



Theory of Market Entry: Dynamic Games

Bachelor's Thesis

Krista Kuuttiniemi

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Instructor: Pauli Murto

Opponent: Mikko Snäkin

Abstract

In this thesis I study the theory of market entry through dynamic games. I answer how economics describes market entry and how parties act in order to maximize their profits. I present the concepts of Nash equilibrium and subgame perfect Nash equilibrium in dynamic games. When studying market entry I first present models of sequential quantity competition using Stackelberg's model and the Spence-Dixit model. Second, I present sequential price competition with identical firms and with differentiated products. Third, I present sequential quality choice. In sequential price competition and in sequential quality choice I use variants of Hotelling's spacial model in my analysis. The models I study here are highly mathematical and abstract. Though these models do not provide a perfect answer in real life scenarios, they offer a guideline on firms' decision-making process in market entry.

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1 Introduction

With the increasing competition in today's economy it is relevant to study the theory of market entry. In my thesis I do this through dynamic games. The world globalizes at an increasing speed. Countries' tear down their market entry barriers and open their markets for new players with negotiations over free trade agreements such as the Transatlantic Trade and Investment Partnership (TTIP) and The Comprehensive Economic and Trade Agreement (CETA). Globalization in Finland can be seen from the governments' efforts in increasing Finland's competitiveness with a competitive agreement (in Finnish "Kilpailukyksopimus"). Politicians often rely on economists guidance, who base their recommendations on existing research and by making additional research of their own.

Though theory of market entry and dynamic games is relevant today it has been a classic object of interest for economists for a long time. Researchers such as Von Neumann and Morgenstern, Nash, Tucker and Selten contributed heavily to game theory, Selten especially contributing to dynamic games with his subgame perfect Nash equilibrium. Based on the static, simultaneous move game studies of Cournot and Bertrand researchers such as Von Stackelberg made their own models appropriate for dynamic games.

In my Bachelor's Thesis I study the theory of market entry through dynamic games. I will answer how economics describes market entry and how parties act in order to maximize their profits. This thesis is a literature review but I will use visuals and mathematical models when necessary in order to better illustrate the meaning and reasoning behind these models. In the section of dynamic games I will use case examples based on real life situations to better demonstrate different formats of competition.

The structure of my thesis is as follows. First, I present game theory and Nash equilibrium. I analyze Tucker's prisoner's dilemma and Selten's subgame perfect Nash equilibrium used in sequential games.

Second, I go through the theory of market entry with dynamic games. Here I present three ways how to model dynamic games: 1) sequential quantity competition with the classic Stackelberg model and the Spence-Dixit model of capacity competition, 2) sequential price competition in case of identical firms and with differentiated products and 3) sequential quality choice. I refer to

previous research, explain the basic idea of models and demonstrate models with appropriate case examples.

Last section concludes this thesis with some final remarks and comments. Here I present the main results and restrictions of my thesis.

All subjects in my thesis, such as the theory of games, Nash equilibrium and models of dynamic games could each be studied in a more comprehensive matter. As a bachelor's thesis this paper will not provide any revolutionary ideas, nor should it. I study the most relevant parts of these subjects in order to answer my research questions and go through them comprehensively by analyzing the existing research, considering models based on my own judgment and offering guidance through mathematical models and graphs. With case examples I tie these models to real life.

2 Game Theory & Nash Equilibrium

2.1 Introduction to Game Theory

Before one can understand the theory of market entry it is important to be introduced to game theory as it is the base for understanding players' choices in both static and dynamic games. Osborne and Rubinstein (1994) present game theory as a set of analytical tools made for understanding the phenomena of decision-making. Assumptions under the theory are that decision-makers are rational and that they take other decision-makers' behavior into account when making decisions. Models of game theory are highly abstract and thus can be used in several phenomena.

John von Neumann and Oskar Morgenstern were the first to use game theory in economics in their book "Theory of Games and Economic Behavior" (1944). Even though von Neumann first presented the mathematical foundation to game theory in his paper "Zur Theorie der Gesellschaftsspiele" in 1928, von Neumann's work was too mathematical for economists. His collaboration with Morgenstern enabled economists to take this tool and use it to analyze economic problems. According to Nobelprize.org (1994a) the main contributions of von Neumann and Morgenstern were in their two-person zero-sum games. In two-person zero-sum games one player gains as much as the other player loses, such as in a game of chess. In this game they presented a minmax-solution where each player seeks to maximize his utility in the worst possible outcome, depending on the other player's strategy.

As Harold Kuhn states in Von Neumann and Morgenstern (2007), the excitement in game theory started to bloom during 1940-1950. Important contributors to game theory at the time included John Nash, Lloyd Shapley, D. B. Gillies, John Milnor, Harold Kuhn and A. W. Tucker. In this section I will focus on the work of John Nash in the form of Nash equilibrium, which I will demonstrate with A. W. Tucker's Prisoner's Dilemma. Finally I will go through subgame perfect Nash equilibrium, created by Reinhard Selten who received a Nobel Prize with John Nash. Selten's subgame perfect Nash equilibrium is a refinement of Nash equilibrium used in dynamic games, hence relevant when I present market entry with dynamic games.

