Simulating Oligopoly to Enhance Student Learning

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Abstract

How well do students understand price theory, market power, strategic interaction, and oligopoly theory through traditional teaching methods? How can we further enhance their understanding? We describe an extra-classroom activity called Virtual Corporate Reality (VCR) that is designed to engage students' contemplation of and experience with these ideas. Students compete in teams over the course of the semester in a price and location game based on Salop's (1979) circular city. Our experience is that VCR increases students' internalization of concepts such as sunk cost, best-response, Nash equilibrium, differentiated products, and even concepts as seemingly straightforward as pricing above marginal cost. Students receive significant feedback on their success at mastering these concepts. They find it both entertaining and edifying, and come to class better prepared to understand the assumptions, structure, and predictions of oligopoly theory. VCR is freely available for educational use.

Keywords:
JEL codes: A2, L1, L2

Things to do:

1) ***Add URL for a web site where the reader can "play" VCR.***
2) ***Insert material from past play that shows typical output and documents lessons learned.***

1. Introduction

Students learn economics in different ways. Some take to our models quite easily, as they seamlessly integrate the concepts into their thinking. Some students find it difficult to work with abstract concepts, even when the mathematics is simple, and require more concrete instances of our theories. Some students come in with their own preconceived notions of how markets work – either conscious or not – and struggle to modify those notions when they do not conform to economic doctrine. Focusing on this last pedagogical challenge, Bain (2004) finds that even when students want to learn, even when they know how to (and do) perform well on exams, they will not adopt a new way of thinking unless they first experience a failure of their existing mental model. A crucial element to teaching is then providing students with the opportunity to witness the failure of their mental model so that they can then adopt the more compelling mental models that we teach.

In light of these challenges to teaching economics, an attractive complement to the lecture format is for students to experience those concepts "in action" through decision making in a simulated environment. Classroom demonstrations and simulated markets provide a setting for students to learn economic concepts first-hand, make mistakes, and find insights from those mistakes as well as their successes. They provide students with concrete experiences that deliver context for the abstraction of formal economic models.

It is for this purpose that we have designed a simulated market setting – entitled Virtual Corporate Reality (VCR) – to assist students in learning concepts related to imperfect competition and strategic interaction. VCR builds on an impressive body of simulated business environments (for example, Borenstein, 2011), as well as the online treasure trove of games at VeconLab (Holt, 2007). However, VCR is unique in its design because of the singularity of its purpose. The objective is not to approximate managerial decision making or delve into the nuances of game theoretic constructs but rather to be an instructional tool for learning economic concepts. The design of VCR and our desiderata related to this objective are described in Section 2, where we also present the economic model underlying VCR. Section 3 describes the functionality and user interface of VCR, including the decisions students make, the information they have at their disposal when making decisions, and how other software tools can assist in making those decisions. Various pedagogical complements to VCR that enhance students' learning experience are described in Section 4. Having used VCR many times in a classroom setting, Section 5 describes some of the lessons learned by students through their successes and failures while playing the game. A few concluding remarks are offered in Section 6.

2. Economic Model of Virtual Corporate Reality

If the objective of a market simulation program is to provide a training ground for managerial decision making, it makes sense to provide as descriptively realistic an environment as can be programmed and that students can mentally handle. If instead the objective of conducting a game-theoretic exercise in class is to have students "think strategically" and then engage in a post-play analysis that dissects strategic reasoning, it is better to keep the environment narrow and simple, as is typically done with classroom demonstrations, whether involving an auction,

repeated Prisoners' Dilemma, coordination game, or many other classic games. However, if the objective is to learn economic concepts – in our case related to imperfect competition – then the desiderata are quite different.

In designing a simulated environment for learning economic concepts, there is a clear trade-off in the number of decisions student make in any single play. Consider going from a simple decision on price to encompassing capacity, entry, product line decisions, product and process innovation, advertising, capital investment with various depreciation schedules, and so forth. A key feature of these decisions is that they are not separable. For example, whether to enter depends on what investment will occur, which may depend on anticipated advertising, which will depend on the extent of price competition. Thus, tasking students with multiple decision variables can help them think through how those variables interact, whether the decision variables are strategic complements or substitutes, and how one decision (such as entry) depends on later decisions (such as the intensity of price competition). The downside to additional decision variables is that they provide a more complex problem in which students may fail to perceive the connections between and consequences of their decisions. This can make their decision making less systematic and purposeful. One desideratum is then to make the decision making setup rich enough for students to explore the linkages between decisions but simple enough so that they can identify cause-and-effect, whether in the process of making a decision (ex ante) or in seeing how realized outcomes are affected by their earlier decisions (ex post).

Noise – random shocks to demand, cost, product quality, etc. – is descriptively realistic and thus an appropriate element if one wants to provide a training ground for managerial decision making. From the perspective of learning economic concepts, however, noise can further obscure the cause-and-effect mechanism and make ex post learning difficult. It also reduces the value of experimentation and again may reduce the amount of learning. Thus, a second desideratum is to minimize noise in order to promote learning, and retaining only that uncertainty critical to the concepts to be taught.

It was with these two desiderata in mind that we constructed Virtual Corporate Reality (VCR). The market model is one of spatially differentiated products on the unit circle (Salop, 1979). A consumer's willingness to pay for a product is decreasing in the distance between the consumer's ideal and the firm's product. Consumers are uniformly distributed over the circle in terms of their ideal product. Each consumer buys exactly one unit and purchases the good with the highest net surplus, the willingness to pay minus price. As opposed to the line model of Hotelling (1929), the circle avoids the asymmetries created by boundaries.

At any given time, a firm has a collection of products located at various points on the circle. In each period, the firm decides what price to set for each existing product, how much to invest in reducing each one's marginal cost, whether to invest in new products, and whether to withdraw products or relocate existing products. The firm is constrained to finance its investment and product decisions through cash. For each product, the relationship between cumulative cost-reducing investment (X) and that product's current marginal cost is

$$\$50\frac{50{,}000{,}000}{X+50{,}000{,}000}.$$

Fixed costs per period are $500,000 for each product. Most of the cost of product introduction is sunk, as is all cost-reducing investment. Firms produce to meet demand and there are no capacity constraints. Further details of on the cost and demand are given in a handout that students receive before playing the game, Harrington and Ruebeck (2011).

Realized profit is deterministic as neither demand nor cost is stochastic. When setting price, consumer preferences and the locations of available products are common knowledge. Thus, for a given collection of prices, the associated revenue from each product is calculable. Similarly, a firm can calculate its own cost, for that is affected only by its past product investments (which determine the products' level of constant marginal cost) and how much it produces.

There remain two sources of uncertainty. First, other firms' investment decisions are private information, which means that a rival's cost is private information. However, since profit is observable there are instances in which a rival's cost can be inferred. VCR could be run with investment publicly observed but we sought to provide a mild dose of private information to enrich the environment (and provide evidence below that it does so). The second source of uncertainty is strategic, in that a firm will need to form beliefs about other firms' upcoming decisions on price, investment, and product line.

