one to make introspective inferences, we feel that the behavioral sensitivity to pre-installation decisions may represent a lower bound for the effects of forward-induction logic.

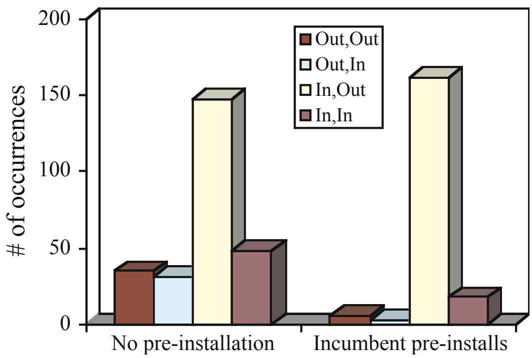

Fig. 3 Dixit outcomes

choices, she also stated a choice (In or Out) for each of the two cases regarding possible pre-installation by the incumbent.

4.2 Predictions

In our context the most fundamental question is, arguably, which of the two players captures the market. In line with the discussion in Sect. 2, the models predict that the incumbent will tend to capture the market in the Dixit game, but that the entrant will tend to capture the market in the B–R game.[10]

Regardless of the nature of the market outcomes, if forward induction or the iterated elimination of weakly-dominated strategies has any influenc in our experimental games, pre-installation choices should affect firms subsequent decisions to participate in the market: A fir should be more likely to participate in the market if it has pre-installed, and less likely to participate if the other fir has pre-installed.

4.3 Experimental results

Our firs focus is the pattern of market capture and pre-commitment. Figure 3 shows the total number of occurrences of each of the four possible market outcomes in each of the subgames in the Dixit sessions.[11]

Overall the incumbent and the entrant become the monopolists in 69 and 8% of the cases. Recall that here only the incumbent can pre-install; with pre-installation, the incumbent becomes the monopolist in 88% and the entrant in only 2% of the instances. Even without pre-installation, the entrant tends to yield to the incumbent, who becomes the monopolist 56% of the time, compared to 12% for the entrant. The firs mover chooses to pre-install 42% of the time. When the incumbent does not pre-install, incumbent and entrant complete the investment in 75 and 30% of the cases, whereas with pre-installation these figure are 95 and 5%.

[10] Exhaustive non-parametric tests (using group-level data) of formal hypotheses can be found in Brandts et al. (2005).

[11] The distribution for each of the six-person groups in the sessions is shown in the supplemental web materials.

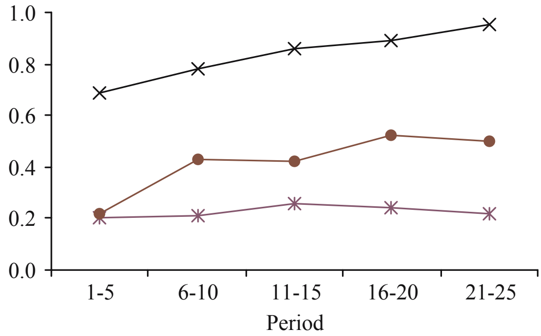

Fig. 4 Choices over time – Dixit sessions

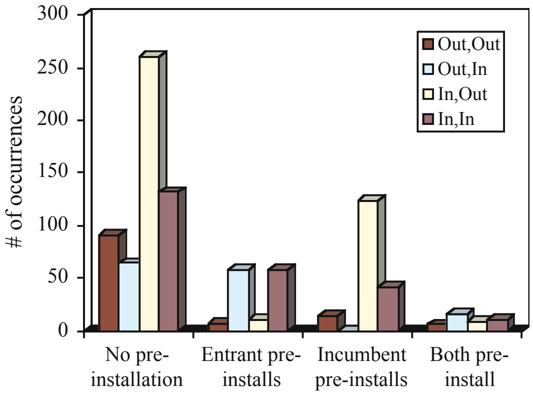

Fig. 5 B–R outcomes

Figure 4 displays entry and pre-installation choices over time in the Dixit sessions: IC refers to the rate of incumbent competition, EC refers to the rate of entrant competition, and IP refers to the rate of incumbent pre-installation. Incumbents were increasingly likely to compete in the market in later periods, with the rate reaching 95% in the last fi e periods. The pre-installation rate also increases over time, while the rate of entrant competition is relatively stable.

Figure 5 shows the total number of occurrences of each of the four possible market outcomes in each of the subgames in the B–R sessions.[12]

Most of the outcomes (61%) involved the subgame in which neither fir has chosen to pre-install. The incumbent was the only pre-installer 20% of the time, while the entrant was the only pre-installer 15% of the time. The subgame in which both firm pre-install was reached less than 5% of the time. Overall, the incumbent pre-installed 24% of the time and the entrant pre-installed 19% of the time; this compares with the 42% pre-installation rate in the Dixit sessions.

With respect to market capture, in the B–R games the result is that the entrant becomes the monopolist only 15% of the time; by comparison, the incumbent becomes the monopolist in 45% of the cases. Coordination failure is substantial

[12] The distribution for each of the six-person groups in the sessions is shown in the supplemental web materials.

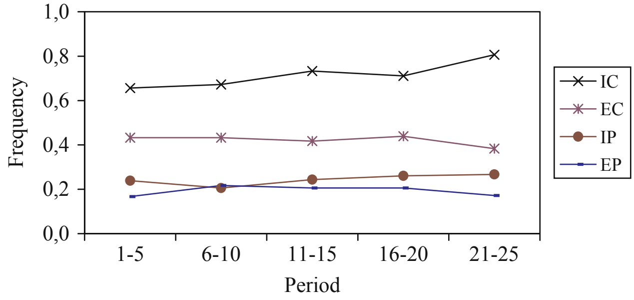

Fig. 6 Choices over time – B–R sessions

with no one in the market 13% of the time and both players in the market 27% of the time. Note, however, that together this 40% is still below the rate of coordination on the incumbent becoming the monopolist.

Is the incumbent's success achieved through his pre-commitment?[13] When there is no pre-installation, the incumbent becomes the monopolist 48% of the time (the corresponding figur for the entrant is 12%).[14] When only the incumbent pre-installs, he becomes the monopolist 69% of the time (the corresponding figur for the entrant when only the entrant pre-installs is 44%), so that pre-commitment does help the incumbent. Taken together these facts allow us to say that the incumbent wins the market frequently and rather effortlessly, more so than the entrant, in contrast to what theory suggests.

Figure 6 displays entry and pre-installation choices over time in the B–R sessions:

In this Figure, IC and EC refer to the respective rates of incumbent and entrant competition, and IP and EP refer to the respective rates of incumbent and entrant pre-installation. We see a slight upward trend for the incumbent pre-installation and entry rates over time, while the corresponding rates for the entrant are either fla or slightly declining over time.

We now focus on different comparisons involving observed frequencies in the different subgames, which we use to more clearly highlight the degree of support for the general notion of pre-commitment as a tool for market control. In the B–R games, we start by observing that the incumbent's pre-installation has only a minor impact on the entrant's pre-installation rate: The entrant chooses to pre-install 17% of the time when the incumbent pre-installs, compared to 21% of the time when the incumbent does not pre-install.