2.2 Nash Equilibrium

Nash equilibrium was created by John Nash and is the most commonly used equilibrium in game theory. During 1950-1953 Nash published four papers, in which he made three contributions to game theory: 1.) dissociated the concept of cooperative and non-cooperative games, 2.) proved an equilibrium for non-cooperative, finite games (Nash equilibrium) and 3.) suggested a Nash bargaining solution for two-person cooperative games with fixed and variable threats (Nash et al. (1950), Nash Jr (1950), Nash (1951), Nash (1953)).

Nash equilibrium is a state of play where each player plays its optimal strategy and in which no player would alone change its strategy. It is an equilibrium of non-cooperative games, hence players cannot make binding agreements such as cartels. Before Nash's equilibrium, there was no general theory of non-cooperative games. Nash equilibrium is based on assumptions of players' rational behavior and that players' rationality is common knowledge.

Nash's contributions largely affected research in game theory. Nash's novel work was contrary to von Neumann and Morgenstern's theory, who publicly criticized Nash's proposals. Nash's work encouraged game theorists to separate cooperative and non-cooperative games, hence increased researchers' interest in non-cooperative games.

2.2.1 Nash Equilibrium in Static Games

Tucker's prisoner's dilemma is a famous example of a game with a Nash equilibrium. According to Nobelprize.org (1994b) Tucker created prisoner's dilemma in 1950's while at a leave from Stanford.

Because of an office shortage he stayed in the Psychology Department, where he held a seminar on his work. For this, Tucker created prisoner's dilemma to introduce game theory, Nash equilibrium and paradoxes in a non-socially-desirable equilibrium.

The following table of Tucker's Prisoners Dilemma demonstrates a case of Nash equilibrium. Below, I interpret the table in detail.

The police interrogate two suspects in a crime. They both are questioned separately, each unaware of what the other suspect says. If both suspects confess they will be sentenced to four years in prison. If neither confesses, both will be sentenced to two years in prison. If only one confesses he will be freed while the other suspect will be sentenced to six years.

It is worth noticing that the table doesn't show the number of years spent in prison but the suspect's utility, hence the higher the number is the better suspect's outcome is. In the table player's are marked as (*Suspect 1*, *Suspect 2*). Here the best situation for players is that neither confesses. However they both have an incentive to confess. Regardless of what the other player does, the other prefers always *Confess* to *Don't Confess*. The game has a unique Nash Equilibrium (*Confess*, *Confess*).

		Suspect 2	
		<i>Don't confess</i>	<i>Confess</i>
Suspect 1	<i>Don't confess</i>	(4, 4)	(0, 6)
	<i>Confess</i>	(6, 0)	(2, 2)

As can be seen, here the unique Nash Equilibrium (*Confess*, *Confess*), isn't the socially optimal result. The optimal result would be (*Don't confess*, *Don't confess*) as here the total utility would be maximized ($4 + 4 = 8 > 2 + 2 = 4$). Hence this demonstrates that even with a unique Nash equilibrium it may not lead to the socially optimal result.

2.2.2 Subgame Perfect Nash Equilibrium

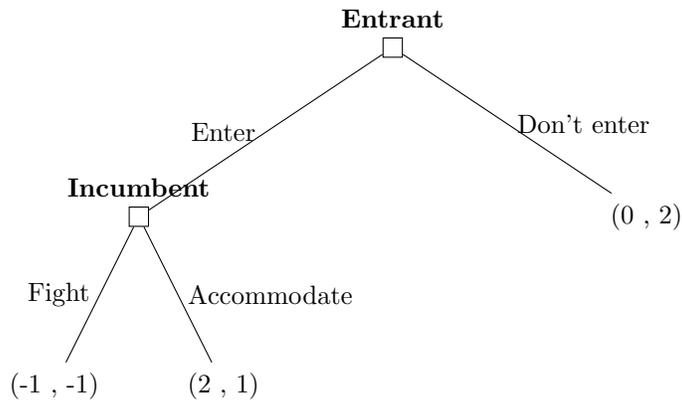
Richard Selten's subgame perfect Nash equilibrium, the most fundamental refinement of Nash equilibrium, is used in finite extensive form games and dynamic, sequential games. The concept of subgame perfection has affected economic policy, oligopoly analysis and economics of information

(Nobelprize.org (1994a)). Subgame perfect Nash equilibrium eliminates uninteresting Nash equilibria in the case of having several non-cooperative equilibria. By using stronger conditions, Selten reduced the amount of equilibria and avoided unreasonable equilibria, hence dissociated perfect and imperfect Nash equilibria.

