Firm Behavior In Oligopolistic Markets: Evidence From A Business Simulation Game

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ABSTRACT

Oligopolistic markets are known to be associated with a high degree of price and output rigidity. This is due to mutual interdependencies among firms in the market with regard to price and production. The primary objective of this research is to use a business simulation game to observe the convergence in pricing that is part and parcel of the gamesmanship that occurs in an oligopoly market. A second objective of this research is to observe how a firm's investments influence future productive potential. A third objective is to explore whether firm behavior changes after the other firms' ex post decisions are revealed after the first four quarters of the simulation. Both descriptive statistics and regression analysis were used. Given the longitudinal nature of the data, random-effects specifications in all regressions were employed. Evidence of price rigidity was observed, especially within the first four periods when firms are not able to observe the other firms' choices. Furthermore, investments in marketing and robotics appear to positively impact production.

Confirming theory and previous literature, oligopolistic firms need to contend with the jockeying for position and the concomitant stickiness in prices. Therefore, it is of critical importance for firms to formulate appropriate strategies in order to succeed in an oligopoly setting.

Keywords: Firm Behavior; Oligopoly; Price Rigidity; Strategic Interdependence

INTRODUCTION

Among the various forms of market structure, including those that are largely theoretical and those that exist in most economies, one can argue that the formulation of business strategy is most critical in an oligopoly.

In perfect competition, the market contains many firms, none of which possesses significant market share. Because the firms produce a homogeneous product, they are considered price takers (i.e., the price that they charge for their product is dictated by the market); therefore, there is little opportunity for strategic behavior.

At the other extreme, a monopoly, by definition, only has one firm. Here, too, in those rare situations where it is economically justified for one firm to provide for an entire market; namely, in the case of a natural monopoly such as a public utility, the firm's ability to select from a menu of different business strategies is subject to government regulation.

Monopolistic competition resembles perfect competition in that there are many firms in the market. The distinguishing characteristic in monopolistic competition is that the product or service can be differentiated. Consequently, by virtue of their ability to invest in differentiation, firms in monopolistically competitive markets are able to generate pricing power. However, because this form of market structure typically contains a large number of firms, it is not uncommon for a firm to carve out a niche for itself independent of the strategy utilized by the other firms. If the firm succeeds in carving out its niche in the market, it certainly can survive in the long run. (This is seen in the vast array of businesses in the retail clothing industry. Some retailers successfully differentiate themselves and earn handsome profits even in down economic cycles. At the same time, other retailers, of course, will go out of business.)

An oligopoly, on the other hand, represents a market where power is concentrated among a small number of firms. The exact number of firms is not important; what matters is that a few firms produce most of the market's output. The barriers to entry for an oligopolistic market are high as a result of the scale of the incumbent firms and the competitive advantages that are derived from that scale. Moreover, unlike perfect competition, monopoly, and monopolistic competition, it is most useful to study an oligopoly in terms of the interdependence and rivalry among its firms. Since this type of market is effectively controlled by a few large firms, it is imperative for the firms to formulate appropriate business strategies and – just as importantly – to react appropriately to the business strategies of competing firms. Any firm in an oligopoly that ignores the critical nature of its interdependence with its competition places its share of the market and its capacity for profits at risk. In today's global economy, a number of markets are experiencing increased concentration and consolidation (i.e., merger activity), and regardless of whether an industry's product is homogeneous (in the case of pure oligopolies such as the steel industry, for example) or differentiated (in the case of differentiated oligopolies such as the automobile industry, the airline industry, or the banking industry, to name a few) when relatively few firms compete for the entire market, a firm's behavior in such markets, in the context of its interdependence and rivalry with the other firms, will go a long way toward explaining that firm's success or failure.

The research on oligopoly markets is rich and there have been many studies on oligopolistic behavior. The purpose of this study is to utilize the results of a business simulation game to demonstrate the nature of the price and non-price competition in an oligopoly, with particular attention focused on the convergence in pricing that exists among the firms.

LITERATURE REVIEW

Modern texts on business and economics address the nature of oligopolistic markets and the ways in which firms within those markets compete with each other. As an example, Baye (2010) traces the evolution of some of the notable models of oligopoly behavior. These models help to show how firms might compete in this form of market – such as on the basis of price, quantity of output, marketing and promotion, research and development, brand equity, or other means –which explains why, unlike the other forms of market structure, there is no single model for firm behavior in an oligopoly.

The seminal models of oligopoly include those developed by Cournot, Betrand, Stackelberg, and Sweezy. Cournot (1838) described an industry where a few firms that served many consumers competed based on the quantity of output they produced. Each firm's output decision was made independent of and simultaneous to the other firms' decision. In Cournot competition, industry output is lower than the socially efficient level, and consequently, equilibrium price will exceed marginal cost, allowing the few firms sharing the market to reap sizable profits.

Bertrand (1883) changed the strategic variable from quantity to price. Bertrand competition assumes that the firms produce homogeneous products at a constant marginal cost and that they react to price changes of other firms. This helps to illustrate the price wars that exist in many oligopolies today, and the strategies that management will undertake to eliminate the perception that the firms' products are identical; in other words, investing into product differentiation will allow the firms to set prices above marginal cost.