At this point one might be tempted to be concerned that the strategic principles put forward in game-theoretic analysis have no effect. Nevertheless, pre-commitment occurs frequently enough in our data to warrant an examination of how firms pre-commitment patterns and their relation to fina participation decisions affect subsequent choices.

[13] In this regard, it is also conceivable that the incumbent may believe that the entrant either may not be able to carry out the necessary rounds of iterated deletion or that the entrant believes that the incumbent, if he pre-installs, is unable to do so. In either case, there may be suff cient uncertainty about the 'rationality' assumption to make Out the prudent choice for the entrant, particularly if the incumbent pre-installs.

[14] Note that the orderings of these percentages (with no entrant pre-installation) is qualitatively similar to those in the Dixit sessions (56 and 12%, for the respective comparisons).

Table 3 Dixit market entry, conditional on pre-installation

Incumbent pre-installs?	Incumbent's entry rate (%)	Entrant's entry rate (%)
No	74.7	30.3
Yes	95.2	11.1

Table 4 B–R market entry, conditional on pre-installation

Players pre-installing	Incumbent's entry rate (%)	Entrant's entry rate (%)
Incumbent only	92.1	23.0
Neither	71.7	35.8
Both	46.3	63.4
Entrant only	51.1	87.2

Table 3 shows that the incumbent in the Dixit sessions easily wins the market even without pre-installation. Nevertheless, we see that an incumbent fir is about 20% points more likely to compete in the market if it pre-installs, while an entrant is about 20% points less likely to compete in the market if the incumbent pre-installs:

Table 4 shows the proportion of eventual entry (choices of In) into the market for each player in the B–R sessions, contingent on pre-installation decisions. We observe the following pattern: When only one of the players pre-installs that player completes the investment more frequently and, hence, can be thought of having an advantage in capturing the market. When neither pre-installs the incumbent completes the investment more frequently than the entrant; when both pre-install, the investment rate is somewhat higher for the entrant.

Notice also that a player is most likely to enter the market when she alone has pre-installed and is much less likely to invest when only her counterpart has pre-installed. Market-entry rates are at intermediate levels when neither player pre-installs or when both players pre-install. The only reversal in the ascending (or descending) pattern in a column occurs because incumbents who have pre-installed are more likely to be deterred from market entry than incumbents who did not pre-install (and who may be oblivious to notions of forward induction). While the aggregate choices of both roles were affected by pre-installation decisions, this may just not be enough to yield the B–R predictions, since the rate of entrant pre-installation is low.

4.4 Tests of statistical significanc

While we cite summary statistics for our data, we must be careful when performing a statistical analysis, given the 25 observations for each participant and the high degree of interaction within each group. Since each group never interacts with any other, we can use group-level data to conservatively test for patterns regarding fir captures of the market. In the Dixit sessions, the incumbent became the monopolist more frequently (overall) than did the entrant in all six of the groups. A simple two-tailed binomial test find behavior this extreme to be significan at $p = 0.031$; the Wilcoxon signed-rank test, which considers the magnitude of the differences across groups as well as the direction, rejects this as random behavior at $p = 0.004$.

Table 5 Probit regressions for market entry: marginal effects

	Dixit		B–R	
	Incumbent	Entrant	Incumbent	Entrant
Preinstall	0.173**	–	0.165***	0.498***
	(0.076)	–	(0.045)	(0.041)
Other Preinstall	–	−0.049	−0.278***	−0.170***
	–	(0.061)	(0.051)	(0.063)
Round	0.011***	0.002	0.007***	−0.002
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	450	450	900	900
Number of subjects	36	36	72	72
Pseudo R^2	0.151	0.004	0.076	0.132

Standard errors in parentheses, clustered by groups
* significan at 10%; ** significan at 5%; *** significan at 1%. The dependent variable is the market-entry decision

Thus, there is also a strong tendency for the incumbent to capture the market in the Dixit environment, in this case as predicted by forward induction.

In the B–R sessions, we fin that the incumbent became the monopolist more frequently (overall) than did the entrant in 11 of the 12 groups. A two-tailed binomial test find this significan at $p = 0.013$, while the Wilcoxon signed-rank test rejects this as random behavior at $p = 0.004$, but in the direction *opposite* to that predicted by the Bagwell and Ramey model. There is a significan tendency for the incumbent to control the market, rather than the entrant.

To identify the effect of own (and other) pre-installation on one's market-entry decision, we perform probit regressions with standard errors clustered at the group level.[15] The marginal effects for the Dixit and B–R games are reported in Table 5.

There is always a significan marginal effect from pre-installation, particularly for the entrant in the B–R sessions. There we also observe a significan and negative marginal effect from the other player choosing to pre-install. In the Dixit sessions, an entrant is less likely to enter the market if the incumbent has pre-installed, but this effect is not statistically significant Thus, it appears that pre-installation generally affects the choices regarding market entry. Incumbents are more likely to enter over time, while there is no significan trend for entrants.

5 Strategies and dynamics

5.1 Strategy choices

Our results may appear puzzling given the theoretical discussion in Sect. 2. After all, the solution via forward induction (or deletion of dominated strategies) looks sensible. One obvious explanation is that the rationality of experimental subjects is lower than what is necessary for achieving the theoretical outcome. But one may wonder just how irrational these agents are. Up to now we have provided a rather synthesized view of the results. Since we elicit strategies for each player, to obtain a more in-depth view of subjects' behavior we can also examine the frequency of

[15] Our results were robust to a variety of specifications including other choices for clustering.

Table 6 Strategy frequencies and ex post expected earnings

Incumbent Strategies			*Entrant Strategies*		
Strategy	Frequency	Exp. Earnings	Strategy	Frequency	Exp. Earnings
Dixit sessions					
NI	0.433	80.0	OO	0.576	60.0
PI	0.400	102.5	IO	0.278	42.8
NO	0.147	60.0	OI	0.089	37.2
PO*	0.020	30.0	II	0.058	17.9
Bagwell–Ramey sessions					
NII	0.333	64.1	**NN**OO	0.422	60.0
NIO	0.192	70.9	**NN**II	0.123	30.0
NOO	0.178	60.0	**NN**IO	0.122	42.3
PII	0.152	81.6	**PN**IO	0.069	59.0
PIO	0.072	80.0	**PP**II	0.062	54.0
NOI	0.053	51.0	**NN**OI	0.052	47.7
POI	0.011	36.4	**PN**II	0.028	46.7
POO*	0.008	30.0	**NP**IO	0.022	55.0
			NPII	0.021	37.4
			NPIO*	0.021	35.0
			PPIO*	0.019	51.7
			PNOO*	0.011	37.3
			NPOO*	0.010	52.7
			PPOI*	0.008	32.3
			PPOO*	0.006	30.0
			PNOI*	0.003	25.0