Selten realized that even though a combination of strategies satisfied conditions of Nash equilibrium it might still include irrational strategies (Nobelprize.org (1994b)). To exclude these imperfect Nash equilibria he proposed the concept of subgame perfection in "Spieltheoretische Behandlung eines Oligopolmodells mit Nachfrageträgheit" (Selten (1965)). Below I present an example of a sequential game which has several Nash equilibria and explain why Selten's subgame perfect Nash equilibrium is needed to find an optimal strategy.

Below is a decision tree describing a monopoly market in which a new player (entrant) desires to enter and where the incumbent threatens the entrant with a price war. The entrant has two choices: it can enter the market or stay out. Accordingly the incumbent has two choices: it can execute its threat and fight or it can accommodate. The entrant makes its decision based on the possible outcomes and whether it believes the incumbent will fulfill its threat.

This example has two Nash equilibria. The first Nash equilibrium is that the entrant takes incumbent's threat seriously and doesn't enter the market. Here, incumbent's threat isn't carried out and so is not a cost for the incumbent. Hence, the first Nash equilibrium is (*Don't enter, Fight*). The second Nash equilibrium is that the entrant doesn't take the incumbent's threat seriously. For example if the entrant realizes the incumbent faces high costs in price war, hence would accommodate, the entrant enters the market. The incumbent will not start price war ($-1 < 1$), hence the second Nash equilibrium is (*Enter, Accommodate*). The second Nash equilibrium (2, 1) is also a subgame perfect Nash equilibrium, since it fulfills Selten's requirement of taking account only credible threats.



Here I have demonstrated Selten's subgame perfect Nash equilibrium and explained why Nash equilibrium doesn't work in sequential games. In this decision tree I only demonstrated the subgame perfect Nash equilibrium with discrete choices. However, in the next section of market entry and dynamic games the choice set is continuous as there is an infinite amount of options.

3 Market Entry: Dynamic Games

According to Pepall et al. (2011) dynamic games are games in which players take their actions sequentially and where one player's choice establishes the environment in which a subsequent player moves. These sequential move games involve passage of time between one move and the next unlike simultaneous or static move games, which are played at a certain point in time. In dynamic games, the first choice is made by a first-mover after which a second-mover makes his move. Pepall et al. (2011) note that the order of play often presents an advantage to one player or another, often in favor of the first-mover. Though first-mover advantages appear often, many markets also have an advantage when playing second, called second-mover advantage.

Naturally, in a real market setting games can happen simultaneously and consist of multiple rounds with several players. In my thesis I mainly focus on dynamic games with two rounds of play and two players but I also present outcomes of several moves when it supports intuition and is easy to follow. I consider all games to have a subgame perfect Nash equilibrium with only one possible outcome in each subgame. In the subsections below I will verbally explain the different models of market entry and present case examples. In the Stackelberg model of quantity competition I use mathematics as I find it supports readers' intuition and is quite easy to follow.

3.1 Sequential Quantity Competition

3.1.1 The Stackelberg Model

The Stackelberg model of quantity competition is one of the most well-known models of market entry. The Stackelberg model was introduced by Heinrich von Stackelberg in his book "Market Structure and Equilibrium" in 1934 (English translation of Von Stackelberg (1952)). Stackelberg model is a case of imperfect competition on a non-cooperative, sequential game.

In the Stackelberg model firms compete in a sequential play with the level of output. Though there are Stackelberg models with multiple players here I only observe the case of two players in a one period game where both players have one move. The first-mover can be referred to as market leader as it chooses first its level of output q_1 . By the time the second-mover makes its choice of output q_2 it knows first-mover's choice. Accordingly, the first-mover knows this information is available for the second-mover.

The Stackelberg model has a subgame perfect Nash equilibrium, hence it presents the theoretical optimal choice of quantity under imperfect competition in a non-cooperative, sequential game. The following notation is by Pepall et al. (2011) but I renewed the functions in order to demonstrate the Stackelberg model in a more thorough way. The functions below describe the moves made by both players in the Stackelberg model. Here player 1 is the first-mover and player 2 is the second-mover.

First-mover's profit is a function of quantities q_1, q_2 :

$$\pi_1(q_1, q_2) = P(q_1 + q_2)q_1 - cq_1$$

Where $P(q_1 + q_2)$ is a function determining price per produced unit, c is cost per produced unit (there are no fixed costs) and q_i ($i = \{1, 2\}$) is the level of output or quantity.