In some oligopolistic industries, the Cournot model might better describe the actions of the member firms; in others, the Bertrand model might be more appropriate. We are assuming here that these industries are competitive ones; certainly, however, the firms within an oligopoly can also engage in non-competitive behavior, such as in the example of a cartel. In this scenario, the firms can benefit at the expense of consumers by agreeing to restrict output or to charge higher prices. Similar to how a fiercely competitive oligopoly can be explained by the Cournot or Bertrand model, a collusive oligopoly can also be explained by these models.

Stackelberg (1934) modified the Cournot model by revealing that one of the firms in an oligopoly might have some sort of advantage by enabling it to determine its quantity of output before its rivals. Clearly, certain oligopoly markets today have a dominant firm that might enable it to possess first mover advantages. Stackelberg competition indicates that all the other firms in the market will take the leader's output as given and select outputs that will maximize their profits given the leader's output. Similar to Cournot's theory, industry output is below the socially efficient level and firm profitability is sizable, although it is likely that this will be skewed to the benefit of the first mover.

Sweezy (1939) developed a model based on the assumption that firms will respond to price increases differently than they will to price cuts. Specifically, in Sweezy competition, there is a kink in the prevailing demand curve at the existing price. If a firm increases price, then it risks losing market share; conversely, if a firm decreases price, the other firms will follow in order to retain their market share, and, as a result, industry output will drop below the socially efficient level. In this model, therefore, marginal costs can fluctuate without changing equilibrium price and quantity and the market becomes defined by the stickiness of its prices.

The kinked demand curve was a significant departure from earlier microeconomic theory in the context of the nature of rivals' reactions to pricing decisions, and with its emphasis on price rigidity in the market, it became a critical link between classical research and subsequent research on oligopoly behavior. Given that the primary characteristic of any oligopoly is the interdependence and rivalry among its firms, much of the research became involved with the strategic interaction among firms. A number of economists, including Shubik (1959) and Fellner (1960), broadened the research about the gamesmanship that takes place among the firms in oligopolistic markets. Subsequent studies have examined firm behavior in specific industries and in specific countries. In addition, various studies have continued to expand the literature on the effects of price rigidity in oligopolistic markets. Among these, Maskin and Tirole (1988) authored multiple studies on the implications of price competition and market share vis-à-vis the kinked demand curve, while Dozoretz and Matanovich (2002) warn us that the dangers of price competition can escalate into price wars of such severity that competitors and consumers alike are made worse off, resulting in a lose-lose game.

Game theory became a separate discipline following the groundbreaking work of John von Neumann. In *Theory of Games and Economic Behavior* (with Oskar Morgenstern, 1944), von Neumann analyzed strategic interaction in terms of a mathematical science. Game theory has helped to guide decision-making under uncertainty and during the second half of the twentieth century, it was successfully applied to fields other than management. There have been a variety of games that have been developed – simultaneous-move games, one-shot games, infinitely repeated games, finitely repeated games with an uncertain final period, finitely repeated games with a known final period, multistage games, etc. – each with its own theory and applications and each adding to the body of knowledge surrounding strategic thinking.

As a result of the applicability of game theory to real world decision-making, several computer games have been created in recent years to simulate the strategic decisions of business firms. In order to be useful, these business simulation games are generally quite involved and require significant work. The existing literature shows that some studies have been tested in classroom settings. Repeated games designed to be played throughout an entire term lend themselves well to pedagogical objectives. Simko (1991) utilized such a business simulation game in order to study the nature of the interaction of the members of the decision-making team. Meister (1999) and Sorenson (2002) also employed business simulation games over the course of an entire term. The focus of these studies was not only on the decision-making process in oligopoly firms, but also on the outcomes of the decisions, and the students in both studies learned that the attempt to have the greatest market share did not necessarily equate with success in terms of profitability.

A comprehensive study was undertaken utilizing a business simulation game that would be played in five waves (i.e., five datasets, for five different classes) in order to determine which of the decision variables were most important in increasing the firm's internal rate of return and to assess the degree of interdependence within a simulated oligopoly market.

METHODOLOGY

The business simulation game that was used for this study was the fifth edition of The Executive Game (Henshaw & Jackson, 1989). The game was played over the duration of an entire term in five different sections of the capstone MBA course in Strategic Management at Monmouth University's Leon Hess Business School - Spring 2011, Summer B 2011, Summer E 2011, Spring 2012, and Summer B 2013.

In each term, the game began at the same point. The game's algorithm and its assumptions were unchanged. It is important to note, however, that a particular strategy that might have been successful in one term might not necessarily yield the same results in another, since the relative strategies of the firms make each play of the game different.