*Indicates that a strategy is at least weakly dominated in the f rst round of iterations. The strategy **PN**IO, for example, means the entrant pre-installed and played In if the incumbent didn't pre-install, but didn't pre-install and played Out if the incumbent did pre-install

play for each strategy, as well as its expected earnings. Table 6 displays this information for the B–R and Dixit sessions, where strategies have been ordered by the frequency of their choice. Expected incumbent (entrant) profit are calculated using the observed frequencies of entrant (incumbent) strategies in the population.[16]

While the predicted strategies are not always the most frequently-chosen ones, there is nevertheless a strong positive relationship between a strategy's profitabilit and how frequently it is chosen, particularly for entrant strategies. The Spearman rank-order correlation coefficien (see Siegel and Castellan 1988) between frequency of use and the profitabilit of entrant strategies in the B–R sessions is $r_S = 0.5258$, significan at $p = 0.018$ on a one-tailed test. In the Dixit sessions, profitabilit and frequency are in perfect positive alignment, as would happen with an ex ante probability of $p = 0.042$. The correlation for the incumbents is a bit weaker, but is still marginally significant the Spearman test gives a positive correlation that is significan at $p = 0.054$ and $p = 0.100$ in the B–R and Dixit sessions, respectively, despite the few observations. Note that no strategy that is at least weakly dominated in the firs round of iterations is ever played more frequently in its category than any strategy not weakly dominated in the firs round.

[16] The number of times each strategy was chosen in each group is shown in the supplementary material on the web.

5.1.1 Dixit sessions

The incumbent strategy that should be played according to forward induction in the Dixit sessions is **PI**, pre-install and compete in the market. This strategy is very profitable yielding over 85% of the maximum feasible profi of 120, and is played 40% of the time; there is a clear positive trend as well.[17] The most common incumbent strategy is **NI**, the one that presumes that the first-m ver has the advantage even without pre-installing. This policy provides a payoff that is substantially lower than the payoff from playing **PI**. **NO**, the safe strategy, is chosen with an overall frequency of 14%, but with a strong downward trend. The strictly-dominated strategy, **PO**, is only played with frequency 2% and appears to be vanishing.

The predicted entrant strategy in the Dixit sessions is the safe one, OO. Deferring to the incumbent is by far the most common strategy and is easily the most profitabl strategy; it also gets decidedly more popular over time. Strategy IO, deferring if the incumbent pre-installs but competing otherwise, is played about one-quarter of the time even though its expected payoff is poor. The other two strategies are rarely played. Thus, in the relatively simple Dixit game, we see behavior largely operating in concordance with the forward induction prediction.[18]

5.1.2 B–R sessions

The two incumbent strategies that should be played according to forward induction are **N**OO and **N**IO. **N**OO, the completely safe strategy, is chosen almost 18% of the time. **N**IO is played 19% of the time, and does best of all the no-pre-installation strategies. So the incumbent strategies consistent with B–R equilibrium are played 37% of the time.

The most common incumbent strategy is **N**II; choosing **N**II is consistent with the simple view that everyone knows that the firs mover has the advantage. Nevertheless, the firs mover could increase own payoffs by choosing **N**IO, avoiding the market if he observes pre-installation by the second player. He would earn even more by just pre-installing and playing **P**IO or, even better, **P**II. Pre-installing really clears the way for the incumbent's market dominance here. The most profit able incumbent strategy, **P**II, is chosen 15.2% of the time (with an increasing time trend). **P**IO instead avoids the market if the second player pre-installs, and offers a very good expected payoff; it is chosen 7% of the time. Finally, **N**OI, **P**OO, and **P**OI are played with such low frequencies that one may view them as errors or experiments.

The most common entrant strategy is the completely safe **NN**OO, which consists of never pre-installing and always staying out of the market. It was chosen more than three times as frequently as any other strategy; in fact this strategy pays the best ex post. The next-most-common entrant strategies are **NN**IO and **NN**II.

[17] The time trends for this and other strategies in the Dixit and B–R sessions can be found in Brandts et al. (2005).

[18] The quantal-response equilibrium model proposed by McKelvey and Palfrey (1995) has been used successfully to explain behavior in a variety of games (see Goeree and Holt 2001. Here the results of the simulations performed by *Gambit* show that it does a moderately good job of explaining behavior, since it predicts behavior consistent with forward induction. More precisely, it predicts the incumbent will choose strategy **PI**, and the entrant will mix between strategies **OO** and **IO** with equal weights.

While **N**NIO (don't pre-install in either case, choosing In if and only if the incumbent does not pre-install) seems not unreasonable, it receives an expected payoff of only 42.3, since 72% of the incumbents choose In in subgame AC. It is better to play **PN**IO, as fewer incumbents choose In when the entrant pre-installs; this is nearly as profitabl as the safe strategy and is played 7% of the time. **NN**II, the pure second-mover advantage play, does quite poorly, with an expected payoff of 30.0.[19]

Why doesn't the iterated elimination work in the B–R sessions? It appears from our data that subjects do largely avoid weakly-dominated strategies. Recall that the only dominated strategy for the incumbent is **P**OO. For the entrant, there are seven strategies that are dominated in the firs round and none of these are played very often. The highest frequency is 2.1%; collectively this is 7.8%, which is still quite low, particularly when one considers that they might have been used to test the response of the incumbent to different modes of pre-commitment.

But, crucially for the lack of empirical success of the B–R predictions, the subsequent round of deletion fares much more poorly in the data.[20] The firs and the fourth most used strategies for the incumbent are **N**II and **P**II (frequencies 33.3 and 15.2%), which are dominated if the firs round of deletion goes through. So given that those strategies dominated in the firs round are used so rarely, how do these relatively-common other strategies survive? The answer is that the strategies for the entrant that make this domination apparent are also quite infrequent. Hence, a pre-conception, like the notion of the firs mover having an advantage can completely stall the progress of iterated deletion. But even if agents are (mildly) boundedly rational, it may be possible for them to learn to avoid dominated strategies via the repeated interaction. In Sect. 5.2 we will formally show that this argument is misleading.

5.2 Dynamics

We mentioned earlier that it is now widely recognized that learning by boundedly rational agents does not necessarily eliminate weakly-dominated strategies. As the intuitive arguments suggest, under learning or evolution a strategy that does worse than another one will tend to be observed less frequently. But if the strategy against which the dominated strategy does poorly is also decreasing over time (so that the advantage of the dominating one becomes smaller as well), the decrease of the

[19] The quantal-response equilibrium model proposed by McKelvey and Palfrey (1995) has been used successfully to explain behavior in a variety of games (see Goeree and Holt 2001). We have applied it to both our Dixit and B–R games, using simulations performed by *Gambit* (http://econweb.tamu.edu/gambit). In the Dixit case, the QRE model does a moderately good job of explaining behavior, since it predicts behavior consistent with forward induction. More precisely, it predicts the incumbent will choose strategy **P**I, and the entrant will mix between strategies **O**O and **I**O with equal weights. However, it is not a good predictor of behavior in the B–R game, as it predicts that the incumbent will mix equally between strategies **N**OO and **N**IO and the entrant will mix between **PP**II, **PN**IO, **PP**IO and **PN**II, with larger weights on the firs two strategies. *Gambit* computes QRE by choosing errors independently from an extreme value distribution with parameter λ. If one leaves complete freedom in the error distribution, QRE can match *any* observed frequency distribution of play (as shown in Haile et al. 2003).