In sum, VCR puts aside enough of the complexity of descriptive realism to provide a structure designed for learning in a reasonable time span. Three decision variables – product line and location, investment, and price –achieve a balance of richness so that lessons about the interactions of decisions can be learned, with enough simplicity so that the problem is mentally solvable for students and they can see cause-and-effect while making decisions and evaluating outcomes. The presence of a little bit of private information and the lack of randomness to demand and cost allow uncertainty to largely be strategic in origin and to permit outcomes to be more informative to students as to the correctness of their decisions. VCR thus cuts through the noise to help students learn about strategic interaction and oligopoly theory.

Within the VCR environment, students are part of a team making decisions on price, investment, and product line. Having multi-member teams helps students learn about the dynamics of group decision making, and they learn more deeply about the course's concepts through their intra-team discussions. We have typically run the game with two decisions each week. This frequency balances having enough periods within a single quarter or semester class to provide ample time to learn, and enough time between periods so that students can carefully think through their decisions.

3. Functionality of VCR: Playing the Game

Students use a web-based interface to make their decisions each period and afterwards to view others' public decisions and the resulting market outcomes. Starting from a state of perfect information, students subsequently have access to a mixture of public and semi-private information about what has transpired. Each student on each team has a login and a password that allows him or her to enter decisions for the firm, analyze the options, and view results. The

main screen provides a concise summary of the student's team and the current state of the game. Each screen's pull-down menu provides navigation to the other parts of the interface.

Initial Position

At the start of play, each team is endowed with a single product at a given location. These initial products are spaced evenly around the circle. Starting with a symmetric configuration is fair – no team inherits an advantage – and allows students to know that any differences in performance are due to their decisions and not their endowed positions. With four teams of students, for example, the initial products are positioned on the unit circle at locations 0 (or 1, which are the same), 0.25, 0.5, and 0.75. Each product is endowed with the same marginal cost of production ($50, as described above) and each firm has an initial cash balance of $25,000,000.

The user interface is composed of four components: Current Decisions, Public History, Private History, and Scenarios.

Current Decisions Screen

Students directly enter current price and investment on the Current Decisions screen (Figure 1). All products and their locations are listed. For a team's own products, marginal cost and accumulated investment are also listed. For each of its products, a team will enter a price for the current period and new investment (if any) to be made toward reducing marginal cost in the next period. The team's current cash is also displayed because that constrains how much can be invested; the game does not allow borrowing (no negative cash balances). Students can also decide whether to scrap, move, or auction off existing products.

Figure 1 about here

The 'Manage Introductions' button on the Current Decisions screen provides access to a subscreen for new product introductions (Figure 2). Product introductions are typically quite common during the earlier rounds of play. As the text at the bottom of the Current Decisions screen reminds the user, these introductions (and likewise the scrap, move, and auction decisions) are only announcements and do not take effect until the following period. Hence, firms always make their decisions knowing the current configuration of products.

Figure 2 about here

Public and Private History Screens

The displays of the game's history appear in three screens. All of them can be displayed either for a single period (Figure 3) or for the entire history (Figure 4).

The two public screens are viewed by all teams and so are common knowledge. One of those, shown in Figure 3, lists the market outcome for each product in each period: the price charged, how many units were sold, and whether its owner chose to scrap, relocate, or auction it off in the following period. Introductions are implicitly evident here and are also evident in the Current

Decisions screen, described above (see Figure 1); they are not labeled "new product" but students aware of previous product locations can see where new products have been introduced by comparing the current product configuration to the previous period's configuration.

Figure 3 about here

A second public screen reports the financial history: each firm's profit and cash position in each period (see Figure 4). Teams cannot "reverse engineer" the investment information from changes in rivals' cash balances as long as those teams have made investments in multiple products. It is likewise difficult to infer these investments from profits if a team has multiple products because only total team profits are reported in this screen. Money spent on non-production decisions is reflected here in the firms' cash balances; "profits" refer only to production revenues and costs (both fixed and variable).

Figure 4 about here

Figure 5 depicts the Private History screen; it can only be seen by the team members, although it includes both private and public information. The items shown here that are not on the two public screens are each product's existing investment, marginal cost, variable expense, and profit. Note again that while profits are broken out by product in this screen, the profit shown in Figure 4's public screen is aggregated to the firm level.

Figure 5 about here

Scenarios Screen and Offline Investigations

The 'Scenarios' button in the upper left of the Current Decisions screen (see Figure 1) links to the interactive display shown in Figure 6. Students use the Scenarios screen to test out changes in their product(s) and to analyze the effects that other teams' anticipated changes may have. These changes include pricing decisions, introductions, and how much investment other teams have made and might make. The Scenarios screen also calculates the resulting profits for all products for the hypothesized situation (though recall that, in actual play, those profits are private information). Up to four user-specified scenarios may be compared in the display. A new scenario defaults to the current product mix and is easily modified to reflect anticipated introductions, withdrawals, and other conjectured future changes. The scenarios are held in memory for each team; thus one team member may run some comparisons that are loaded later when another team member logs into the system. Because the Scenarios screen is a crucial component to VCR and integral to student decision making, we recommend homework exercises below to familiarize students with its functionality.

Figure 6 about here

The browser features are provided through Ajax (Asynchronous JavaScript and XML) techniques (Garrett, 2005) in the Scenarios screen, and HTML for all other screens. The data is stored in a mySQL database and screens are generated with PHP (a recursive acronym for PHP is a Hypertext Preprocessor) which is an interface often used for database-driven dynamic web

pages. The advantage of Ajax over HTML is a more responsive and flexible form, but the drawback is that the data are not easily exported to a spreadsheet program. The ability to save other screens' HTML tables makes this less important; students can use a spreadsheet application such as Microsoft's Excel or Apple's Numbers to create their own in-depth analyses that go beyond the scenario interface. We describe some of these off-line activities below.

4. Enhancing the Learning Experience

Preparing Students to Play VCR

Before initiating play, students receive a detailed VCR Manual (Harrington and Ruebeck, 2011) that explains the logical and mathematical structure of the game. It is useful to spend some time explaining the environment and decision variables to students before they read it, lest they be intimidated by its level of formality and detail. Some students may want to skip to the synopsis at the end of the manual and then pick back through it for clarification. The first discussion during lecture can also walk students through the components of the manual, in particular introducing them to the idea of the one-dimensional circular city—a concept they may not have seen before and one that can be conceptually challenging.

It is important for students to start play with a fairly good understanding of the strategic environment and the functionality of the VCR program. Our experience has been that some teams will make considerable investments early on – in terms of both product introductions and cost reduction – in which case initial misunderstandings can result in miscalculations with long-run consequences. Even though students will still make mistakes, this initial introduction and practice will help them learn more from them.

We recommend several approaches to help students get up and running. First, students need to become comfortable with using the Scenarios component of the VCR program. This software component is useful throughout the game, but is especially valuable at the beginning of play since market experience is lacking; the only experimentation available is through these hypothetical analyses. Scenarios provide a "proving ground" for testing strategies and, more generally, understanding how decisions map into outcomes.

Second, students can complete a graded homework assignment, due prior to play, that asks them to think carefully about VCR with particular emphasis on the nature of price competition in a differentiated products market. Combining both these goals, the assignment has students spend some time running both prescribed and open-ended analyses with the Scenarios tools. The assignment is due before the first period of play; it is discussed after students see the results of the first round's decisions and have completed a follow-up assignment in which they graph the declining average cost curve whose formula is in the VCR manual.