In the first class of each term, students were divided into teams. The number of teams varied by term, dependent on the number of students enrolled in the course:

- Spring 2011 (15 students) – five teams with three students each
- Summer B 2011 (10 students) – five teams with two students each
- Summer E 2011 (29 students) – seven teams; six with four students and one with five students
- Spring 2012 (23 students) – six teams; five with four students and one with three students
- Summer B 2013 (21 students) – six teams; three with four students and three with three students

Each team (i.e., firm) began the game with identical market share, cash, and income. This was important to reflect the interdependence and rivalry of the firms in an oligopoly and to help simulate the kinds of strategies that would be needed to succeed in the game. In other words, regardless of the number of firms, the market was concentrated among a few large sellers.

Table 1 shows the report that each firm receives in the first class to begin the game. The game is based on the assumption that the firms are competing in a pure oligopoly; the instructor informs the students that the product that their firms sell is a surge protector. The students are also told that the previous owner of the firm has died and has given away equal parts of the firm. (In Table 1, which shows Period 1 data in the Summer B 2013 game, each of the six firms has a 16.7 percent share of the market.)

Table 1: Period 1 Report

Executive Game- 590SUB		Period 1 JAS	Price Index 101.0	Forecast, Annual Change 5/2%	
	Seas. Index 95	Next Qtr 115	Econ. Index 101	Forecast, Next Qtr 95	
		Information	on	Competitors	
	Price	Dividend	Sales Volume	Net Profit	IRR
Firm 1	$19.99	$53,000	$157,750	$25,806	5.61%
Firm 2	$19.99	$53,000	$157,750	$25,806	5.61%
Firm 3	$19.99	$53,000	$157,750	$25,806	5.61%
Firm 4	$19.99	$53,000	$157,750	$25,806	5.61%
Firm 5	$19.99	$53,000	$157,750	$25,806	5.61%
			Firm 1		
			Operating Statements		
Market Potential			190418		
Sales Volume			157750		
Percent Share of Industry Sales			16.7		
Production, This Quarter			145000		
Inventory, Finished Goods			0		
Plant Capacity, Next Quarter			106086		
Receipts, Sales Revenue					$3,153,422
Expenses					
	Marketing			250,000	
	Research and Development			50,000	
	Administration			330,177	
	Maintenance			115,000	
	Labor (Cost/Unit Ex. Overtime $5.68)			938,648	
	Material Consumed (Cost/Unit $6.29)			912,605	
	Reduction, Finished Goods Inv.			153,000	
	Plant & Eq Depreciation (2.50%)			183,125	
	Robotics Depreciation (5.0 %)			0	
	Finished Goods Carrying Costs			0	
	Raw Material Carrying Costs			60,000	
	Ordering Costs			50,000	
	Shift Change Costs			0	
	Plant Investment Expenses			6,250	
	Financing Charges and Penalties			0	
	Sundries			84,458	$3,133,262
Profit Before Income Tax					$20,160
Net Profit After Tax (incl. Inc Tax Credit)					$25,806
Dividends Paid					$53,000
Addition to Owner's Equity					($27,194)
Net Assets, Cash					243,536
Inv Value, Finished Goods					0
Inv Value, Materials					2,037,395

The Period 1 report is based on inputs that the instructor has already entered into the model. In Period 1, each firm shows the following: a sales price of $19.99; sales volume of $157,750; net profit of $25,806; and an internal rate of return of 5.61 percent. The objective is to be the firm with the highest IRR at the end of the game.

The grades that the students earn at the end of the game are tied to performance, and they are based on a formula that is applied to their firms' ending IRR. Although the results of the game are of interest to the firms – and the game is highly competitive – the primary purpose is pedagogical in its examination of oligopoly behavior. Each of the firms presents a "post-mortem" in the class following the conclusion of the game, when they reveal the critical thinking behind their business decisions during the course of the game.

This is a finitely repeated game with a known final period. For the five waves of the game, the number of periods ranged from eight to eleven and the number was dependent on the length of the term, with the Summer terms being shorter than the Spring terms.

There is no "end game" that firms can play. In other words, while the firms are aware of the final period of the game, they are warned not to zero out investments or materials purchased (i.e., they need to make decisions in the last iteration as though the business is ongoing). The algorithm of the game is designed to penalize firms whose decisions show large swings from period to period. This aspect of the game is important as it replicates experiential literature on strategic decision-making.

Each firm makes nine decisions for each period:

- Price
- Production (number of units)
- Marketing Investment
- Research & Development Investment
- Maintenance
- Dividends Paid
- Robotics Investment
- Plant & Equipment Investment
- Materials Purchased

Price is central to the game and firms that decide on extreme values assume the related risk. If they are priced low to gain market share, they might not be able to cover their costs. On the other hand, if they are priced high, they might not attain a sufficient share of the market.

The decision regarding *Production* is also central to the game. Firms will generally begin with either a Walmart strategy of low price-high volume or a Mercedes Benz strategy of high price-low volume.

Marketing and *R & D* investments are a means to remain competitive, particularly perhaps for firms whose strategy is to set relatively high pricing and production volume. In the game, the impact of a marketing investment hits in the current period; anything that is not used is lost in the next period. The impact of an R & D investment is lagged; firms are told that roughly one-third of the investment hits in the current period, another third in the next period, and the final third two periods out.