By backward induction I can find out the equilibrium in sequential games, hence I need to solve the second-mover's decision. To determine the first-mover's maximized profit I replace q_2 with second mover's best-response function $R_2(q_1)$. In the Stackelberg model players' rationality is assumed. Hence as it is impossible to know second-mover's future decision q_2 I assume that the second-mover acts in its best interest and chooses its level of output by its best-response function $R_2(q_1)$.

$$\max_{q_1} \pi_1[q_1, q_2(q_1)] = P[q_1 + R_2(q_1)]q_1 - cq_1$$

To maximize profit it is necessary to take the derivative with respect to q_1 of the profit function above. We get:

$$P[q_1 + R_2(q_1)] + q_1 P'[q_1 + R_2(q_1)] - c = 0$$

which can be written as

$$P + q_1 \left[\frac{dP}{dQ} \right] \left[1 + \frac{dR_2(q_1)}{dq_1} \right] - c = 0 \quad (1)$$

I assume that demand is given by a linear function $P = A - BQ = A - B(q_1 + q_2)$ and both players have the identical and constant marginal cost c . Firm 2's profit can be written as

$\pi_2 = [A - B(q_1 + q_2) - c]q_2$. When taking the derivative with respect to q_2 we get

$\frac{\partial \pi_2}{\partial q_2} = A - c - Bq_1 - 2Bq_2 = 0$. By rearranging the function we get second-mover's response:

$$R_2(q_1) = q_2 = \frac{A - c}{2B} - \frac{q_1}{2}$$

Now that the best-response function is solved I can simplify a part from equation 1

$$q_1 \left(\frac{dP}{dQ} \right) \left(1 + \frac{dR_2(q_1)}{dq_1} \right) = -B \frac{q_1}{2}$$

Here $P = A - BQ$. The derivative of P with respect to Q is $\frac{dP}{dQ} = -B$ and the derivative of $R_2(q_1)$ with respect to q_1 is $-\frac{1}{2}$ thus $\left(1 + \frac{dR_2(q_1)}{dq_1} \right) = \frac{1}{2}$.

Equation 1 presented the first-mover's maximized profit. By placing the above results in equation 1, I can find the level of output for both players:

$$A - B \left[q_1 + \frac{A - c}{2B} - \frac{q_1}{2} \right] - B \frac{q_1}{2} = c$$

Here $P = A - BQ$, $q_1 = \left[q_1 + \frac{A - c}{2B} - \frac{q_1}{2} \right]$, $q_2 = -B \frac{q_1}{2}$ and c is the identical and constant marginal cost.

Simplification of results gives us the equilibrium quantities

$$q_1 = \frac{A - c}{2B}; \quad \text{and} \quad q_2 = \frac{A - c}{4B} \quad (2)$$

The result in equation 2 presents that in the case of identical and constant marginal cost c the Stackelberg leader produces twice as much as the second-mover. Furthermore, we learn that Stackelberg-leader makes double profits when there are no fixed costs.

The Stackelberg model with its sequential decision making provides a more realistic approach to market entry than its predecessor, the Cournot model with simultaneous decision making. Majority of the existing Stackelberg research compares it with Cournot's model, hence Cournot has been a topic of interest for many researchers studying Stackelberg (one can read for example Amir and Grilo (1999), Hamilton and Slutsky (1990), Dowrick (1986), Huck et al. (2001)). Since my thesis focuses on dynamic games, I will not study the Cournot model here but you can find more information from the original paper of Cournot (1838) and from research by Davidson and Deneckere (1986).

The Stackelberg model does not apply perfectly to real life scenarios. Though the Stackelberg model can include more than two players and they can have different cost structures, it still has a requirement of players' producing identical products. The model does however prove existence of first-mover advantage in quantity competition. In the next paragraph I demonstrate the use of Stackelberg model with a fairly appropriate case example.

Case of Selling Christmas Trees. Let's consider an example of selling Christmas trees in Töölöntori, Helsinki. There are two Christmas tree producers. One can assume that the producers' costs and the Christmas trees are identical, they are sold at the same price and that the inhabitants of Töölö can not buy a Christmas tree from anywhere else than Töölöntori's market place. Assumed is that both players retrieve their trees from the same forest.

The first-mover gets to the forest first. He can now take as many trees as he prefers. After he has collected the trees he enters the market, Töölöntori, where he sells trees to customers. As he is the first player in the market he has now more time for selling Christmas trees on a limited time period. After the first-mover has gained a market leader position, the second-mover decides to join the market. There is now less potential customers in the market, since many have purchased a

tree from the first-mover. Naturally, there is less potential for making profit for the second-mover than there was for the first-mover. Since the second-mover brings less trees it can also sell less and thus make less profit. This is a fairly good example, where the Stackelberg model can be applied in real life.

3.1.2 The Spence-Dixit Model

In this section I present the Spence-Dixit model of capacity competition. Compared to the Stackelberg model, the Spence-Dixit model is more applicable to real life as it interprets quantities as capacities. Hence presenting the Spence-Dixit model is relevant when discussing market entry. According to Tirole (1990) the Spence-Dixit model regards the Stackelberg model to be only one of sequential capacity choices. Though the Spence-Dixit model is related with deterring competitors entering the market I will not focus on entry deterrence. In this section I aim only to explain the basic concept of the Spence-Dixit model, its differences to the Stackelberg model and briefly presenting the models' most relevant entry deterrence concepts.

Before examining the Spence-Dixit model further it is worthwhile to notice that this is not the same as the (Spence-)Dixit-Stiglitz model of monopolistic competition (Dixit and Stiglitz (1977)) or as Spence's and Stiglitz' Nobel Prize awarded work for their analyses of markets with asymmetric information (Spence (1973), Stiglitz (1985)).