In sum, here is our recommended order of events at the beginning of playing VCR:

Lecture A: Hand out the explanatory packet, discuss it, and assign homework with exercises on the Scenarios simulator.

Outside class: Students complete the homework assignment.

Lecture B: Collect the homework and ask for questions. Remind students of the game's structure and the initial period's coming deadline. Assign homework that includes graphing the average cost curve.

Outside class: Students enter decisions for the first period.

Lecture C: Hand back homework. Discuss the pricing decisions and cost curve. (See the discussion in the section on initial play below.)

Several goals are accomplished through this series of events. Pedagogically, students' brains are 'primed' with a context for the experiences they are about to have. They also are more likely to understand that cost curves can be a useful (and essential) tool. Mechanically, it gets students 'over the hump' of learning how to use the simulator. Most important, it enhances how much they learn from the first-period pricing decisions, which translates into more effective learning and decision making in later periods.

Writing Component

With VCR, students are engaging in a quantitative analysis in the context of a game-theoretic mathematical structure. In addition to the preparatory assignments described above and the grading incentive we will describe below, we have found that a useful complement to this analytical reasoning is for students to write about the experience of making decisions and to assess and evaluate the other teams' decisions. The writing should not be onerous, but it should be regular. It is convenient to use a web-based electronic bulletin board (available in typical class-management systems as a "discussion board" or "forum") with each student's entries hidden from the other teams but available to their own team's members.

Students in each team can take turns briefly explaining the most recent period's decision. With a team of three students and two decision periods per week, this is not an onerous task. In addition, at the end of playing VCR, we recommend having each student write a short paper describing what transpired over the course of the game, which could be in the style of a business school case study. Students have commented in their course evaluations that these introspective assessments increase their ability to learn. From the instructor's perspective, they also provide insight on students' motivations, and students' comments can be used to initiate classroom discussion by linking some of the observations from the current or past semesters to lecture topics, to short discussions about the game while it is in progress, and during a full debriefing of the game's play at the end of the semester. Examples will be evident in the discussion below.

Data Analysis

After saving the web pages as an HTML or TXT file, or copying-and-pasting the data into spreadsheet software, students may choose to conduct quantitative analyses on the data using tools outside of VCR. Our experience is that some students creatively design their own analytical

methods rather than passively limiting themselves to the tools provided in the Scenarios simulator.

More broadly, experience has shown that students mull over much of the information even when not directly analyzing the data; they discuss it with each other and reflect on it between decision due dates. Course evaluations and stories told by the librarians, information technology staff, and others around campus reveal that students are arguing and talking with each other about the game throughout the week, sometimes late into the night. This level of activity bodes well for VCR's effectiveness as a learning tool.

Grading

While some students may be intrinsically motivated to perform well in the competitive environment of VCR, assigning a grade will ensure that all students – even those not innately competitive or who are less inclined to invest themselves in the course – will exert adequate effort to understand the concepts taught in the game. To measure performance, we have measured the firm's value as cash plus the present value of its profit stream. To estimate the latter, students choices in the last three periods are limited to only price changes in the established product line and level of investment. The present value of the profit stream is the average profit of those last three periods divided by the discount rate. This firm value then goes into determining a team's grade.

There are various ways in which firm value can be mapped into a grade, but some may have undesirable features. For example, having a student's grade based on how his or her team's firm value compares to the value of other teams inserts an unrealistic measure of relative performance and could encourage spiteful play (that is, choosing an action which, while it lowers one's own profits, reduces the profits of other teams even more). It is better to tell students that their grade will be based on a comparison of their firm's value to some benchmark profit level set (but not revealed) prior to the start of play. Thus, in principle, all teams could earn an "A" or all teams could earn a "C" (or worse). From where does this benchmark come and how is it conveyed to students? The benchmark we have used is average firm value from past years (which is available for instructors when they first use VCR). We believe it is best not to tell students the exact level of benchmark values because this could lead to satisficing behavior or taking on excessive risks (when a team's current performance indicates a low grade) or being excessively cautious (when a team's current performance indicates a high grade). By withholding the comparison standard, we can further reinforce that each team's goal is to maximize the expected net present value of its profit stream, a more accurate analog to firm behavior.

For a large class in which several industries can be run simultaneously (each with a competing set of teams), an alternative benchmark is to compare a team's value with the average value earned in the other industries. This method is also useful when the instructor has not previously run VCR and wishes to establish his or her own historical benchmark.

When following our recommended grading structure, it is crucial to emphasize to the students that a firm is not being compared in terms of its performance to other firms in the same industry. Some students naturally think in terms of relative performance and, only after some disastrous

experiences, learn that absolute performance is what matters. Emphasizing this point at the beginning of the game also means students will remember it during debriefing discussions weeks later when the game is over. "I told you not to think that decreasing others' profits leads directly to increasing your profits! Wasn't that good advice? Did everyone follow it?" The answers are invariably, "Yes!" and "Unfortunately, no."

Some students have expressed concern with a grade based on profit because it is not fully in their control; it depends on the choices of other teams. Of course, part of the assigned task is to accurately conjecture what others will do, in which case low profit and a low grade because of poor conjectures is appropriate. However, even accurate conjectures and sound decision making can lead to low profit if other teams insist on being aggressive to the point of low profit for them as well as others. In this case, a team's low grade because other teams are excessively competitive (e.g., a team seems to be trying to maximize its profit compared to average industry profit) is indeed unjust. Or perhaps a student is teamed with some people who are neither clever nor amenable to persuasion.

One response to these grading concerns is to simply tell students that business is not always fair. As the old adage goes, "It's better to be lucky than smart." As such clichés are unlikely to placate most students, a more constructive response is to make the above-mentioned writing component part of a student's grade. This reflective writing can also help students understand (perhaps with a reminder) that their conjectures were not all that accurate nor their decision making truly sound—the poor results for this student's team were not simply due to other team's poor decisions, but also depended on the ways in which this student's team reacted to others' actions. Furthermore, if VCR can be played twice in a semester, students appreciate having a second round to apply the hard-won knowledge from the initial round. Even when students are still paired with the same teammates (recommended) and the same teams in their industry for the second round, the experience has educated not only the student, not only her or his teammates, but the other students and teams in the industry as well. It is very unlikely that the more egregious mistakes we discuss below will be part of this second session of VCR play.

Cheating

It is important to spend some time at the beginning of the semester emphasizing that explicit collusion is equivalent to cheating on an exam and thus is a violation of the institution's student code of conduct. In their previous economics classes, students are likely to have heard about the potential benefits of collusion and they may have even been involved in classroom demonstrations or experiments that encourage such cooperation. That all students can earn a high grade on VCR if they all earn high profits is likely to plant the thought of collusion in their collective heads. It is then important to be unambiguously clear that trying to collude is not the point of the game, just as it is not intended to be the point of commerce in most economies. Describing the various types of laws and resulting fines for collusion brings home the consequences of breaking anti-trust laws. It might also help to show the movie *The Informant!*, and describe how price-fixers can end up in jail!

5. Lessons Learned by Students

The primary goal of VCR is to teach the lessons of imperfect competition and strategic interaction. Other basic ideas are also reinforced, such as the concepts of a cost function and profit-maximization. We describe students' experiences with these and other concepts below. The data are from six semesters of playing VCR, with two industries, and (usually) four teams per industry. One semester had five teams in each industry, and one semester had an industry with three teams. In all but the first two semesters, students played the game twice, with membership in the team constant over the two runs and industry assignments mixed between each run.

