Fostering or stifling innovation? Investigating the consequences of a horizontal merger in Cournot and Bertrand markets.

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Abstract

For decades countries have tried to impose strong regulations on mergers and acquisitions through competitive law. How a merger might affect a market prior to the merger happening is almost impossible to determine, especially if you look at how it might affect innovation. This thesis considers how a merger in a continuous market might affect Bertrand and Cournot competition in a simultaneous game, where they compete through price/output and cost-reducing R&D with technological spillover and product differentiation. The study supports the view presented by Jullien and Lefouili (2018): the overall impact of a merger on innovation might be either positive or negative. This study finds that if the market has significant technological spillover among firms, the merger increases the probability of reducing the firms' investments, regardless of the competitive form. Furthermore, the study finds that price competition incentivizes a more competitive market, leading to a consistently lower required degree of spillover for a merger to affect the industry negatively.

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1. Introduction

In 1957, Solow studied the shifts in US non-farm aggregated production between 1909 and 1949. He identified that the gross output per hour worked had doubled in the period, and 87% of the increase could be attributed to technological change, while the remaining 13% could be linked to increased use of capital. Solow's study highlights the importance of innovation and technological advancement in a thriving economy. An innovative market can be facilitated in several ways by policymakers, but central for everything is the firms, how many there are, and how they interact and compete.

An anti-competitive merger and acquisition (from now on referred to as M&A) can significantly disrupt market dynamics, as highlighted in a US congressional report from 2020, where it was revealed through a series of emails between the CEO of Facebook (now Meta) Mark Zuckerberg, and the company's CFO that Facebook "can likely just buy any competitive startups" and that the acquisition of Instagram in 2012 was motivated to remain a monopoly power and to bottle future competition (Nadler, 2022).

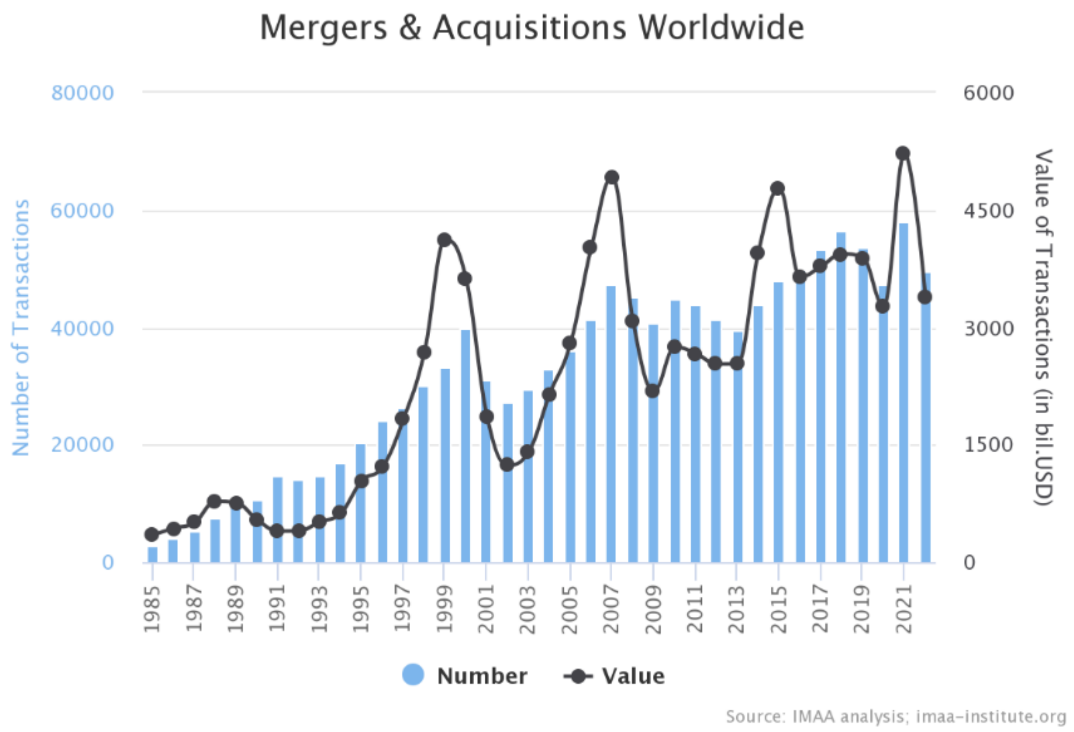

Figure 1: The number of M&As and total market value 1985-2022.