The Spence-Dixit model is based on the separate work of Michael Spence (Spence (1977)) and Avinash Dixit (Dixit (1979), Dixit (1980)). Their work analyzed further Joe Staten Bain's suggestions of his limit-pricing model, which is the most famous entry barrier model (Bain (1949), Bain (1956)). Bain proved that because of potential market entry threat, firms did not charge a revenue maximizing prize. Hence, existing firms did not set a monopoly price but instead a limit price which is the highest price established firms can charge without inducing entry. According to Tirole (1990) Bain's theory remained controversial until it was studied further by other researchers such as Spence and Dixit.

Similar to the Stackelberg model, the Spence-Dixit model is a case of sequential quantity competition. The difference between these models is roughly that while the Stackelberg model assumed firms compete only with level of output the Spence-Dixit model makes a separation between level of output and capacity. The Spence-Dixit model assumes that level of output determines the market

only in the short run. In the long run the Spence-Dixit model assumes that firms compete with capacity. Here incumbents' advantage is based on the possibility of early capital accumulation which leads to larger capacity and to possibility of charging lower prices, hence deterring competitors from entering the market and for a monopoly for the incumbent. The Spence-Dixit model assumes that capacities are sunk costs which are difficult to change in the short-run. Capacity can be thought here as ownership of machines but it can also be considered in a broader way such as ownership of technology.

Spence presented his version of capacity competition before Dixit. According to Schmalensee (1981) Spence assumed that incumbents build themselves such a large capacity that they can produce almost as much as the entrant could. Before potential competitors' entry they would act as a monopolist but if a competitor tries entering the market the incumbent threatens to use all of its capacity. Spence assumes that this threat is believed, hence entry is deterred and the monopoly situation remains. The problem with Spence's assumption is that a threat to increase output after entry is not believable - why indeed would an entrant take this threat seriously if it knows that by implementing its threat the incumbent would make significant losses.

Schmalensee later compares Spence's work to Dixit's model, where Dixit restricts the scenario so that incumbent makes only threats that they would prefer to execute after the competitor has entered the market. More specifically Dixit assumes established firms to behave rationally and non-cooperatively in response to potential competitors entry, which are quite similar to the assumptions of the Stackelberg model. Bulow et al. (1985) claim that as Spence's equilibrium depended on a non-credible threat, Dixit showed that Spence had studied an imperfect equilibrium to obtain his result of firms holding excess capacity to deter entry. Unlike Spence, Dixit only admits a case of entry deterrence when the incumbent has such a large capacity before potential competitors appearance that they can profitably deter competitors entry. Even though Bulow et al. criticize Spence's work they also point out that Dixit's conclusion depends on his assumption of each firm decreasing marginal revenue in the other's output, which is such a restrictive assumption that it never satisfies the relevant range of constant elasticity of demand. Bulow et al. later conclude that under quite plausible conditions incumbents can install capacity that will be left idle, given that all players are rational. Hence, by combining both Spence's and Dixit's arguments in the Spence-Dixit model it is possible to have a feasible theory.

Unlike the Stackelberg model, the Spence-Dixit model answers questions such as why we have a

scenario where one firm chooses first and why quantity can represent commitment and so cannot be changed. An incumbent may have a market leader position because of adopting the needed technology first. Also as investment in capacity is a sunk cost it commits incumbent to this specific field because these costs cannot be changed later. If one tries to answer these questions in the conditions of the Stackelberg model of quantity competition, providing logical explanations becomes a lot more challenging.

The Spence-Dixit model presents three cases of market entry: accommodated entry, deterred entry and blocked or blockaded entry. Accommodated entry occurs if an incumbent prefers second-mover to enter the market rather than deterring its entrance. Deterred entry is the opposite of the previous scenario, hence a case where the incumbent prefers deterring second-mover's market entry. Blocked or blockaded entry is a case of high fixed costs of market entry. Here the fixed costs are too high, hence the second-mover will not enter even if the incumbent produces the amount of monopoly's capacity.

Case of Apple's iPad. To demonstrate the Spence-Dixit model through a real life example let's consider the case of Apple's iPad. Here the capacity is thought via ownership of technology. I assume that players compete only with the level of capacity and that price, costs and product are the same with different producers. Though in reality other firms produced early versions of tablet computers before Apple, I omit them here as they never made it as a popular consumer device.

As Apple began producing iPads it needed educated employees, hardware, office spaces, etc. Naturally as Apple produced iPads its productivity and knowledge rose and it made large profits as the market leader. When other players such as Samsung entered the market, they had to start from the very beginning as they were new players and producing tablet computers was an unfamiliar territory. Even with competition Apple had still a market advantage which enabled the position of market leader and to constantly improve its product development. Apple mostly gained its first-mover advantage by acquiring the technology before its competitors. The first-mover advantage is perhaps easier to see here in the sequential capacity competition than it would be in the Stackelberg model of sequential quantity competition.