Initial Pricing

Students can be uncertain where to price initially because this abstract market has none of the conventional context that a firm would typically have for pricing; there are no markets for similar products to use as a guide. Students have a cost function, and they have the Scenarios simulator with which to experiment. Most students jump right in and try out prices using the simulator, enjoying the creative, unbounded nature of the assignment. Yet some students can find it outside their 'comfort zone', with insufficient information to guide them; they may be accustomed to the typical cut-and-dried academic assignment. Thus, VCR can immediately be a pedagogical device that forces students to think about pricing in a way quite distinct from its abstract presentation in a textbook. It is useful to remind students that firms introducing radically new products face similar challenges. When they were first introduced, how did the innovator decide on the price to set for a microwave oven? a Rubik's Cube? an iPod? In this case (as in many of those), students need to think about the situation that will occur once imitators have entered, anticipating others' anticipations of your price, etc. Students also may need to be reminded that 'brand loyalty' does not exist in VCR.

Marginal Cost Pricing

Generally one of the teams makes the mistake of initially pricing close or equal to marginal cost—or even below marginal cost—focusing on the perfectly competitive result, or on revenue maximization, or the zero-sum strategy of "we are better off when other teams are worse off." Pricing below marginal cost is consistent with a predatory strategy or a price war to establish collusion, and it is useful to refer to those early failed attempts during lectures on those more advanced topics later in the semester. At the beginning of the semester, focusing such a strategy's short-run losses is useful. (And this is likely the enduring lesson in the long run as well.)

With a declining average cost curve, there is no quantity at which $p = MC$ is profitable. Given that each firm's initial cost function is $C(q) = 500{,}000 + 50q$ (prior to any investment), marginal cost is constant and thus always below average total cost. Given total market demand of 346,000 (when there are four products), average cost is 51.44 from selling to the entire market and 55.78 when demand is equally shared among four firms. Nevertheless, there is often a firm that prices at 55 or less. Pricing at 50 has occurred as well, and there was even a price of 20 in one case!

These pricing strategies are unlikely to ever prove profitable and, in practice, were not beneficial for the students that tried them.

Students that try pricing at or near marginal cost have exhibited some surprise when it didn't work, which is a moment of epiphany for them and an exemplar of peril for others. The timing of discussing marginal cost pricing—at the beginning of the semester—is also appropriate for models presented in lecture at that time including 1) the review of perfect competition and its extensions such as near-infinite elasticity of demand facing a single firm, and 2) the monopolist's optimal choice where marginal revenue (not price) is equal to marginal cost. An industrial organization course is likely the students' first class where the focus is on firms with market power, as opposed to a typical Principles or Intermediate course where the large majority of the discussion's foundation is on perfectly competitive markets. Our students' observed behavior provides evidence that the takeaway message from those previous courses for many students is that price equals marginal cost. The initial period of VCR's play can help reinforce how the nature of imperfect competition differs from that of the perfectly competitive market.

Mistaken Principle of Minimum Differentiation

The decision to place a new product introduction very close to or even coincident with an existing product is often made by one or more firms in the game's early periods. For example, there have been instances in which a firm has introduced a new product at 0.26 when there is a product at 0.25, an introduction at 0.48 with a product already at 0.5, and there have been four introductions within 0.01 from the existing 0/1 location. Inevitably, such trivial product differentiation produces intense price competition. Students have made the same mistake that Hotelling (1929) committed in predicting that firms would offer identical products.

While there are intertemporal equilibria that rationalize both marginal cost pricing and minimal product differentiation, experience shows that these behaviors are mistakes in actual VCR play. First, students typically reverse these decisions over the course of play (eventually one of the products is withdrawn) and avoid repeating co-location strategies when VCR is played a second time. Second, marginal cost pricing (as described above) and minimal product differentiation generate low short-run *and* low long-run profits. These experiences are useful pedagogically throughout the semester when discussing perfect competition, market power, and the difficulty of profitably engaging in predatory pricing.

Using Observed Sales to Infer Demand

Students learn – often the hard way – about forgetting to control for other factors when making comparisons and drawing inferences. Though students are told that demand is uniformly distributed around the unit circle, there have been instances in which they forget that fact and infer from sales that some segments of the circle are more heavily populated. For example, with products at 0, 0.15, 0.5, and 0.8, high sales by the product at 0.5 have led some students to mistakenly express that there is a greater density of consumers near 0.5. Students can learn from this experience that they need to take into account the differences across products, which includes both prices charged and the distance from adjacent products. This observation suggests a potentially interesting extension of VCR in which teams are initially uninformed about the

distribution of consumers around the circle. Such an extension introduces learning from sales, experimentation, and the use of regression analysis by students who have taken Econometrics.

Sunk Cost and Endogenous Entry

All cost-reducing investment in VCR is sunk, as is most of product introduction cost. Students learn the usual wisdom about sunk costs—that these costs should have no bearing on future decisions once the funds are committed—in particular when they deal with the natural regrets they have after making investments or introduction decisions that prove unprofitable. It is precisely their difficulty in "letting go" of the unprofitable locations that teaches students this valuable lesson about sunk costs. Here we see again that it is the mistakes, the failure of students' existing mental models of the world, that can convince them of the value of the new models they learn through studying economics.

Leading from what we might call this first-order message about sunk costs, students can also think about the connection between sunk costs and forward-looking behavior. Using the Scenarios screen, students can test their conjecture that an introduction will prove profitable, given their beliefs about other firms' reactions to it. They can also consider the returns to cost-reducing investment. Advanced students have used spreadsheets, sometimes elaborate ones, to make present-value calculations on the returns to investment. They may experience some regret in this case as well if their conjectures are incorrect and they either invested too little or too much based on those mistaken conjectures.

Oligopolistic Interaction: Homogeneous and Differentiated Products

We have seen that some general economic concepts can be reinforced by VCR and now turn to concepts that are more specific to Industrial Organization and the later topics that might be covered in Intermediate Microeconomics, Game Theory, or a Strategy course. These begin with the introduction to best-response and Nash equilibrium.

Textbooks generally introduce the mathematical details of homogeneous goods duopoly equilibria in the Cournot and Stackelberg quantity games, and then develop the price game equilibria descriptively - see, for example, Chapter 6 in Carlton and Perloff (2004) and Chapter 9 in Pepall, Richards, and Norman (2005) – though Chapter 7 in Cabral (2000) introduces homogeneous goods Bertrand before Cournot. All of these texts wait until a later chapter or section to discuss price games with differentiated products, yet students' experiences setting prices of differentiated products in VCR is valuable background even as a first introduction to strategic behavior and their ability to quickly grasp homogeneous goods oligopoly models.

Their experience is particularly useful when presenting Cournot reaction curves. The derivation and explanation of the Cournot-Nash equilibrium can be challenging because the graphical development moves from the plot of a single firm's marginal revenue and marginal cost on p-q axes to the graph of both firms' best-response curves on q_1-q_2 axes, where each axis crucially represents both independent and dependent variables. Students appear to grasp this material faster when their VCR experience provides context before the best-response concept is presented in class. They are more receptive to the idea of an optimal response, and they are also more

likely to understand the iteration involved in the intuition behind strategic interaction because they have already tried to respond optimally to other firms' decisions in VCR, they have tried to anticipate others' actions, and even tried to predict others' anticipations.