Maintenance is a function of production and firms are advised to determine how much to spend based on a formula. If a firm spends too little on maintenance, then the game's algorithm can cut the firm's production in a given period; if a firm develops a pattern for underspending on maintenance, then the algorithm can shut down the firm's production in a given period.

Dividends paid clearly are at the discretion of the firms. Firms are instructed to consider paying a dividend following any period in which they show a profit. The rate of return in the game is driven in large part by Owner's Equity and not necessarily by Net Income. Firms that make a dividend payout from profits are demonstrating the company's worth to its shareholders. Firms that opt not to make a dividend payout typically believe that profits are best re-invested back into marketing, R & D, and capital.

Investment into *Robotics* is a way for firms to drive down their labor costs. Firms need to determine whether the payback from robotics would be worthwhile. Robotics, like R & D, has a three-period lag in the game before the full effect of an investment takes hold.

Similarly, investment in *Plant & Equipment* has a three period lag. Similar to marketing and R & D, any firm that is motivated to grow its share of the market will likely benefit from a competitive capital investment strategy.

Lastly, *Materials Purchased* are directly linked to the level of output that a firm produces. Consequently, firms are urged to monitor their inventory levels to ensure that they can handle their production needs.

Each period's report displays three indexes, which are built into the game's algorithm - a price index, a seasonal index, and an economic index. The firms need to develop their decisions in the context of these external factors.

Periods represent quarters in this game. Period 1 is July-August-September; Period 2 is October-November-December; Period 3 is January-February-March; and Period 4 is April-May-June. The cycle repeats in Period 5 and subsequent periods.

In each period's report, firms only receive the following information for their competitors - price, dividends paid, sales volume, net profit, and IRR. As a consequence, firms are required to make their decisions in an environment marked by considerable uncertainty. After every four periods, additional year-end comparative data is provided. Therefore, while firms will react to limited competitor data (mainly price) after each quarter, the availability of information reported after each year typically results in broader reactions on the part of rivals. In a ten-period game, however, if a firm finds after the first four periods that it has not invested competitively, then it could lose significant ground in the market. Clearly, the game simulates the non-cooperative nature of oligopolistic markets.

Any firm that finds itself in a hole with a negative cash balance will see that finance charges are automatically generated on its income statement. Generating growth in this market is not easy, since each firm begins with a cash balance of $243,536. Sound decision-making is critical in this game, since firms that might be inclined to aggressively break ahead of the pack need to be able to offset spending with revenues.

In view of this, an important element of the game's algorithm is that in the first four periods, firms are constrained as to how much they can produce by only being allowed to run one shift and pay overtime. Beginning in Period 5, firms may employ multiple shifts. This single shift constraint, coupled with their small amount of cash at the outset of the game, simulates the price rigidity that is illustrated by the kinked demand curve. In theory, those firms that have established themselves in a good position in this market over the first four periods can, if they choose to, ramp up production in year two when the rules of the game are relaxed.

The authors decided to test the relationship among the nine decision variables with their independent variable – IRR – using Stata software to run a simple Ordinary Least Squares regression. Regression on each of the waves game would be run together, using their panel data of the same decisions in multiple periods. They expected to observe a few things as the game was played out and then proceeded to test these assumptions to see if they were borne out in the data:

- First and foremost, the authors expected to see the price convergence that has been described, with firms essentially jockeying for position in the market, by way of their decisions, particularly in the first year. With such a premium placed on budgeting, they expected for pricing to "bunch" within a fairly narrow band. In addition, because firms will only be able to see the competition's price, dividends paid, sales volume, profit, and IRR, except for at the end of every four periods, it was expected that this would also factor into why pricing would stay close among the firms throughout the game.

- Second, the authors expected that relatively high investment in marketing, R & D, plant & equipment, and materials purchased would yield high production (that production would generate sales volume as long as a firm's price strategy was competitive).
- Third, because they knew that spending on maintenance should be correlated to production, the authors expected to see collinearity between these two variables. They were less certain about their other variables, but because they knew that their variables were all endogenous, with each depending, to some extent, on the others, they wouldn't be surprised if there was additional redundancy among the predictors.
- Fourth, the authors were concerned that by using a large amount of data (had data for twenty-nine firms, which, including Period 1, totaling 255 observations), results would cancel each other out, potentially causing the predictions to be poor.

DISCUSSION

The simple OLS yielded unsatisfactory results. Regressing all nine variables on IRR, only price proved to be useful. Its coefficient of -0.024% meant the higher the price, the lower the IRR; its t-statistic showed that this impact was statistically significant at 1%. The coefficients of the other eight variables were small, confirming that multicollinearity among the variables was an issue.

The authors looked closely at their data for outliers and removed the most extreme values from the estimation in order to make the distribution more normal and eliminate the undue influence that these values might have on their results. Despite this, price remained the only consistent explanatory variable.