It is important to keep in mind that in reality Apple and its competitors compete also with product differentiation, price and have a very different cost structure, hence this is not a perfect example of the Spence-Dixit model. However with some modifications this case example fits the Spence-Dixit

model and can be quite well applied in real life.

3.2 Sequential Price Competition

Sequential price competition is another case of dynamic games. Here the first-mover sets its price first, followed by the second-mover setting its price second. The players can be identical or have a differentiated product portfolio.

3.2.1 Sequential Price Competition with Identical Firms

In the case of sequential price competition with identical firms I assume there are two firms, first- and second-mover, which produce the same product and have the same unit cost. Pepall et al. (2011) state that this scenario is similar to the simultaneous price competition model of Bertrand (1883) in which consumers buy from a firm with the lowest price. As the case of sequential price competition is quite simple, I will go through this briefly with an explanation and case example after which I move to the case of price competition with differentiated products.

Both in the case of Bertrand duopoly and in the case of two identical firms competing with price the outcome is a Nash equilibrium where prices equal to the amount of marginal cost c . If both players set the same prices they get half of the market. In a sequential game the first-mover makes its choice first and this is followed by the move of the second-mover. The second-mover benefits from setting its price lower than the first-mover if first-mover's price is over marginal cost c . As the products are identical, this would lead the second-mover to gain the whole market and profit. However, the first-mover knows this and so as a rational player sets its price $p_1 = c$. Accordingly the second-mover's choice is to set its price to $p_1 = c = p_2$ because with identical products it has no chance of selling with a higher price. Here I assume players' rationality, hence that neither one will choose a price $p_{1,2}$ of under c as this would lead to monetary losses.

Case of Selling Christmas Trees, part 2. Here I consider again a similar case example of selling Christmas trees as I did in the case example of the Stackelberg model. I consider the same example here for two reasons: 1) since these models only differ in the form of competing with quantity to competing with price it is natural to use the same example and 2) by using the same case example I aim to make it clear to the reader the differences between these models.

Here we again have two Christmas tree producers selling their trees in Töölöntori, Helsinki. I

assume that the producers' costs and the Christmas trees are identical, that the inhabitants of Töölö can not buy a Christmas tree from anywhere else than Töölöntori's market place and that both players retrieve their trees from the same forest. I assume here that in the beginning of this game, both players collect the same amount of trees, hence they have a equal amount of products. In this example, the price is not fixed and may vary among producers. I also assume that the players will not form a cartel.

The first-mover enters Töölöntori's market place. As the first-mover is the only player in the market, he can set any price he prefers. I assume here that he sets a price larger than the marginal cost, hence $p_1 > c$. As the first-movers sells his Christmas trees the possibility of earning profit in the market lures a second-mover to the market place. The second-mover knows that by setting his price lower than the first-mover he will get all customers. Hence the second-mover sets his price at $p_2 < p_1$. As the first-mover sees the second-movers price it has no other choice than to set its price equal or lower than the second-mover. This will eventually lead in a price war, where both players lower their prices until they reach a point where they have same prices which are equal to the marginal cost c . Neither will go lower than the marginal cost c as this would lead to monetary losses. Hence the Nash equilibrium is $p_1 = p_2 = c$.

3.2.2 Sequential Price Competition with Differentiated Products

In sequential price competition with differentiated products firms compete with price but I assume that they have differentiated products. Hence, firms do not compete by differentiating their products, they compete with price. This game is closer to real life than the one I presented in the previous subsection, sequential price competition with identical firms. As Tirole (1990) argues, assumption of firms producing a homogeneous product where price is the only variable is an unlikely scenario as in reality products are differentiated and the cross-elasticity of demand is not infinite at equal prices. Pepall et al. (2011) argue that with differentiated products all customers do not buy from the firm with lower prices due to product differentiation. In this subsection I introduce the most popular model used to examine sequential price competition with differentiated products, Hotelling's spatial or location model. Hotelling's spatial model can also be used in sequential quality choice as I demonstrate in section 3.3 . As Hotelling's model can be used to study different scenarios, researchers often vary Hotelling's model to fit their exact research question.

Pepall et al. use a variant of Hotelling's spatial model to illustrate sequential price competition in a differentiated products market. Tirole also uses Hotelling's model but in two different ways: he presents a variation of Hotelling's (linear) model and a circular city model of Salop (1979). Salop's circular city model is a famous variant of Hotelling's model. Here, firms locate in a circle and consumers may choose from zero to one of differentiated products but their remaining income has to be spent on a homogeneous, non-differentiated product.

Harold Hotelling first presented the Hotelling spatial or location model in his article "Stability in Competition" in 1929. Hotelling's spatial model demonstrates the relationship of pricing and location between different players. In Hotelling's spatial model firms differentiate their products only by the choice of location. Location differentiates the products and is predetermined, hence Nash equilibrium is solved with respect to price (Pepall et al., Tirole). Hotelling represented notion of his spatial model through a fixed length line and assumed all customers to be identical with a different location, evenly dispersed along the line. Though many researchers use Hotelling's model it is often been varied based on researcher's exact research question.