All the industrial organization texts mentioned above reserve some space to describe, and in one case present graphically, the movement along Cournot reaction curves that firms might make if they alternatively make best-replies to each other's previous quantity choices. This graph provides some of the intuition and support for Cournot-Nash equilibrium, but it is also a chance to make to alert students that the Cournot-Nash solution is not a dynamic model. By observing that any firm that anticipates the other's response (as students often have done in VCR) will jump ahead of the other firm, students can appreciate that a naïve conjectural variations approach lacks insight into the dynamics of strategic behavior.

Product Differentiation and Excessive Entry

Given the gains to early discussions of Nash equilibria in games with strategic variables quite different from those in VCR (homogeneous products), it is not surprising that a later discussion of differentiated products—when the strategic situation is much closer to VCR—is also more understandable to students. The mathematical setup in the VCR description handout is applicable here, and can be augmented by a graphical discussion of consumer utility and producer surplus. Students can also apply their VCR experiences to discussions of social welfare and excess entry in differentiated products markets. Because VCR has made the concepts of producer and consumer surplus less abstract, students will be more likely to follow the mathematical development in a discussion of Salop's model.

Advanced Strategic Interaction

After playing VCR, it is easier to convince students that predatory pricing is difficult to justify theoretically, and it is easier for them to understand why well-documented cases of predation are rare. When students' VCR teams have products in very close proximity, as described earlier, they become engaged in a war of attrition from which neither is likely to exit quickly, thereby highlighting its costliness. As the team that predated may not have fully thought through the consequences of their actions, discussing such experiences highlights the importance of forward-looking behavior when making decisions.

Another opportunity to learn from the experience of co-located firms is in a discussion of the Bayesian-Nash equilibrium solution concept. Although that is not a topic typically covered in undergraduate I.O. (an exception is Church and Ware's text), the experience of co-located firms highlights the importance of beliefs in games of incomplete information. As teams try to decide whether to exit or not, the team members typically observe (in their private, written analyses) that their firm will win the war of attrition if its product has lower production cost than the other firm's product does. Although it is the *belief* of lower cost that matters, it is also instructive to share with the students at the end of the VCR project that the firm that won the war of attrition has always been the one that actually did have lower costs. Thus, it is useful that VCR maintains these costs as private information; it usually takes a few periods for one firm to determine that

the other firm will not "blink" and the firm that does "blink" has always been the one with higher marginal cost.

Market Valuation, Sunk Cost, and Related Concepts

When they decide to remove a product, students often try to sell it rather than scrap it. They are typically surprised when they learn that others don't value the product any more than they do: in practice, products offered for sale are seldom bought. Although there may be a non-zero price at which the nearby firm would buy it, evidently this price has always been lower than the $1,000,000 scrap value. (Note that this is also the portion amount of the $5,000,000 product introduction fee that is not sunk.) This behavior is rational on the part of potential buyers, but the expectation of the team dumping the product may be more 'hopeful' than rational. In their written reports, these students reveal that they seldom attempted to calculate the value of the product to support their belief of other teams' willingness to pay for it. There is a question of causality here: it is probable that students likely to introduce a product that later needs to be withdrawn are also likely to be those students that take a less quantitative approach to VCR.

In a related topic, some of the best students take the course material further because of their generally quantitative approach to the game, analyzing the decision to bring down production costs through investment, calculating the net present value of that and other investments. The spreadsheets that students produce on their own initiative to summarize the states of the game are testament to the motivation and engagement provided by VCR. Most students that take these advanced steps to analyze their decision making use this analysis in conjunction with conjectures about other students' behavior, but some of these students erroneously find that no investment is useful because they assume a non-dynamic response (or no response) from others. This can also be cast as the students' ignoring the usefulness of creating a cost advantage; that is, the pricing power they would have over other firms that don't invest.

6. Concluding Remarks

Competing in the simulated environment of VCR lifts some of the traditional constraints faced by students when solving economic problems. Part of answering traditional homework assignments is finding a way to figure out the designer's expected answer, while an activity like VCR allows students to step outside that paradigm because economic success can be achieved in various ways. This aspect of the game appeals to many types of students. The student that is academically strong has a chance to apply his or her prowess "in the field." The student that is capable but not academically serious or suffers from testing difficulties might respond most significantly to the game precisely because it looks more like "reality" to them and offers an opportunity to deploy "street smarts" and "common (business) sense." Enthusiasm for course material by even weak students increases as reflected in class discussions surrounding VCR. These students are animated, demonstrative, and often burst out with contributions during the discussion.

We come back to one of the key features of VCR: its balance between a rich set of factors and a simple design. The instructor is more likely to be able to help students pull apart the tangled

strings of causality when there is no random element and there are only a few drivers of cost, demand, price, and profit. Other games may achieve more "surprises" and produce an industry evolution that might be more "intriguing," but they may only be surprising and intriguing because they can't be adequately explained! It is unfortunate if students take away little more than the excitement of battle and unenlightening surprises rather than a deeper understanding of economic theory. With VCR, it does seem that students more effectively learn the economic concepts associated with imperfect competition. Again recognizing Bain's (2004) observations of college-level teachers, students don't really learn what we teach them unless they first understand how they must *change* the way they view the world. We know they'll remember that they had fun playing in a simulated environment, but what we really want is for that thrill to distill itself into a changed view of how real markets operate in the context of imperfect competition and strategic interaction.

In future work we plan to systematically assess students' learning with VCR, as well as test hypotheses about how students learn using shocks to demand or cost and other game parameters. We will also use self-assessment methods to investigate how different students' learning styles are affected by VCR.

Please contact us if you are interested in using VCR software at your institution. It is freely available for educational use.