[20] This is in line with previous experiments and simulations (e.g., Nagel 1995; Roth and Erev 1995) that indicate that people are limited in their ability to work through many levels of iterated removal.

dominated strategy will be slower and slower, so that it can stabilize at a positive level.

We now show, more formally within a deterministic-dynamics framework, that the equilibria with iteratively-dominated strategies can survive in the long run under learning in this game.[21]

5.3 Deterministic dynamics

We must firs introduce some notation: Let S_i be the set of pure strategies for an agent i and s_i be a generic member of that set. Let S_{-i} be the set of strategies for the opponent of i and s_{-i} be a generic member of that set. The payoff function for agent i will be denoted by $u_i(s_i, s_{-i})$. For mixed strategies, let $x_i \in \Delta_i$ be a mixed strategy for agent i, where Δ_i is the simplex that describes player i's mixed-strategy space, and let $x_i^{s_i}$ be the probability assigned by the player i to strategy s_i. We will use the standard (somewhat abusive) convention to denote payoffs for mixed strategies, so that $u_i(x_i, x_{-i})$ is the expected payoff for player i when using mixed strategy x_i against mixed strategy x_{-i}.

We formalize the behavior of each player in terms of the mixed strategy he adopts at each point in time, so the vector $x(t) = (x_1(t), x_2(t))$ will describe the state of the system at time t,[22] define over the simplex $\Delta = \Delta_1 \times \Delta_2$ of which Δ^0 is the relative interior.

Assumption d.1 The evolution of $x(t)$ is given by a system of continuous-time differential equations:

$$\dot{x}_i^{s_i}(t) = D_i^{s_i}(x(t)).$$

We require that the autonomous system satisfie the standard regularity conditions; i.e. D must be (i) Lipschitz continuous with (ii) $\Sigma_{s_i \in S_i} D_i^{s_i}(x(t)) = 0$. Furthermore, D must also satisfy the requirements in the following two assumptions:

Assumption d.2 D is a regular (payoff) *monotonic* selection dynamic. More explicitly, let $g_i(s_i, x(t)) \equiv \dot{x}_i^{s_i}(t)/x_i^{s_i}(t)$ denote the growth rate of strategy s_i. Then, for all s_i, s_i' and all $x(t)$, it must be true that $g_i(s_i, x(t))$ is a Lipschitz continuous function and that:

$$\text{sign}\big[g_i(s_i, x(t)) - g_i(s_i', x(t))\big] = \text{sign}\big[u_i(s_i, x_{-i}(t)) - u_i(s_i', x_{-i}(t))\big].$$

Assumption d.2 merely says that a strategy that has a higher payoff, given the current state of the population grows faster (decreases more slowly) than a strategy with a lower payoff.

[21] Deterministic dynamics can (and perhaps should) be interpreted as limits of stochastic dynamics for large populations (Cabrales and Ponti 2000) or for slow adaptation (Börgers and Sarin 1997). For this reason, we also performed simulations, using experience-weighted attraction learning (Camerer and Ho 1999), a stochastic learning model, with small populations and short time-horizons. These simulations share several qualitative features with our data. For example, they show that also in this environment iteratively weakly-dominated strategies can survive for the duration of our experiment. Readers interested in the simulations may consult (Brandts et al. 2005).

[22] As is common in the evolutionary literature $(x_1(t), x_2(t))$ can also be interpreted as the proportions of people playing each strategy when a game is repeatedly played by a randomly-matched large population.

Assumption d.3 $x(0) \in \Delta^0$ That is, the initial conditions are in the strict interior of the strategy simplex. In other words, all strategies have strictly positive weight at the outset.[23]

We will now show that the elements in one of the subgame-perfect equilibrium components that do not survive iterated deletion are limit points of the dynamics from some interior solution. To state the theorem we introduce more notation.

Let $S_1^* \equiv \{NIO, NII\}$. The set S_1^* includes all the strategies where the incumbent does not pre-commit and then decides to produce when no player pre-commits. Let $S_2^* \equiv \{NNOO, NNOI, NPOO, NPOI\}$. The set S_2^* includes all the strategies where the entrant does not pre-commit if the incumbent does not pre-commit and then decides not to produce.

Proposition 1 *Assume that the initial weight on strategies NII for player* 1 *and strategy NNOI for player* 2 *is sufficiently large, and that for any player* $i = 1, 2$ *the initial weight on any strategy* $s_j \notin S_i^*$ *is sufficiently small. Then, for any player* $i = 1, 2$ *and any strategy* $s_j \notin S_i^*$ *we must have that* $\lim_{t\to\infty} x_i^{s_j}(t) = 0$.

Proof See the Appendix.

In other words, the equilibrium component where neither player pre-commits, where the incumbent keeps the market and the entrant yields the market, is a limit of any trajectory that starts with a sufficientl high weight on strategies **N**OI and **NN**OI and sufficientl small on any strategy $s_j \notin S_i^*$.[24]

To understand how this proposition works, notice firs that as long as the weight of **N**II remains high enough, the payoff for the entrant of strategies in S_2^* is strictly higher than the payoff for strategies outside that set (by an amount bounded away from zero). This implies that the growth rate of strategies outside S_2^* is negative (and bounded away from zero), so they will vanish in the limit. Similarly the payoff to **N**OI and **N**II is strictly higher than that for other strategies of the incumbent if the weight of **NN**OI remains high. Now, both **N**II and **NN**OI may have a lower payoff than other strategies, but only against strategies that are vanishing over time. So, given that the initial weights of **N**II and **NN**OI are high enough, they may decrease, but this rate of decrease is smaller and smaller as time goes by, and they will never go beyond the threshold where the growth rate of strategies outside S_2^* is negative. The more delicate part of the proof involves showing precisely that this is true. In other words, strategy profile in an equilibrium component with iteratively dominated strategies can be played even when time goes to infinit provided the dynamics start close enough to that component. This can happen because the

[23] This assumption is a technical necessity because regular dynamics are such that a strategy with zero initial weight will always have zero weight. So a weakly-dominant strategy will have no power against dominated ones, when the strategies of other players against which it does well are never used. This assumption guarantees that the survival of dominated strategies does not arise simply due to an initial non-existence of those strategies. It also implies, together with continuity, that all strategies will have positive weight for all t. But as the proposition makes clear, in the limit the weight of strategies can tend to zero.