A stepwise regression was then performed in order to try to identify a better model. This regression automatically removed many of our predictive variables from the estimations that it deemed unsuitable by conducting a sequence of F-tests on possible model specifications to identify which better fit the data-generating process. However, the best specification revealed significant t-statistics, but the coefficients of the variables (except for price) were still small, suggesting that the decisions of the firms were cancelling each other out. As an example, with some firms spending aggressively on marketing and others spending conservatively, the relationship between the explanatory variable and IRR yielded an inconclusive result.

The advantage of simple OLS is that, under certain circumstances, it is easy to estimate and interpret; the advantage of a stepwise regression is that it can aid in identifying which variables have the most influence on the IRR. However, with neither yielding satisfactory results, the authors discarded them as their model and moved to a log linear estimation. According to standard statistical reasoning, if the ratio of the largest to smallest value is ten times or more, then the data are best expressed in log scale. This was especially the case for IRR, which was their dependent variable. Moreover, if a graphical examination of the data shows skewed distributions or a large spread – as was the case with many of their variables – then log transformation is likely to improve estimations.

The authors were interested in determining the IRR based on price, production, marketing, materials, plant and equipment, research and development, as well as robotics. Written as an equation, the model can be described as:

$$\log(IRR) = \beta 0 + \beta 1 * x1 + \beta 2 * x2 + \beta 3 * x3 + \beta 4 * x4 + \beta 5 * x5 + \beta 6 * x6 + \beta 7 * x7$$

where

x1 = lnprice
x2 = lnproduction
x3 = lnmarketing
x4 = lnmaterials
x5 = lnplant&equipment
x6 = lnr&d
x7 = lnrobotics

Focusing on the effect of price, they take two values of price, p1 and p2, and hold the other predictor variables constant. The equation above yields the following:

$\log(IRR)(p2) - \log(IRR)(p1) = \beta2*(\log(p2) - \log(p1))$

This can be simplified to $\log(IRR(p2)/IRR(p1)) = \beta2*(\log(p2/p1))$, leading to

$IRR(p2)/IRR(p1) = (p2/p1)^{\beta2}$.

This includes that as long as the ratio of the two prices - p2/p1 - stays the same, the expected ratio of the outcome variable – IRR - stays the same. For example, for any 10% increase in price, the expected ratio of the two geometric means for IRR will be $1.10^{\beta2} = 1.10^{.4085369} = 1.0397057$. In other words, expect about a 4% increase in IRR when price increases by 10%.

Maintenance or dividends paid were not included in the regression. As expected, there was a very strong correlation between maintenance and production. The correlation coefficient between these two variables was +0.97, which almost represents a perfect one-to-one relationship. Also as expected, while firms making a profit were encouraged to consider paying dividends, the authors believed that these payments would not strongly influence IRR. When IRR was regressed on dividends, a positive but insignificant coefficient was observed.

Note that log linear estimation cannot take a log of a negative number. Consequently, any periods where the IRR was less than zero would be eliminated from the model. The number of observations that ended up being dropped was small.

Panel data methods were also used to help control for firm heterogeneity due to characteristics that are team specific. Specifically, a dummy variable was created for each firm, by setting a different intercept and a different slope for each firm, thereby allowing random effects or fixed effects regressions to be performed. A Hausman test revealed that random effects estimation is more suited to this data. Controlling for panel effects compensated for firms that were either very cautious or very aggressive.

Table 2 shows the results of using log linear estimation while controlling for random effects. The log linear model provided larger coefficients as well as greater significance. Over the course of the entire game, both price and production were positively related to IRR, as reflected in the value of their coefficients. Moreover, these variables were also statistically significant.

Table 2: Random Effects Estimations for IRR

	(1) IRR	**(2) IRR**
	All periods	**Periods 2-4**
Log price	3.149	6.656
	(3.29)**	(2.25)*
Log production	0.736	-3.998
	(2.17)*	(3.59)**
Log marketing	-0.070	-0.847
	(0.35)	(2.04)*
Log materials	0.138	0.009
	(1.41)	(0.08)
Log plant & equipment	-0.197	0.205
	(1.54)	(0.71)
Log R & D	-0.117	-0.852
	(0.98)	(1.95)
Log robotics	0.054	-0.245
	(0.53)	(1.42)
Simulation 1	0.023	-0.579
	(0.04)	(0.75)

Table 2 cont.

Simulation 2	-0.240	-1.979
	(0.50)	(2.58)**
Simulation 3	0.570	0.025
	(1.20)	(0.04)
Simulation 4	0.149	0.248
	(0.32)	(0.39)
Constant	-19.993	43.911
	(4.11)**	(2.54)*
Observations	123	49
Number of firms	27	25
Rho	0.37	0.76
Wald $chi^2(11)$	29.33**	33.58**

Absolute value of z statistics in parentheses. * significant at 5%; ** significant at 1%.

Importantly, as Table 2 shows, as opposed to its practical significance over the course of the entire game, price is twice as important when the analysis is restricted to Periods 1 through 4 only. Moreover, production, marketing, and R & D are all statistically significant during the first year, but they are negatively related to IRR. This seemed to confirm the hypothesis since it reflected the critical nature of pricing in the initial periods, but not as much in later periods when it became less important and the ability of firms to ramp up production became more important as a means to help drive up IRR.