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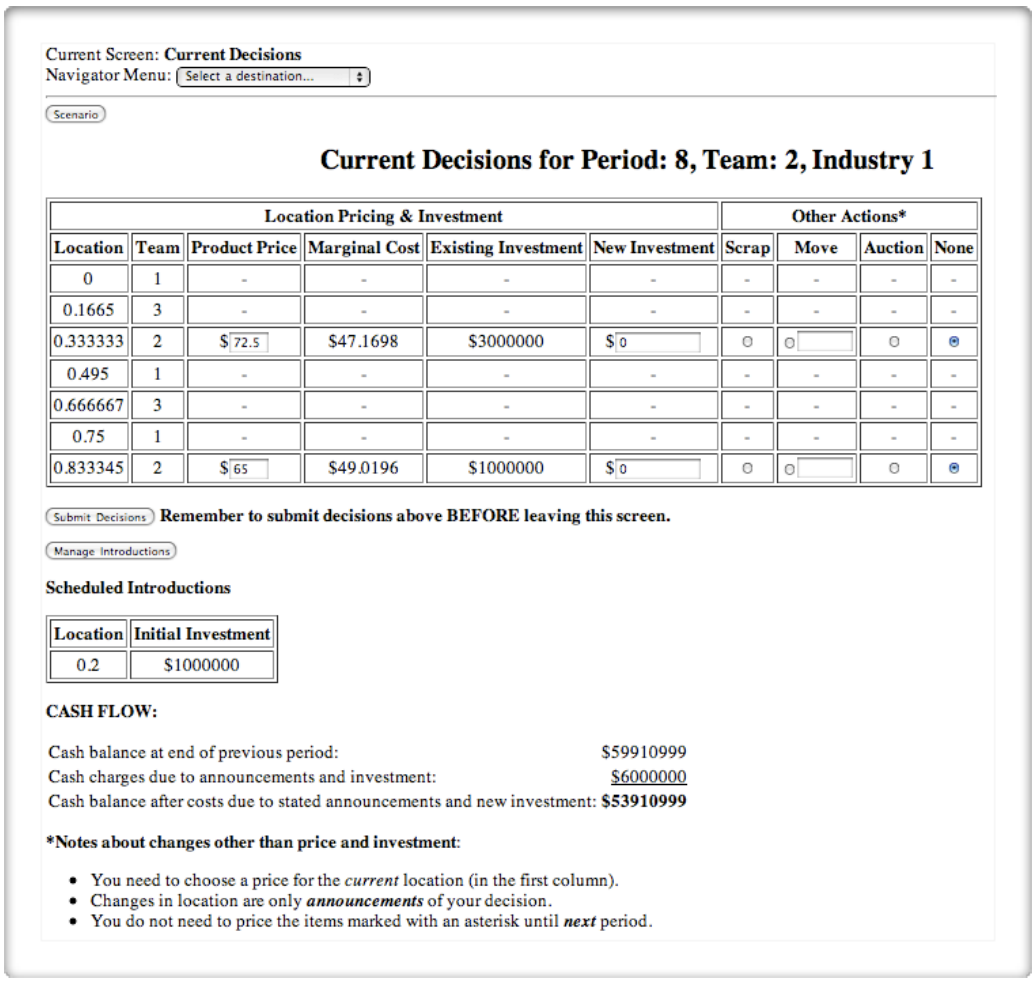


Figure 1: Screen for entering the current period's decisions.

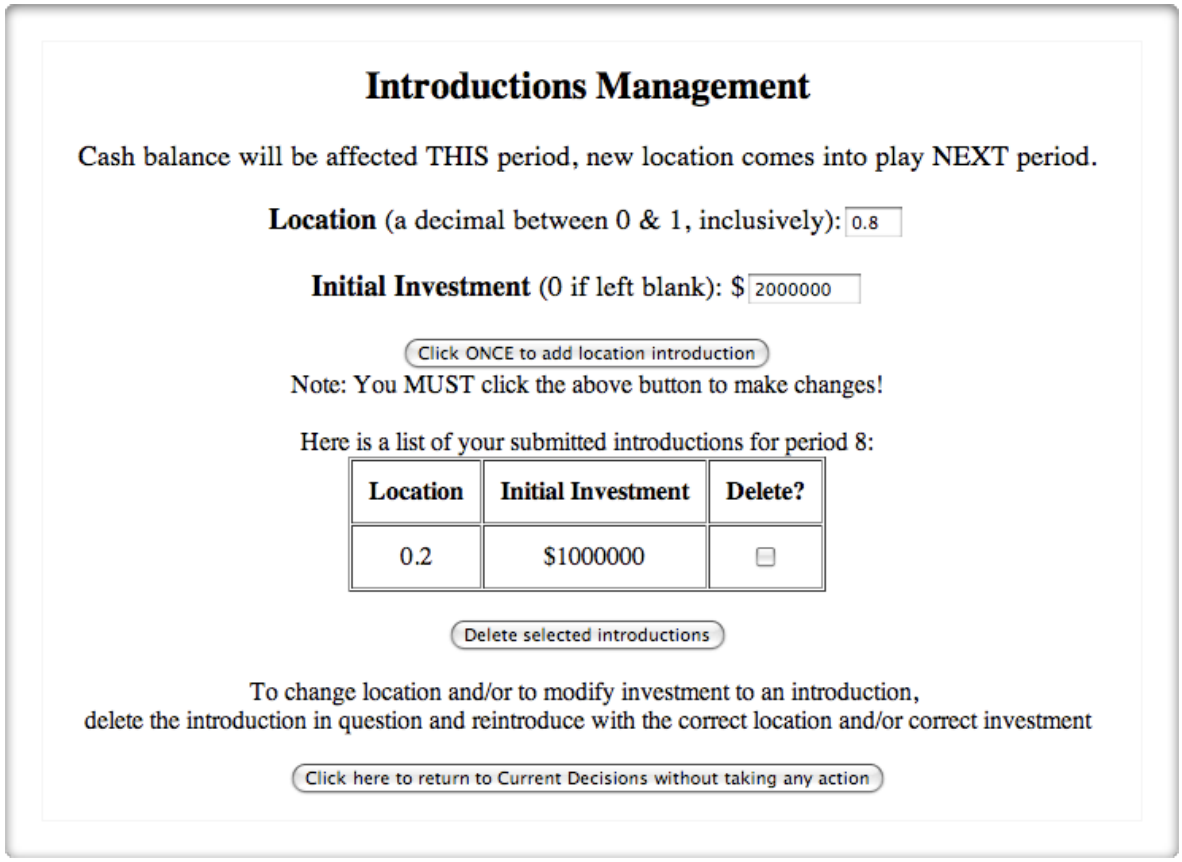
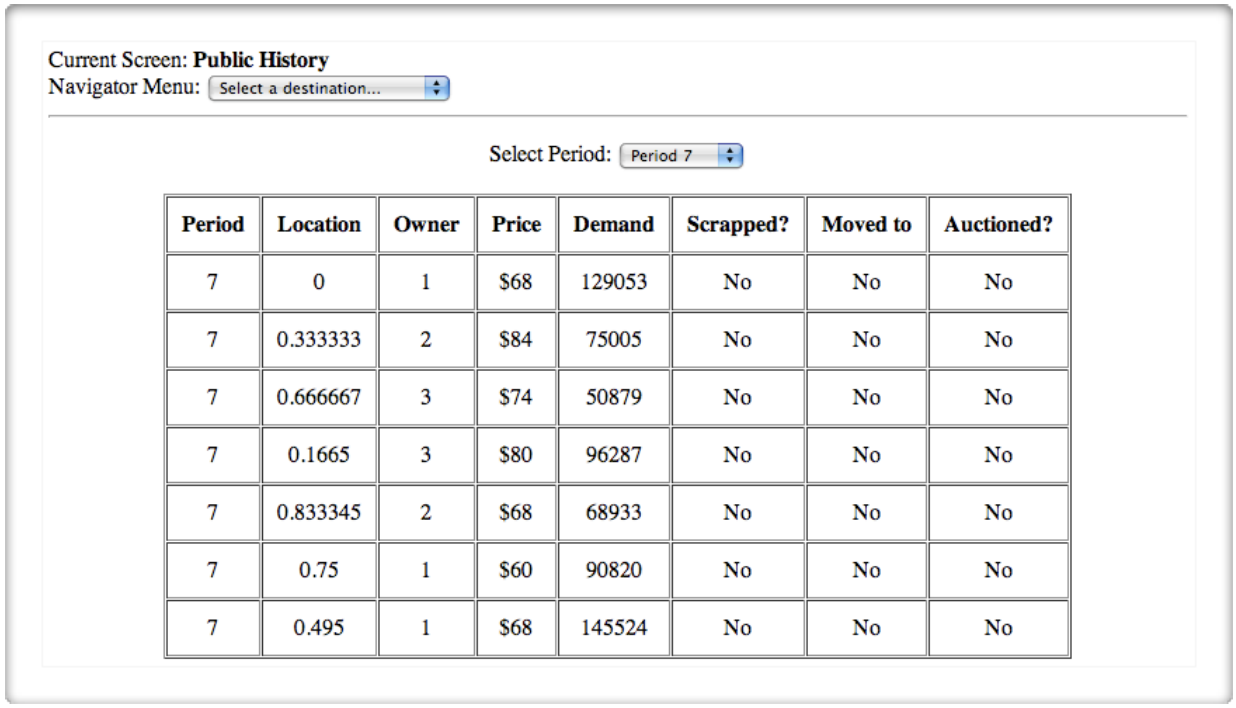
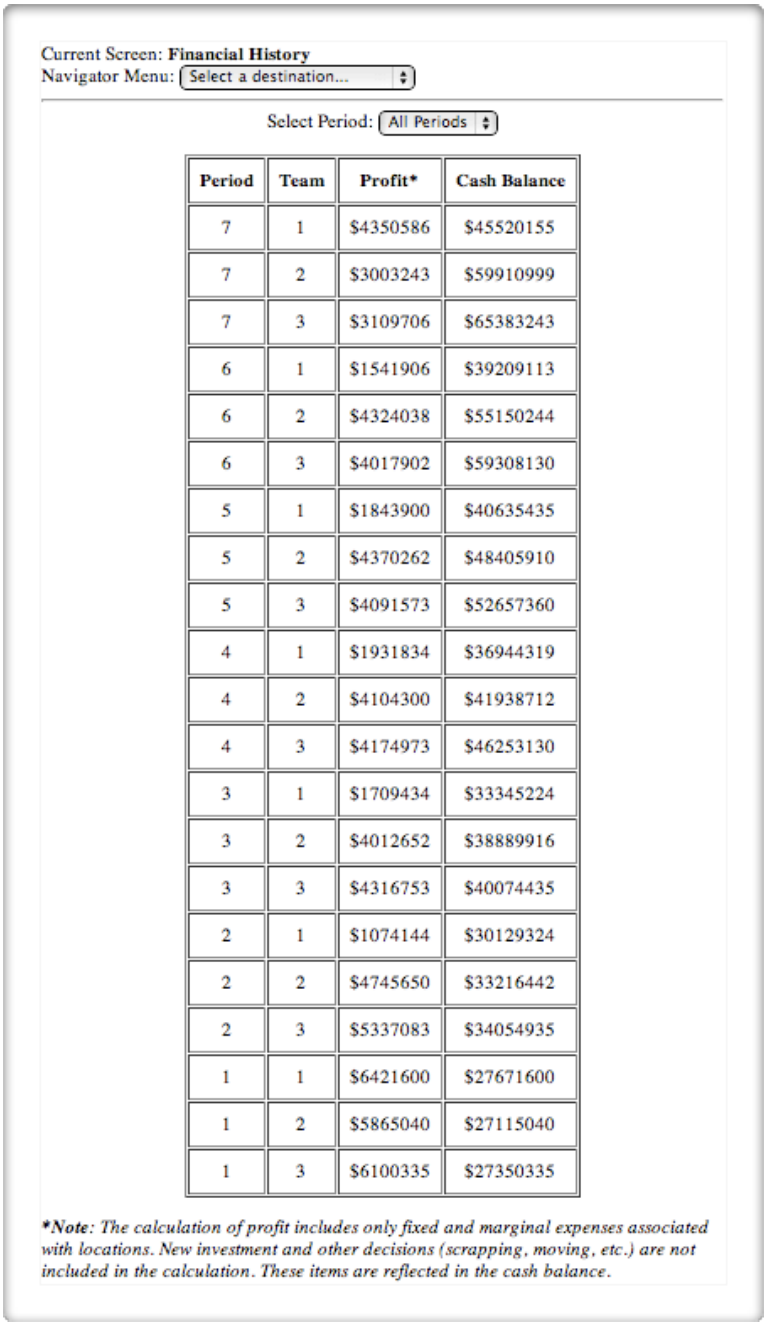