Below I present a variant of Hotelling's model visually in order to better demonstrate its usage in sequential price competition with differentiated products.

Let's have a look at a duopoly of two players, Player A and Player B. A and B are both selling balloons on the same street. I assume here that players' selection of balloons is identical, players' marginal cost is greater than zero $c > 0$, players set a price over marginal cost $p_{A,B} > c$ and that consumer's are distributed evenly along the street.

As players' balloon selection is identical, consumers' utility is formed by the price and the distance to A or B. The geographical location is the only differentiating factor on A's and B's products. Players maximize profits by choosing a price. Players are located at a street going from left to right $[0, 1]$. Player A is located in a and Player B is located in b .

With this simple case example I aim to connect this variant of Hotelling's spacial model in sequential price competition with differentiated products to real life.

3.3 Sequential Quality Choice

In sequential quality choice players differentiate their products by choosing the quality of their product. As in the previous subsection 3.2.2 here I also use Hotelling's spacial model to studying sequential quality choice.

According to Pepall et al. (2011) when using Hotelling's model in sequential quality choice, consumers agree on the appropriate product's price but they disagree on which is the highest quality product. Pepall et al. introduce also another approach, a vertically differentiated product market, where consumers agree on what is the highest quality product but disagree on the price. In the vertically differentiated product market Pepall et al. end in the result of maximal differentiation, where one player chooses the high-quality product and the other player chooses the low-quality product. This is due to Pepall et al. argument that if follower would choose to produce the same quality product then both player would be producing identical products, which would result in both firms earning zero profits. In this section I will however use the traditional Hotelling model as it has been popular among researchers. However, as in the previous subsection 3.2.2 in sequential price competition with differentiated products, researchers have varied Hotelling's model when making their own research.

When using Hotelling's model in sequential quality choice one must be introduced with the principle of minimum differentiation. The term "principle of minimum differentiation" was first introduced by Boulding (1966). (Hotelling (1990)) presents that when firms differentiate their products by choice of location they will choose to locate at the center of a linear market. Hence, firms prefer to make their products similar. This model has raised both positive and negative arguments among researchers. First I present Hotelling's model visually in order to better explain how it can be used and what Hotelling meant with his principle of minimum differentiation. Second I present researchers positive and negative arguments for Hotelling's model.

Here we have a duopoly of two players, Player A and Player B. Both players own a grocery store. I assume here that players' grocery stores are identical, players' marginal cost is greater than zero

$c > 0$, players set an equal price, which is over marginal cost $p_A = p_B > c$ and that consumers are distributed evenly along the street.

As players' grocery stores are identical consumers are indifferent about whether they purchase from A or B, hence consumers' utility is formed by the price and the distance to A or B. Players try to maximize profits by choosing an ideal location from a street going from left to right $[0, 1]$. Let's first look at a situation where Player A is located in 0 and Player B is located in 1.

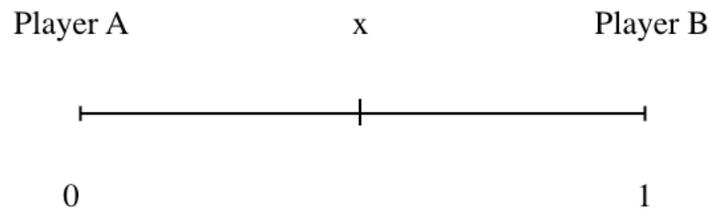


Figure 2: Hotelling's linear city model

If A and B have equal prices, then all consumers located on the left of x would go to A, accordingly all consumers located on the right of x would go to B. Hence, both players would receive a 50% market share and half of the profits, given that the customers are evenly distributed.

Hotelling's result shows that in the Nash Equilibrium both A and B locate in the middle of the street. This is due to the fact that both players have an incentive to move closer to the center in order to get a part of other player's customers.

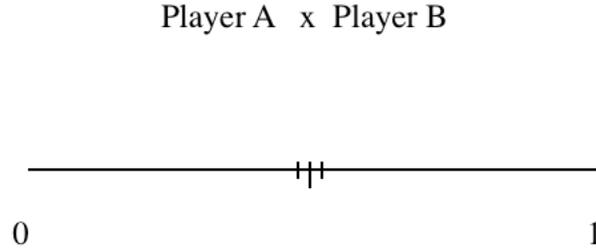


Figure 3: Hotelling's Nash equilibrium

Though Hotelling's model has been popularly used among researchers it has also faced critique. d'Aspremont et al. (1979) claimed Hotelling's model to be invalid as Hotelling did not consider players' undercutting strategies of choosing prices that take away all of their competitors' market share. On the contrary to Hotelling's result of a Nash equilibrium where each player locates on the center of the market, d'Aspremont et al. argue that because of these undercutting strategies a pure price equilibrium doesn't exist when the two players are close to each other. d'Aspremont et al. alter Hotelling's model in a way that it enables a price equilibrium at all product positions. On the contrary to Hotelling's results, d'Aspremont et al. find that each player's equilibrium strategy is to locate at the end of the market and to maximize their differentiation.