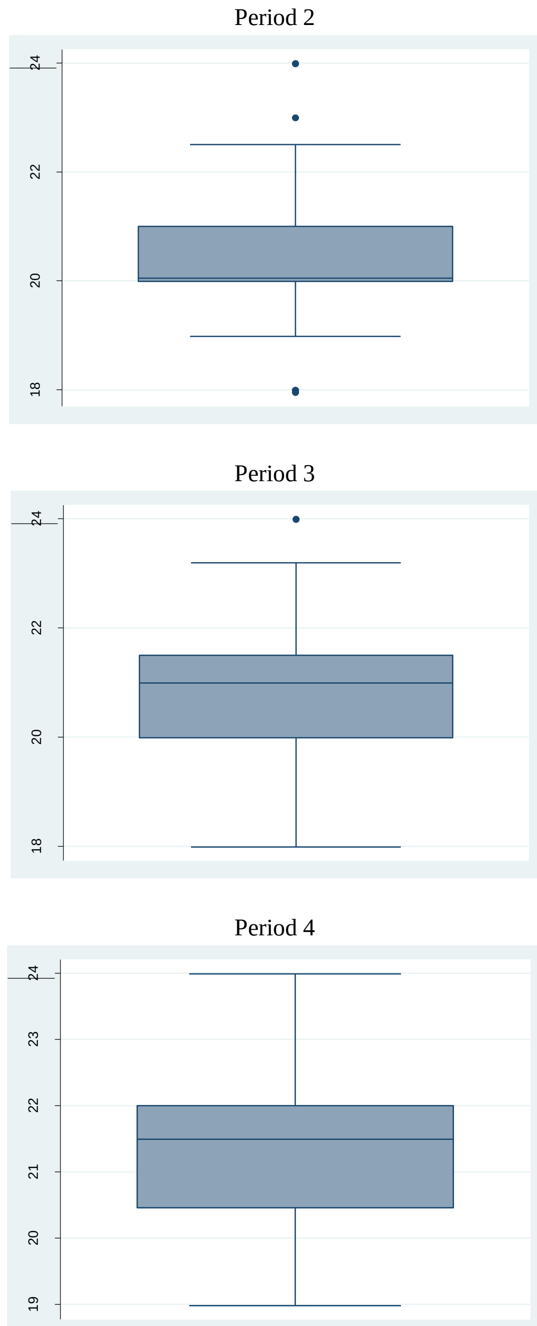
Given this finding, and because the authors were most interested in studying the price rigidity that describes oligopolistic behavior, they focused much of their analysis on the first year of the game, when it was particularly evident. This price rigidity is further illustrated in Table 3 which shows that following Period 2, when firms first were able to set their own values, the standard deviation in price decreased in Periods 3 and 4, which is indicative of price convergence.

Table 3: Summary Statistics for Price over the First Four Periods

	Mean	Standard Deviation	Minimum	Maximum	Observations
Period 1	$19.99	0	$19.99	$19.99	29
Period 2	$20.33	$1.44	$17.95	$23.99	29
Period 3	$20.78	$1.36	$17.99	$23.99	29
Period 4	$21.34	$1.35	$18.98	$23.99	29

Figure 1 reveals box plots for Periods 2 through 4. Each box displays the respective period's upper and lower quartiles for price, while the line in the box displays the median price. The points represent extreme values which become fewer in number as prices converge. The box body represents the distribution of values and the whiskers represent the tails, so one can see how the distribution became increasingly normal, or bell shaped, in Periods 3 and 4, and hence less skewed from the median.

Figure 1: Box Plots for Price for Periods 2 – 4



The authors looked closely at the relationship between price and market potential in the first four periods of the game and observed that the negative correlation between price and market potential weakened through the first year, which suggests that firms scaled back on price when they realized that it was set too high for them to generate sufficient sales volume. This is because, in the first year, firms were situated along an inelastic arc of the kinked demand curve. As a result, the correlation coefficients were -0.9475 in Period 2, -0.7281 in Period 3, and -0.3523 in Period 4. This supports the notion that as firms raised their price above their rivals, they risked a decline in total revenue.

Table 4 examines the relationship among price, market potential, sales volume, sales revenue, and IRR for three different groups during Periods 2 through 4. The first group roughly represents the top quartile of firms, whose average price was $1 or more *above* the overall average. The second group roughly represents the middle two quartiles of firms, whose average price was within $1 of the overall average. The third group roughly represents the bottom quartile of firms, whose average price was $1 or more *below* the overall average. As expected, there were two conclusions that were drawn from this comparison: (1) the high price group had lower market potential and sales volume than the other groups and (2) the low price group had higher market potential than the other groups, but the lowest sales revenue and IRR. Interestingly, after four periods, the high price group still had a higher IRR, but the authors believe that this position would not be sustainable in subsequent periods given a strong negative correlation between total spending and IRR during Periods 2 and 4. They established that total spending largely consisted of marketing, R & D, maintenance, robotics, plant & equipment, materials, and dividends paid. The individual correlation coefficients were -.67 in Period 2, -.71 in Period 3, and -.52 in Period 4.