Figure 2: The product introduction interface.



Period	Location	Owner	Price	Demand	Scrapped?	Moved to	Auctioned?
7	0	1	$68	129053	No	No	No
7	0.333333	2	$84	75005	No	No	No
7	0.666667	3	$74	50879	No	No	No
7	0.1665	3	$80	96287	No	No	No
7	0.833345	2	$68	68933	No	No	No
7	0.75	1	$60	90820	No	No	No
7	0.495	1	$68	145524	No	No	No

Figure 3: Publicly available decisions history, chosen here for the most recent period.



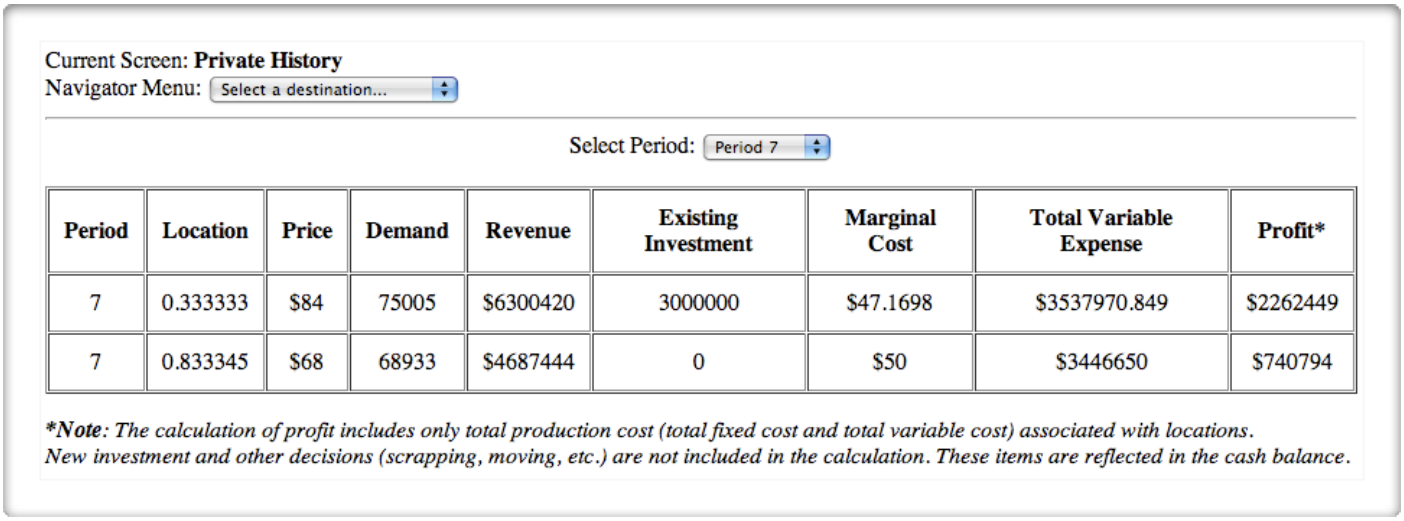
Current Screen: **Financial History**
Navigator Menu: Select a destination...