[24] This is not quite the same as showing that this equilibrium component is asymptotically stable. Close to one end of the component, trajectories will move away, in the direction another component. But, as in Binmore et al. (1995), or Cabrales and Ponti (2000), the addition of small perturbations/mutations, would make the component asymptotically stable.

strategies against which the ones in the component do badly are vanishing over time.[25]

6 Discussion

Bagwell and Ramey (1996) propose an alternative model of the timing in the entry game, in which the ‘first-m ver advantage’ disappears through the logic of forward induction. They suggest that this is the reason that incumbent firm do not engage in entry deterrence. In this paper we study behavior in a simplifie version of the B–R model and compare it to observations from a simpler Dixit-style game. We fin that in both games the firs mover tends to capture the market, so that the B–R rationale cannot be the key to explaining the entry-deterrence puzzle.

For the Dixit game the first-m ver advantage is predicted by theoretical arguments. In our data this advantage is strong even when the incumbent does not engage in entry-deterrence; when the incumbent does pre-install, however, this advantage is substantially more pronounced. Pre-installation in this game also serves to greatly reduce inefficien y from 32 to 12%. In the B–R environment, theory suggests that the entrant should have the advantage, as he or she has the fina opportunity to pre-install prior to the choices about market participation. Nevertheless, we fin that the incumbent is much more likely to control the market than the entrant. This advantage is substantial even without incumbent pre-installation, but grows considerably when the firs mover pre-installs. We go beyond the purely negative implication of our results – the rejection of the B–R rationalization – and provide an explanation for observed behavior.[26]

Our answer, suggested by some of the regularities that we have just discussed, is that there is a perceived first-m ver advantage in this game. In the B–R game, there is a large difference in B–R investment rates (72 vs. 36%) when neither player pre-commits; note also the difference in these rates when only the other player has chosen to pre-install, 51.1% for the incumbent versus 23.0% for the entrant. The investment rate for incumbents is more than double the investment rate for entrants in both cases. Thus, for most players the pattern is *as if* the incumbent had a ‘natural’ first-m ver advantage, something not captured by the strategic analysis presented above. We also see this in the Dixit game, where an incumbent who does not pre-install nevertheless is nearly fi e times as likely to control the market as the entrant.

In the B–R game, the strategy in which the incumbent does not pre-install, but nevertheless enters the market regardless of the entrant’s pre-installation decision, is by far the most common (chosen fully 1/3 of the time). The logic of forward

[25] This proposition only illustrates a theoretical possibility. Even though the strategies that form the sets S_1^* and S_2^* are chosen over 50% of the time, that equilibrium component does not characterize well the aggregate behavior of our subjects. Indeed, no equilibrium component does. A more accurate analysis of the data from a learning perspective would require estimating or calibrating with a more f exible learning model. The interested reader is referred to Brandts et al. (2005) where such an analysis is performed using experience-weighted attraction learning (Camerer and Ho 1999).

[26] Of course, we realize that we have not ruled out many other candidate explanations. For example, one reviewer points out that the normal-form presentation might, under certain not unreasonable assumptions, lead to a behavioral advantage for the row player. While such an explanation might well contain a kernel of truth, we have not investigated it in this study.

induction makes some inroads against an a priori perception of a first-m ver advantage, but generally must surrender to it – the strategy leading to the highest expected payoff for an entrant in the B–R game involves always staying out of the market. On the other hand, forward induction and such a perception work together in the Dixit game, and the incumbent enjoys an overwhelming advantage.[27]

One may wonder about the origins of a perceived first-m ver advantage. There are several studies on the topic of the order of play in experimental games. Rapoport et al. (1990,1993), and Rapoport (1997) fin evidence of a first-m ver advantage in bargaining games and sequential common resource dilemmas; in the latter case, earlier movers take larger portions than do later movers. Weber et al. (2004) and Müller and Sadanand (2003) fin that when simple two-person games that are 'simultaneous' in terms of information are played sequentially, the firs mover tends to do better than when both players make actual simultaneous choices.

Huck and Müller (forthcoming) fin evidence of a first-m ver advantage in a control treatment in which one player firs selects one of two battle-of-the-sexes matrices (identical but for labeling); even though this move is in principle irrelevant, the likelihood of the firs player's favored equilibrium increases dramatically, so that people do not appear to ignore unobserved prior moves. Our environment is slightly different in that moves are actually simultaneous, even though the participants are told that the incumbent makes the firs choice about whether to pre-install. In fact, in our setting the 'first-m ver advantage' successfully works against the ability to perform forward induction that is present to some degree in the population. Perhaps there is something general in the psychology of reasoning about timing that favors earlier movers.[28] In any case, there seems to be a widespread social norm that firs movers have a greater entitlement (as in "the early bird gets the worm" or "firs come, firs served").

To obtain a wider perspective on our results, it may be useful to think of equilibrium selection as simply a coordination problem. Forward induction is a notion that suggests why certain beliefs might be more plausible than others. However, other mechanisms for forming beliefs may be more focal for participants; if the order of play establishes beliefs that are stable, then forward induction may have little influence[29] One can draw some useful parallels to some previous experimental finding on equilibrium selection. Brandts and Holt (1992, 1993) show, in

[27] Our answer to the question why the B–R prediction is not supported by our data requires a second part. Just to posit the existence of a perceived f rst-mover advantage is not a sufficien explanation of our data; one must also clarify why learning does not do away with this pre-conception. Our theoretical result with deterministic dynamics provides a rationale for why the initial behavior does not change too much over time. Thus, it is not simply that people have limitations in their depth of reasoning. Rather, matters start with a pre-conception that subsequent experience with the environment is unable to erase.

[28] Weber et al. (2004) fin that "virtual observability" (sequential but uninformed versus true simultaneous) is an important distinction, and suggest that players may be better at reasoning backward, about events known to have already happened, than reasoning forward; description of possible outcomes of previously-occurring events is often richer and more complex than description of later-occurring events.

[29] Cooper et al. (1997) also provide evidence that stable beliefs may not easily disappear through adaptation. In their signaling games subjects that had experienced an environment with only a separating equilibrium remained (after being switched to a game with a pooling and a separating equilibrium) stuck in that equilibrium rather than reverting the pooling equilibrium to which inexperienced subjects converge.

some simple signaling games, that naïve beliefs based on the principle of insuffi cient reasoning determine initial play, as well as out-of-equilibrium beliefs once behavior converges to a stable configuration What is particularly interesting in our environment is that this first-m ver advantage appears to manifest without any precedence in physical time; it seems that a mere asymmetry in the instructions generates this effect in the B–R game.

Appendix

Proposition 1 *Assume that the initial weight on strategies NII for player* 1 *and strategy NNOI for player* 2 *is sufficiently large. Then, for any player* $i = 1, 2$ *and any strategy* $s_j \notin S_i^*$ *we must have that* $\lim_{t\to\infty} x_i^{s_j}(t) = 0$.