Table 4: Price Quartiles

High Price ($1 or more than the mean)					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Period 2					
price	6	$22.45	0.928238	21.5	23.99
sales volume	6	121457.7	23007.98	95000	148521
sales revenue	6	$2,713,518.00	438888.9	2279050	3230310
mkt potential	6	134530.3	28600.07	95036	173219
irr	6	0.043083	0.020522	0.0119	0.0733
Period 3					
price	6	$22.53	0.861642	21.99	23.99
sales volume	6	123750	22404.71	95000	149810
sales revenue	6	$2,775,061.00	429614	2279050	3295820
mkt potential	6	129413.2	17653.72	111327	152160
irr	6	0.0400167	0.023805	0.0082	0.0769
Period 4					
price	6	$23.16	0.681188	22.49	23.99
sales volume	6	136529.2	25879.94	106000	177096
sales revenue	6	$3,152,665.00	550562.5	2542940	4071448
mkt potential	6	147456.2	23918.85	127658	193492
irr	6	0.0341333	0.027363	0.0042	0.072
Within $1 of the mean price					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Period 2					
price	16	$20.31	0.426973	19.99	21
sales volume	16	145268.2	12103.42	100000	148521
sales revenue	16	$2,950,570.00	260017.8	1999000	3118950
mkt potential	16	187908.8	18447.37	163619	220598
irr	16	0.035575	0.028597	-0.0398	0.0636
Period 3					
price	17	$20.86	0.597584	19.99	21.5
sales volume	17	143597.2	18151.32	100000	163575
sales revenue	17	$2,996,600.00	393872.6	1999000	3405355
mkt potential	17	168264.4	26331.48	125580	216416
irr	17	0.0317824	0.030006	-0.0217	0.0713
Period 4					
price	16	$21.43	0.583025	20.45	22
sales volume	16	159390.4	30192.98	125000	258825
sales revenue	16	$3,409,725.00	612436.9	2643750	5435325
mkt potential	16	183106.6	60970.02	127798	378942
irr	16	-0.014425	0.157932	-0.5894	0.0931

Table 4 cont.

Low Price (-$1 or less than the mean price)					
Variable	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Period 2					
price	7	$18.56	0.543192	17.95	19
sales volume	7	142384.4	16007.28	106086	148521
sales revenue	7	$2,639,611.00	285683.6	2015634	2821907
mkt potential	7	235018.6	12431.12	214301	252615
irr	7	-0.0083143	0.054982	-0.1317	0.0242
Period 3					
price	6	$18.83	0.409133	17.99	19
sales volume	6	145546.8	10487.95	125000	153409
sales revenue	6	$2,738,631.00	186210.6	2372500	2865095
mkt potential	6	222545	53654.58	185121	325260
irr	6	-0.0493833	0.114416	-0.2822	0.0082
Period 4					
price	7	$19.59	0.56499	18.98	20.13
sales volume	7	155149	2773.534	150760	159132
sales revenue	7	$3,038,827.00	91799.3	2909344	3181040
mkt potential	7	187772.4	22271.81	163587	216352
irr	7	-0.0062429	0.030791	-0.034	0.0559

Regarding firm strategy, those that pursued neither a low price/high volume price strategy nor a high price/low volume strategy from the outset had relatively lower IRRs. To test the hypothesis that firms pursue inconsistent strategies or vary their strategy too much, the authors looked at the percent change in the decision variables from period to period, paying particular attention to price, production, and total spending. They arbitrarily assigned a change from one period to another of 10 percent or more in either direction to signify a large swing for a firm. Using this as a barometer, they found that two-thirds of the sample changed price, production, or total spending by more than 10 percent between periods. The one-third of the sample that was more consistent in their strategy – regardless of whether it was low price/high volume or high price/low volume – showed greater profitability on average. (Redefining the cutoff at ± 25 percent change in price, production, or total spending as a robustness check, the authors observed that the percentage of firms making large swings in their decisions dropped significantly to 38 percent.) Not surprisingly, in Period 5, when the firms were able to move to multiple shifts, the percentage of firms making large swings in their decisions jumped from 67 percent to 83 percent.

Because firms were provided more competitive data in the reports after each full year (and therefore might be more likely to modify their strategy in the next period), the variance was compared across all firms for total spending from Period 4 to Period 5 and again from Period 8 to Period 9. Table 5 shows that the variance, measured by standard deviation, actually increased in Period, 5 but it did decline in Period 9. The increase in Period 5 is understandable since some firms became more aggressive in their spending (as well as pricing) at this time, once they were unshackled in terms of production capability. Other firms, on the other hand, stuck to a more conservative strategy throughout the game. After the year two report, most firms had become entrenched in their respective strategies and the decrease in the variance represented the correction that was expected.