Although M&As can drastically change the market dynamic (like the Facebook/Instagram case), there has been a significant increase in the number and market value of M&As globally.

Figure 1 shows that while M&As might come in waves, there has been a general increasing trend in the last 40 years. According to the report, "*M&A reached record heights in 2021 and deal momentum is set to continue in 2022: PwC analysis*" (PwC, 2022): There were a reported 65,000 M&As completed globally in 2021, crushing the 2020 levels by 24%, coming in at a market value estimated to be $5.1 trillion, a record-breaking 57% increase from 2020. Furthermore, according to the 2023 M&A Trends Survey done by Deloitte[1], all 1400 participants were actively involved in some M&A activity at the time of the interview, indicating that the trend might not slow down in 2023.

Of all mergers challenged by the US Department of Justice and the Federal Trade Commission between 2004-2014, 33.6% were challenged because they were harmful to innovation (Gilbert & Greene, 2014). The focus on facilitating an innovative market is vital for policymakers in several countries' competition laws. Including §16 in Norway, which focuses on market concentration and the creation or strengthening of dominating market positions (Konkurranseloven, 2004), and the 2010 Horizontal Merger Guidelines where the U.S. Department of Justice states:

> *Competition often spurs firms to innovate. The Agencies may consider whether a merger is likely to diminish innovation competition by encouraging the merged firm to curtail its innovative efforts below the level that would prevail in the absence of the merger.*[2]

The problems arising from anti-competitive mergers, such as increased market concentration and diminished investment levels, have prompted policymakers to address these concerns, as reflected in the horizontal merger guidelines and paragraph 16. An analysis of the change in the number of M&As and their total market value over the past 40 years reveals a clear justification for an increased focus on this trend.

One merger that is frequently used in the literature to highlight how complex the balancing of merger effects can be is the Dow/DuPont case (Chadha (2019); Lofaro et al. (2017); Wilson (2019)). Pre-merger, both Dow and DuPont were major actors in the chemical industry. The

[1] The survey was conducted between October 25 and November 11, 2022, the survey polled 1400 executives, all participants in the survey held a senior rank. All firms had to have an excess off $250 million revenue, and where a mix of globally US-based and domestic (US) firms.

[2] Chapter 6.4. Innovation and Product Variety

merger of these two industrial giants raised concerns considering the impact on innovation, competition, and consumer welfare. Before the merger, the chemistry industry was highly concentrated, with only five globally active players throughout the entire R&D process. The European Commission raised concerns regarding "*... reduced competition on price and choice…"* and "*... the merger would have reduced innovation."* (The European Commission, 2017*)*. Despite these competitive issues, the European Commission approved the merger following an in-depth review (The European Commission, 2017).

The contradiction between the Due/DuPont merger and §16 and the 2010 horizontal merger guidelines shows how complex a merger can be to analyze for competition authorities, and it also emphasizes the importance of literature on the subject.

This thesis is based on an underlying desire to understand further how innovation and horizontal mergers affect different markets. In the baseline model, I present a framework to investigate the implications of a merger in an industry with an unspecified number of firms where the competitive structure remains undefined. The framework can be angled to investigate both price and quantity competition, abstracting from any efficiency gains in R&D. I study the effect of a merger between two symmetric firms in a market characterized by some technological spillover and where the firms can compete with differentiated products. I show that the overall impact of the merger on the level of investment in R&D activities can vary depending on the two mentioned effects and the competitive form. When a merger occurs in price competition, it could increase per-firm R&D spending, while the symmetric quantity competing market may experience a reduction. Following the incentives highlighted by Jullien and Lefouili (2018) and Bourreau et al. (2021), I will explain what incentivizes the firms to behave as they do and why the merger might increase or decrease the per-firm investments. Furthermore, I will focus on the distinct market conditions that make the merger go from increasing to decreasing the investment level and how these conditions differ between price and quantity competition.