Proof of Proposition 1 We firs make precise the assumption on initial conditions for NI and NNOI. Namely, we assume that.

$$\exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\text{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\text{NII}}(0)}\right)\frac{\left(1-\sum_{s_i\notin S_2^*}\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right)}{\sum_{s_i\in S_2^*} x_2^{s_i}(0)}x_2^{\text{NNOI}}(0) > \frac{17}{24}$$

and that

$$\exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i\notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right)\frac{\left(1-\sum_{s_i\notin\{\text{NIO,NII}\}}\frac{x_1^{s_i}(0)}{x_1^{\text{NII}}(0)}\right)}{\sum_{s_i\in\{\text{NIO,NII}\}} x_1^{s_i}(0)}x_1^{\text{NII}}(0) > \frac{7}{8}.$$

Where :

1. The constant $K > 0$ has the property that $g_i(s_i, x) - g_i(s_i, \hat{x}) \geq -K\left|x - \hat{x}\right|$ for all $i \in \{1, 2, \}x, \hat{x} \in \Delta_1 \times \Delta_2$ and it exists by the Lipschitz-continuity of $g_i(., .)$
2. The constant $h_{(a)} > 0$ has the property that $g_2(s_i, x) - g_2(\text{NNOI}, x) < -h_{(a)}$ whenever, $u_2(s_i, x_1) - u_2(\text{NNOI}, x_1) \leq -\frac{45}{4}$, and it exists by continuity and assumption d.2.
3. The constant $h_{(c)} > 0$ has the property that $g_1(s_i, x) - g_1(\text{NNOI}, x) < -h_{(c)}$ whenever, $u_1(s_i, x_2) - u_1(\text{NNOI}, x_2) \leq -\frac{15}{2}$, and it exists by continuity and assumption d.2.

We now show that the following statements hold:

(a) For all $s_i \notin S_2^*$, and for all t,

$$x_2^{s_i}(t) < \exp(-h_{(a)}t)\frac{x_2^{s_i}(0)}{x_2^{\text{NNOO}}(0)}$$

(b) For all t, $x_2^{\text{NNOI}}(t) > \frac{17}{24}$.

(c) For all $s_i \notin \{\text{NIO, NII}\}$, and for all t,

$$x_1^{s_i}(t) < \exp(-h_{(c)}t)\frac{x_1^{s_i}(0)}{x_1^{\text{NII}}(0)}$$

(d) For all t, $x_1^{\text{NII}}(t) > \frac{7}{8}$.

Statements (a) and (d) will establish the proposition. The proof will be done by contradiction. Suppose that (a) is the statement that stops being true the earliest, that it does so for strategy $s_i \notin S_2^* = \{\text{NNOO, NNOI, NPOO, NPOI}\}$ and that the boundary time is t'. Then it must be true that:

$$x_2^{s_i}(t') = \exp(-h_{(a)}t')\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}.$$

Note that the payoff for $s_i \notin S_2^* = \{\text{NNOO, NNOI, NPOO, NPOI}\}$ against NII is at most 30, and that otherwise the maximum payoff in this game is 120. Note also that by (d) and the assumption here, for all $t < t'$, $x_1^{\text{NII}}(t) \geq 7/8$. Then, we must have that for all $t < t'$, $u_2(s_i, x_1(t)) \leq 30x_1^{\text{NII}}(t) + 120(1 - x_1^{\text{NII}}(t)) \leq 30 \cdot \frac{7}{8} + 120 \cdot \frac{1}{8} = \frac{165}{4}$, and also that $u_2(\text{NNOI}, x_1(t)) \geq 60(x_1^{\text{NOI}}(t) + x_1^{\text{NII}}(t)) \geq \frac{210}{4}$.

Thus, $u_2(s_i, x_1(t)) - u_2(\text{NNOI}, x_1(t)) \leq -\frac{45}{4}$, which implies that $g_2(s_2, x(t)) - g_2(\text{NNOI}, x(t)) < -h_{(a)}$ for all $t < t'$. Then, by integrating, we have that $\frac{x_2^{s_i}(t')}{x_2^{\text{NNOI}}(t')} < \exp(-h_{(a)}t')\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}$, which implies $x_2^{s_i}(t') < \exp(-h_{(a)}t')\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}$ $x_2^{\text{NNOI}}(t') \leq \exp(-h_{(a)}t')\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}$, a contradiction. □

Suppose, then, that (b) is the statement that stops being true the earliest, that it does so for strategy s_i and that the boundary time is t'. Then it must be that: $x_2^{\text{NNOI}}(t') = 17/24$. As before, we will reach a contradiction, but before we will prove the following:

Claim For all $s_i \in \{NNOO, NPOO, NPOI\}$

$$g_i(\text{NNOI}, x(t)) - g_i(s_i, x(t)) \geq -2K(1 - x_1^{\text{NOI}}(t) - x_1^{\text{NII}}(t)).$$

Proof of Claim For all $s_i \in \{\text{NNOO, NPOO, NPOI}\}$, since $u_2(s_i, \hat{x}_1)) = u_2(\text{NNOI}, \hat{x}_1)$, for all $\hat{x}_1$ such that $\hat{x}_1^{\text{NIO}} + \hat{x}_1^{\text{NII}} = 1$, we have that $g_i(\text{NNOI}, \hat{x}_1(t)) = g_i(s_i, \hat{x}_1(t))$. So, by Lipschitz-continuity we have that for all x_1

$$g_i(\text{NNOI}, x(t)) - g_i(\text{NNOI}, \hat{x}(t)) \geq -2K\left|x_1(t) - \hat{x}_1(t)\right|$$
$$g_i(s_i, \hat{x}(t)) - g_i(s_i, x(t)) \geq -2K\left|x_1(t) - \hat{x}_1(t)\right|$$

But since $g_i(\text{NNOI}, \hat{x}(t)) = g_i(s_i, \hat{x}(t))$, adding the previous two inequalities yields the result. □

Now, by the claim, $g_i(\text{NNOI}, x(t)) - g_i(s_i, x(t)) \geq -2K(1 - x_1^{\text{NOI}}(t) - x_1^{\text{NII}}(t))$, but by assumption, for all $t < t' x_1^{s_i}(t) < \exp(-h_{(c)}t)\frac{x_1^{s_i}(0)}{x_1^{\text{NII}}(0)}$ for all $s_i \notin \{\text{NIO, NII}\}$ so that

$$g_i(\text{NNOI}, x(t)) - g_i(s_i, x(t)) \geq -2K\left(\exp(-h_{(c)}t)\frac{\sum_{s_i \notin \{\text{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\text{NII}}(0)}\right).$$

Then by integration we have that

$$\frac{x_2^{\mathrm{NNOI}}(t')}{x_2^{\mathrm{NNOI}}(0)}\frac{x_2^{s_i}(0)}{x_2^{s_i}(t')} > \exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right).$$