Prescott and Visscher (1977) admit Hotelling's model has served as a foundation to theory of location in product characteristic space. However Prescott and Visscher criticize Hotelling's model for its assumption that location and price may be altered without costs, hence it is difficult to study markets with product differentiation. As a solution to problem of relocation costs Prescott and Visscher suggest to model firms' location decisions as a sequential once-and-for-all decision.

Despite the critique Hotelling's model and principle of minimum differentiation has received it has also been shared by other researchers. De Palma et al. (1985) argue that if consumers taste is heterogeneous, firms locate on the center of the market and charge prices that are higher than their marginal cost. Eaton and Lipsey (1975) find that principle of minimum differentiation exists if there are only two firms and they choose a strategy of zero conjectural variation.

In order to better demonstrate sequential quality choice I present a case example. To demonstrate also the differences between sequential quality choice and sequential price competition with differentiated products, I use the same movie theater case as in the previous subsection 3.2.2. The following case example provides similar results as in Hotelling (1990), hence in this example I omit the critique of d'Aspremont et al. and Prescott and Visscher. By doing so, I do not mean to take a stand on whether the critics are correct or not but merely want to present a simplified case example.

Case of Two Movie Theaters, part 2. In the market there are two movie theaters, Theater 1 and Theater 2. Here, they do not have a fixed location but they have set a price, which is identical. These two theaters are the only theaters in this town, hence towns' inhabitants make a choice between these two theaters. I assume here that both theaters have an identical selection of movies and movies are played at the same time. Consumers are evenly distributed along the town and consumers' utility is formed by their distance to the movie theater and by theater's price. Theaters compete against each other by choosing a location, hence location is the only differentiating factor.

Theater 1 chooses its location first. If both players have only one move and they know this then Theater 1 needs to take into account Theater 2's best response. For example if Theater 1 chose a location on the west side of town, Theater 2 could go next to it on the east side and so attract all the customers from Theater 1's east side. Knowing this, Theater 1 chooses a location in the center of the town. Accordingly, Theater 2 chooses to locate also in the center of the town, next to Theater 1.

In the previous section I presented sequential price competition with identical firms and with differentiated products. In this section I presented sequential quality choice. Though I discussed these separately it is possible to study these simultaneously. For example Moorthy (1988) studied a model in which two identical firms compete on product quality and price. Moorthy proved that firms' equilibrium strategy is to differentiate their products, where the high quality producer chooses a higher profit margin. Shaked and Sutton (1982) study a case of a three stage non-cooperative game with two firms where in the first stage firms decide whether they enter the market or not. In the second stage firms choose their product's quality. In the third stage firms choose their price, which Shaked and Sutton assume results in a Nash equilibrium. The end result is that two firms enter the market, produce differentiated products and make profit. Though the research by Moorthy and Shaked and Sutton is interesting it is outside the scope of my thesis, hence I omit further analysis here.

4 Conclusion

Theory of market entry through dynamic games has gone a long way. Nash (1951) introduced the concept of non-cooperative games with mathematical analysis. Nash equilibrium, where each player plays its optimal strategy and where no player would alone change its strategy, set the path for other game theorists such as Selten (1975) who came up with subgame perfect Nash equilibrium, which excluded imperfect Nash equilibria and is appropriate for dynamic games.

The theory of market entry through dynamic games can be modeled in three different ways: 1) sequential quantity competition with the model of Von Stackelberg (1952) or the Spence-Dixit model of capacity competition (Spence (1977), Dixit (1979), Dixit (1980)), 2) sequential price competition with identical firms or sequential price competition with differentiated products and 3) sequential quality choice.

Sequential price competition with differentiated products and sequential quality choice both can be solved with different variations of the spatial model of Hotelling (1990). In sequential price competition with differentiated products Hotelling's model should be varied so that firms do not choose a location, only a price. In sequential quality choice one can use Hotelling's traditional model, where firms differentiate their products by choosing their location.

Though I demonstrated the models with simple mathematics and visuals all models are highly mathematical and at times abstract. Because of their abstract nature and due to the fact that they often have strict restrictions these models are difficult to apply in real life scenarios. However, these models do offer concrete results by mathematical analysis, hence they offer a guideline in how strategies in market entry through dynamic games can be structured and direct the reader to the right path in their decision-making process.

With simplifications and restrictions it is possible to apply theory in real life. The research I referred to in my thesis is merely the tip of an iceberg. I omitted a lot of interesting research as they mostly concentrated on a specific niche case. Hence, by defining a narrow, very exact research question one can study an object of interest in a more comprehensive matter. I could have taken this thesis further by presenting more models or by examining games with n players with multiple moves. However, the simplifications done in this thesis were necessary in order to provide a meaningful overview on the subject of market entry through dynamic games.

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