Select Period: All Periods

Period	Team	Profit*	Cash Balance
7	1	$4350586	$45520155
7	2	$3003243	$59910999
7	3	$3109706	$65383243
6	1	$1541906	$39209113
6	2	$4324038	$55150244
6	3	$4017902	$59308130
5	1	$1843900	$40635435
5	2	$4370262	$48405910
5	3	$4091573	$52657360
4	1	$1931834	$36944319
4	2	$4104300	$41938712
4	3	$4174973	$46253130
3	1	$1709434	$33345224
3	2	$4012652	$38889916
3	3	$4316753	$40074435
2	1	$1074144	$30129324
2	2	$4745650	$33216442
2	3	$5337083	$34054935
1	1	$6421600	$27671600
1	2	$5865040	$27115040
1	3	$6100335	$27350335

***Note**: The calculation of profit includes only fixed and marginal expenses associated with locations. New investment and other decisions (scrapping, moving, etc.) are not included in the calculation. These items are reflected in the cash balance.*

Figure 4: Publicly available financial history, chosen here to display all past periods.



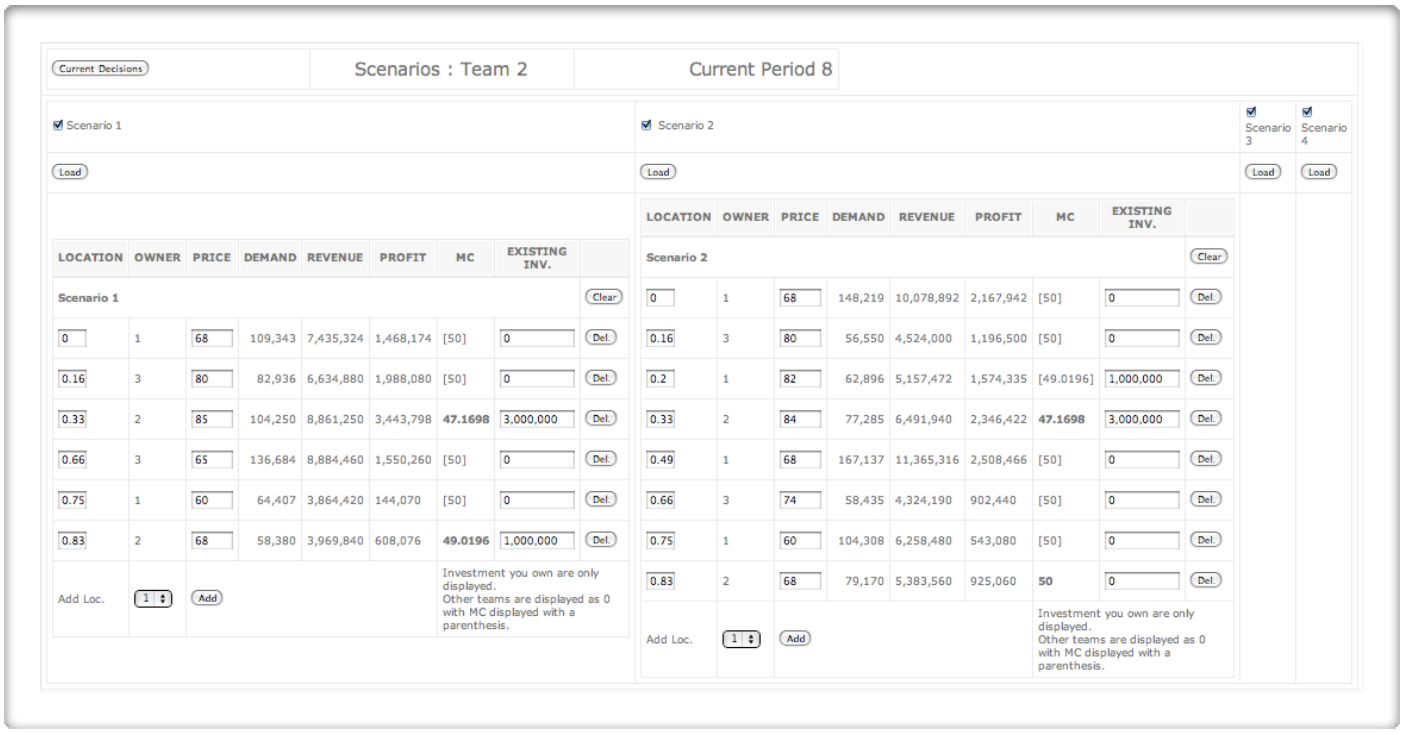
Current Screen: **Private History**
Navigator Menu: Select a destination...

Select Period: Period 7

Period	Location	Price	Demand	Revenue	Existing Investment	Marginal Cost	Total Variable Expense	Profit*
7	0.333333	$84	75005	$6300420	3000000	$47.1698	$3537970.849	$2262449
7	0.833345	$68	68933	$4687444	0	$50	$3446650	$740794

***Note**: The calculation of profit includes only total production cost (total fixed cost and total variable cost) associated with locations. New investment and other decisions (scrapping, moving, etc.) are not included in the calculation. These items are reflected in the cash balance.*

Figure 5: Privately available decisions history, for the most recent period.



Current Decisions | Scenarios : Team 2 | Current Period 8

Scenario 1 — Load

LOCATION	OWNER	PRICE	DEMAND	REVENUE	PROFIT	MC	EXISTING INV.	
Scenario 1								Clear
0	1	68	109,343	7,435,324	1,468,174	[50]	0	Del.
0.16	3	80	82,936	6,634,880	1,988,080	[50]	0	Del.
0.33	2	85	104,250	8,861,250	3,443,798	**47.1698**	3,000,000	Del.
0.66	3	65	136,684	8,884,460	1,550,260	[50]	0	Del.
0.75	1	60	64,407	3,864,420	144,070	[50]	0	Del.
0.83	2	68	58,380	3,969,840	608,076	**49.0196**	1,000,000	Del.

Add Loc. 1 Add

Investment you own are only displayed.
Other teams are displayed as 0 with MC displayed with a parenthesis.

Scenario 2 — Load

LOCATION	OWNER	PRICE	DEMAND	REVENUE	PROFIT	MC	EXISTING INV.	
Scenario 2								Clear
0	1	68	148,219	10,078,892	2,167,942	[50]	0	Del.
0.16	3	80	56,550	4,524,000	1,196,500	[50]	0	Del.
0.2	1	82	62,896	5,157,472	1,574,335	[49.0196]	1,000,000	Del.
0.33	2	84	77,285	6,491,940	2,346,422	**47.1698**	3,000,000	Del.
0.49	1	68	167,137	11,365,316	2,508,466	[50]	0	Del.
0.66	3	74	58,435	4,324,190	902,440	[50]	0	Del.
0.75	1	60	104,308	6,258,480	543,080	[50]	0	Del.
0.83	2	68	79,170	5,383,560	925,060	**50**	0	Del.

Add Loc. 1 Add

Investment you own are only displayed.
Other teams are displayed as 0 with MC displayed with a parenthesis.

Scenario 3 — Load

Scenario 4 — Load

Figure 6: Investigating hypothetical scenarios