This implies that

$$\frac{x_2^{\mathrm{NNOI}}(t')}{x_2^{\mathrm{NNOI}}(0)} x_2^{s_i}(0) > \exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right) x_2^{s_i}(t'),$$

and by adding over all $s_i \in S_2^* \equiv \{\mathrm{NNOO, NNOI, NPOO, NPOI}\}$ we have that:

$$\begin{aligned}\frac{x_2^{\mathrm{NNOI}}(t')}{x_2^{\mathrm{NNOI}}(0)} &= \frac{1}{x_2^{\mathrm{NNOI}}(0)}\frac{17}{24}\\ &> \exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right)\frac{\sum_{s_i\in S_2^*} x_2^{s_i}(t')}{\sum_{s_i\in S_2^*} x_2^{s_i}(0)}\\ &= \exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right)\frac{\left(1-\sum_{s_i\notin S_2^*} x_2^{s_i}(t')\right)}{\sum_{s_i\in S_2^*} x_2^{s_i}(0)}\\ &\geq \exp\left(-2\frac{K}{h_{(c)}}\frac{\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right)\frac{\left(1-\sum_{s_i\notin S_2^*} \frac{x_2^{s_i}(0)}{x_2^{\mathrm{NNOI}}(0)}\right)}{\sum_{s_i\in S_2^*} x_2^{s_i}(0)}\end{aligned}$$

where the firs equality is true by the assumption used to reach a contradiction and the last inequality is true by (a). This yields a contradiction with the assumption about the initial conditions.

Suppose that (c) is the statement that stops being true the earliest, that it does so for strategy s_i and that the boundary time is t'. Then it must be true that:

$$x_1^{s_i}(t') = \exp(-h_{(c)}t')\frac{x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}.$$

Note that the payoff for $s_i \notin S_1^* = \{\mathrm{NIO, NII}\}$ against *NNOI* is at most 60, and that otherwise the maximum payoff in this game is 120. Note also that by (b) and the assumption here, for all $t < t', x_2^{\mathrm{NNOI}}(t) \geq 17/24$. Then, we must have that for all $t < t', u_1(s_i, x_1(t)) \leq 120(1 - x_2^{\mathrm{NNOI}}(t)) + 60 \cdot x_2^{\mathrm{NNOI}}(t) \leq 120 \cdot \frac{7}{24} + 60 \cdot \frac{17}{24} = \frac{155}{2}$ and also that $u_1(\mathrm{NII}, x_1(t)) \geq 120 \cdot x_2^{\mathrm{NNOI}}(t) \geq 120 \cdot \frac{17}{24} = \frac{170}{2}$. Thus, $u_1(s_i, x_2(t)) - u_1(\mathrm{NII}, x_2(t)) \leq -\frac{15}{2}$, which implies that $g_i(s_i, x(t)) - g_i(\mathrm{NII}, x(t)) < -h_{(c)}$ for all $t < t'$. Then, by integrating, we have that $\frac{x_1^{s_i}(t')}{x_1^{\mathrm{NII}}(t')} < \exp(-h_{(c)}t')\frac{x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}$, which implies $x_1^{s_i}(t') < \exp(-h_{(c)}t')\frac{x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)} x_1^{\mathrm{NII}}(t')$ $\leq \exp(-h_{(c)}t')\frac{x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}$, a contradiction.

Suppose, then, that (d) is the statement that stops being true the earliest, that it does so for strategy s_i and that the boundary time is t'. Then it must be that $x_1^{\mathrm{NII}}(t') = 7/8$. As before, we will reach a contradiction, but before doing so we will prove the following:

Claim $g_i(\text{NII}, x(t)) - g_i(NIO, x(t)) \geq -2K\left(1 - \sum_{s_i \in S_2^*} x_2^{s_i}(t)\right)$.

Proof Since $u_1(\text{NIO}, \hat{x}_2)) = u_2(\text{NII}, \hat{x}_2)$, for all $\hat{x}_2$ such that $\sum_{s_i \in S_2^*} \hat{x}_2^{s_i}(t) = 1$, we have that $g_i(\text{NII}, \hat{x}(t)) = g_i(\text{NIO}, \hat{x}(t))$. So, by Lipschitz-continuity we have that for all x_2

$$g_i(\text{NII}, x(t)) - g_i(\text{NII}, \hat{x}(t)) \geq -2K\left|x_2(t) - \hat{x}_2(t)\right|$$
$$g_i(\text{NIO}, \hat{x}(t)) - g_i(\text{NIO}, x(t)) \geq -2K\left|x_2(t) - \hat{x}_2(t)\right|$$

But since $g_i(\text{NII}, \hat{x}(t)) = g_i(\text{NIO}, \hat{x}(t))$, adding the previous two inequalities yields the result. □

Now, by the claim,

$$g_i(\text{NII}, x(t)) - g_i(\text{NIO}, x(t)) \geq -2K\left(1 - \sum_{s_i \in S_2^*} x_2^{s_i}(t)\right),$$

but by assumption, for all $t < t' x_2^{s_i}(t) < \exp(-h_{(a)}t)\frac{x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}$ for all $s_i \notin S_2^*$ so that

$$g_i(\text{NII}, x(t)) - g_i(\text{NIO}, x(t)) \geq -2K\left(\exp(-h_{(a)}t)\frac{\sum_{s_i \notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right).$$

Then, by integration we have that

$$\frac{x_1^{\text{NII}}(t')}{x_1^{\text{NII}}(0)}\frac{x_1^{\text{NIO}}(0)}{x_1^{\text{NIO}}(t')} > \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i \notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right).$$

This implies that

$$\frac{x_1^{\text{NII}}(t')}{x_1^{\text{NII}}(0)}x_1^{\text{NIO}}(0) > \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i \notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right)x_1^{\text{NIO}}(t')$$

By adding this inequality plus

$$\frac{x_1^{\text{NII}}(t')}{x_1^{\text{NII}}(0)}x_1^{\text{NII}}(0) > \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i \notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right)x_1^{\text{NII}}(t')$$

which is true since

$$\exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i \notin S_2^*} x_2^{s_i}(0)}{x_2^{\text{NNOI}}(0)}\right) < 1,$$

we have that

$$\frac{x_1^{\mathrm{NII}}(t')}{x_1^{\mathrm{NII}}(0)} = \frac{1}{x_1^{\mathrm{NII}}(0)}\frac{7}{8}$$
$$> \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i\notin S_2^*} x_2^{s_i}(0)}{x_2^{\mathrm{NNOI}}(0)}\right)\frac{\sum_{s_i\in\{\mathrm{NIO,NII}\}} x_1^{s_i}(t')}{\sum_{s_i\in\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}$$
$$= \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i\notin S_2^*} x_2^{s_i}(0)}{x_2^{\mathrm{NNOI}}(0)}\right)\frac{\left(1-\sum_{s_i\notin\{\mathrm{NIO,NII}\}} x_1^{s_i}(t')\right)}{\sum_{s_i\in\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}$$
$$\geq \exp\left(-2\frac{K}{h_{(a)}}\frac{\sum_{s_i\notin S_2^*} x_2^{s_i}(0)}{x_2^{\mathrm{NNOI}}(0)}\right)\frac{\left(1-\sum_{s_i\notin\{\mathrm{NIO,NII}\}} \frac{x_1^{s_i}(0)}{x_1^{\mathrm{NII}}(0)}\right)}{\sum_{s_i\in\{\mathrm{NIO,NII}\}} x_1^{s_i}(0)}$$

where the firs equality is true by the assumption used to reach a contradiction and the last inequality is true by (c). This yields a contradiction with the assumption about the initial conditions.