Table 5: Variance in Total Spending Between Periods

Total Spending	Mean	Standard Deviation	Minimum	Maximum	Observations
Period 1, year1	$2,468,000	0	$2,468,000	$2,468,000	29
Period 2	$2,219,618	$762,732	$776,000	$4,565,173	29
Period 3	$2,035,394	$819,927	$881,250	$5,147,735	29
Period 4	$2,025,403	$706,136	$556,700	$3,695,001	29
Period 5, year 2	$2,079,714	$1,026,040	$747,750	$4,980,000	29
Period 6	$2,202,902	$1,228,730	$644,500	$6,029,605	29
Period 7	$3,237,871	$5,597,088	$499,750	$31,800,000	29
Period 8	$1,828,487	$909,617	$360,455	$3,675,000	29
Period 9, year 3	$1,532,262	$811,043	$347,750	$2,645,500	11
Period 10	$2,973,719	$2,258,280	$1,395,000	$7,513,350	6
Period 11	$1,666,744	$698,138	$465,000	$2,514,000	6

As indicated previously, the authors were interested in determining whether high levels of spending on marketing, R & D, plant & equipment, and materials purchased would yield high production. They created a regression where log levels of production was the dependent variable and log levels of spending on marketing, plant & equipment, materials, R & D, and robotics were the independent variables. Table 6 shows the relationship between each of the independent variables and production and that the coefficients for marketing, plant & equipment, R & D, and robotics are all significant. Looking at the coefficients of the regressors, one can see how much their dependent variable changes when the independent variables increase by one unit. Thus, for example, a 10 percent increase in spending on marketing increased production by 1.5%. The table shows that two-period lags for plant & equipment, R & D, and robotics were included since the full effect of these investments on production will only be felt two periods out. While reflecting the two-period lag for these variables largely shows a more positive effect on production, the coefficients lose their statistical significance due to the large number of observations, as was suspected.

Table 6: Determinants of Production

	Log Production
Log marketing	0.150
	(2.90)**
Log plant & equipment	-0.113
	(2.67)**
Log plant & equipment (t-1)	0.064
	(1.15)
Log plant & equipment (t-2)	0.061
	(1.17)
Log materials	0.018
	(0.36)
Log R & D	-0.125
	(2.79)**
Log R & D (t-1)	0.047
	(0.66)
Log R & D (t-2)	-0.025
	(0.34)
Log robotics	0.132
	(3.54)**
Log robotics (t-1)	-0.106
	(1.59)
Log robotics (t-2)	0.088
	(1.50)
Constant	9.741
	(9.67)**
Observations	116
Number of firms	26
Wald $chi^2(11)$	44.07**
Rho	0.191

Absolute value of z statistics in parentheses. * significant at 5%; ** significant at 1%.

In looking beyond the first four periods, the major shift in strategy among many of the firms, which was discussed earlier, was observed. As shown in Table 7, from Period 5 through the end of the game, price still had practical significance as an independent variable, but it no longer was statistically significant. On the other hand, production was positively related to IRR and it was the only variable that had statistical significance. Notwithstanding the finding that many of the variables were insignificant because the relatively large number of observations tended to cancel each other out, the practical and statistical significance of production was not lost.

Table 7: Subsequent Years of Simulation (Random Effects Estimation)

	Log IRR
Log price	0.833
	(0.77)
Log production	0.767
	(2.11)*
Log marketing	0.166
	(0.84)
Log materials	0.076
	(0.58)
Log plant & equipment	-0.153
	(1.36)
Log R & D	-0.081
	(0.63)
Log robotics	-0.006
	(0.04)
Simulation 1	1.645
	(2.01)*
Simulation 2	-0.041
	(0.09)
Simulation 3	0.403
	(0.81)
Simulation 4	0.272
	(0.52)
Constant	-15.465
	(2.70)**
Observations	74
Number of firm_id	20
Wald $chi^2(11)$	17.71*
Rho	0.483

Absolute value of z statistics in parentheses. * significant at 5%; ** significant at 1%.

In this study, marketing and robotics did appear to positively impact production and IRR, as was expected. However, investments in R & D and plant & equipment were less conclusive. Much of the estimated specification resulted in few practical or statistically significant regressors, supporting the expectation of poor predictive power within the simulation. Also as expected, maintenance and production were in fact highly collinear, almost showing perfect collinearity. For the most part, the authors were able to observe evidence of price rigidity, especially within the first four periods, when firms were not able to observe the other firms' choices. This finding crystallized the primary objective of the research; namely, to observe the convergence in pricing that is part and parcel of the gamesmanship that occurs in an oligopoly.

The business simulation helped students experience the jockeying for position and the concomitant stickiness in prices that oligopolistic firms need to contend with, as well as the critical importance of formulating appropriate strategies in order to succeed in this type of market. In their post-mortems, firms explained that it became imperative to modify their strategy once the results of competing firms were made available. Students learned that this sort of strategic behavior is common in oligopolistic markets and their feedback concerning the ability to simulate the gamesmanship found in oligopoly theory was overwhelmingly positive.

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