Since this exhausts all cases the result follows.

References

Abrams, E., Sefton, M., Yavas, A.: An experimental comparison of two search models. Econ Theory **16**, 735–749 (2000)

Bagwell, K., Ramey, G.: Capacity, entry and forward induction. RAND J Econ **27**, 660–680 (1996)

Bain, J.: Barriers to new competition. Cambridge: Harvard University Press (1956)

Balkenborg, D.: An experiment on forward versus backward induction. Mimeo (1998)

Basu, K.: Lectures in industrial organization theory. Oxford: Blackwell (1993)

Binmore, K, Gale, J., Samuelson, L.: Learning to be imperfect: The ultimatum game. Games Econ Behav **8**, 56–90 (1995)

Börgers, T.: Weak dominance and approximate common knowledge. J Econ Theory **64**, 265–276 (1994)

Börgers, T., Sarin, R.: Learning through reinforcement and replicator dynamics. J Econ Theory **77**, 1–14 (1997)

Brandts, J., Cabrales A., Charness, G.: Entry deterrence and forward induction: An experiment. Mimeo (2005)

Brandts, J., Charness, G.: Hot vs. cold: sequential responses and preference stability in experimental games. Exp Econ **2**, 227–238 (2000)

Brandts, J., Charness, G.: Truth or consequences: An experiment. Manage Sci **49**, 116–130 (2003)

Brandts, J., Holt, C.: An experimental test of equilibrium dominance in signalling games. Am Econ Rev **82**, 1350–1365 (1992)

Brandts, J., Holt, C.: Adjustment patterns and equilibrium selection in experimental signaling games. Int J Game Theory **22**, 279–302 (1993)

Brandts, J., Holt, C.: Limitations of dominance and forward induction: experimental evidence. Econ Lett **49**, 391–395 (1995)

Broseta, B., Fatás, E., Neugebauer, T.: Asset markets and equilibrium selection in public goods games with provision points: An experimental study. Econ Inquiry (2003)

Cabrales, A.: Stochastic replicator dynamics. Int Econ Review **41**, 451–481 (2000)

Cabrales, A., Ponti, G.: Implementation, elimination of weakly dominated strategies and evolutionary dynamics. Rev Econ Dyn **3**, 247–282 (2000)

Camerer, C., Ho, T.: Experienceweighted attraction learning in games. Econometrica **67**, 827–874 (1999)

Capra, M., Goeree, J., Gomez, R., Holt, C.: Anomalous behavior in a traveler's dilemma? Am Econ Rev **89**, 678–690 (1999)
Cooper, D., Garvin, S., Kagel, J.: Signaling and adaptive learning in an entry limit pricing game. Rand J Econ **28**, 662–683 (1997)
Cooper, R., DeJong, D., Forsythe, R., Ross, T.: Forward induction in coordination games. Econ Lett **40**, 167–172 (1992)
Cooper, R., DeJong, D., Forsythe, R., Ross T.: Forward induction in the battle-of-the-sexes games. Am Econ Rev **83**, 1303–1316 (1993)
Davis, D., Wilson, B.: Firm-specifi cost savings and market power. Econ Theory **16**, 545–565 (2000)
Dekel, E., Fudenberg, D.: Rational behavior with payoff uncertainty. J Econ Theory **52**, 243–267 (2000)
Dixit, A.: The role of investment in entry deterrence. Econ J **90**, 95–106 (1980)
Fudenberg, D., Levine, D.: The Theory of Learning in Games. Cambridge: MIT Press (1998)
Goeree, J., Holt, C. : Ten little treasures of game theory and ten intuitive contradictions. Am Econ Rev **91**, 1402–1422 (2001)
Haile, P.A., Hortaçsu, A., Kosenok, G.: On the empirical content of quantal response equilibrium. Cowles Foundation Discussion Paper 1432 (2003)
Huck, S., Müller, W.: Burning money and (pseudo) first-m ver advantages: An experimental study on forward induction. Games Econ Behav **51**, 109–127 (2005)
Martin, S.: Advanced Industrial Economics. Oxford: Basil Blackwell (1993)
McKelvey, R.M., Palfrey, T.R.: An experimental study of the centipede game. Am Econ Rev **60**, 803–836 (1992)
McKelvey, R.M., Palfrey, T.R.: Quantal response equilibria in normal form games. Games Econ Behav **7**, 6–38 (1995)
Modigliani, F.: New developments on the oligopoly front. J Polit Econ **66**, 215–232 (1958)
Müller, R., Sadanand, A.: Order of play, forward induction, and presentation effects in two-person games. Exp Econ **6**, 5–25 (2003)
Nagel, R.: Unravelling in guessing games: An experimental study. Am Econ Rev **85**, 1313–1326 (1995)
Rapoport, A.: Order of play in strategically-equivalent games in extensive form. Int J Game Theory **26**, 113–136 (1997)
Rapoport, A., Budescu, D., Suleiman, R.: Sequential requests from randomly-distributed shared resources. J Math Psychol **37**, 241–265 (1993)
Rapoport, A., Weg, E., Felsenthal, D.: Effects of f xed costs in two-person sequential bargaining. Theory Decis **28**, 47–71 (1980)
Roth, A., Erev, I: Learning in extensive-form games: experimental data and simple dynamic models in intermediate term. Games Econ Behav **8**, 164–212 (1995)
Rustichini, A., Villamil, A.: Intertemporal pricing in laboratory posted offer markets with differential information. Econ Theory **16**, 613–637 (2000)
Samuelson, L.: Evolutionary Games and Equilibrium Selection. Cambdridge: MIT Press (1997)
Schotter, A., Weigelt, K., Wilson, C.: A laboratory investigation of multiperson rationality and presentation effects. Games Econ Behav **6**, 445–468 (1994)
Siegel, S., Castellan, Jr N.: Nonparametric Statistics for the Behavioral Sciences. Boston: McGraw-Hill (1998)
Tirole, J.: The Theory of Industrial Organization. Cambdridge: MIT Press (1989)
Van Damme, E.: Stable equilibria and forward induction. J Econ Theory, **48**, 476–496 (1989)
Van Huyck, J., Battalio, R., Beil, R.: Asset markets as an equilibrium selection mechanism: Coordination failure, game form auctions, and tacit communication. Games Econ Behav **5**, 485–504 (1993)
Vives, X.: Oligopoly Pricing: Old Ideas and New Tools. Cambdridge: MIT Press (1999)
Vega-Redondo, F.: Evolution, Games and Economic Behavior. Oxford: Oxford University Press (1996)
Weber, R., Camerer, C., Knez, M.: Timing and virtual observability in ultimatum games and 'weak link' coordination games. Exp Econ **7**, 25–48 (2004)