1.1 Research question

Competitive authorities have been concerned with the effects of horizontal mergers on innovation for a long time (Bourreau et al., 2021), both in how the law is viewed and how a horizontal merger might affect a market (Whinston, 2007). If policymakers aim to facilitate a breeding ground for innovation and consumer welfare, I would argue that correctly identifying the underlying incentive to invest in R&D is essential. Furthermore, understanding what market conditions promote increased R&D spending on innovation is crucial. This statement is based on the assumption that some innovation motives are to prefer to others. If the merger results in a reduction of per-firm R&D investments, it becomes imperative for the agencies to examine the additional impacts arising from the merger thoroughly.

There is extensive research regarding a merger's effects on innovation incentives. However, to the best of my knowledge, there seems to be lacking literature on how a firm in a simultaneous game competing through Cournot competition would change its investment level when faced with a merger, compared to an identical firm in a Bertrand game. The thesis aims to fill this gap and answer the question: *How does a firm's investment level in a simultaneous game, competing through Cournot competition, change when confronted with a merger, compared to an identical firm engaged in a Bertrand game?*

1.2 Disposal

The remainder of the paper is structured as follows: Chapter 2 presents the well-known Schumpeter vs. Arrow discussion and some theories regarding how a merger might affect innovation. In Chapter 3, I will present my model. The model is a modification of López and Vives (2019) angled to analyze how a market would respond to different values of spillover and product differentiation effects in both a Cournot and a Bertrand setting. Furthermore, the model analyses a merger's effect on the optimal firm investment level. In Chapter 4, I analyze the difference between the Cournot and Bertrand competition. Chapter 5 discusses how it would affect a consumer's utility and the realism of spillover before a conclusion follows in Chapter 6.

2. Literature

There is extensive literature when it comes to mergers and innovation effects. The literature review will start with a presentation of one of the founding arguments in innovation incentive theory: Schumpeter vs. Arrow, and how a firm's size and market structures affect the incentive to innovate. Lastly, I give an insight into more recent additions to the literature surrounding the effect a horizontal merger will have on the incentive to innovate and the disagreement among leading economists on the presumed total effect.

2.1 Schumpeter vs. Arrow

Innovation in products and processes are separated from one another. Product innovation leads to the development of new products, whereas process innovation reduces the production cost of existing products (Tirole, 1988, p. 389). The literature on innovation incentives starts with Schumpeter (1943) and Arrow (1962). According to Schumpeter, a firm's innovation ability is primarily correlated with its size. His theory revolves around the idea that large firms are not strictly competing through price, but also innovation. Larger firms have a greater incentive and ability to invest in R&D compared to smaller firms, thus, a higher probability of successful and market-changing innovation. Schumpeter further argues that a temporal monopolist gives the right product and process innovation incentives. Following this, Schumpeter implies that the change in the economy is driven by profit-motivated innovation and market shares. Arrow (1962), on the other hand, argues that a monopolist's incentive to innovate is less than that of a competitive firm. He argues that the pre-innovation monopoly power is a strong disincentive to further innovation. The argument stems from the idea that a firm earning substantial profits in a market is more interested in protecting its position than investing in R&D to invent a disruptive new technology (Shapiro, 2011). This theory is further backed by the results of Greenstein and Ramey (1998) suggesting that a product market monopolist has a lower incentive to innovate, compared to a firm facing rivalry in the product market.

These opposing arguments have sparked extensive economic literature relating to innovation and competition. Tirole (1988) argued that a monopolist making a substantial profit, even when not innovating, has a lower incentive to invest in R&D than a competitive firm facing fierce market competition. He argues that the monopolist's profit difference between post-innovation and pre-innovation profits will not be a sufficient incentive. Comparatively, a firm facing stronger competition, gains more from investing in R&D. Motta (2004, p. 56) uses a simple example to show that a monopolist might be dynamically inefficient because it has little incentive to innovate. Consider a case where a monopolist has the option to implement a process innovation that would enable it to produce at a lower marginal cost c_L rather than the existing cost c_H by paying a fixed cost F. The profits using the new (low-cost) and old (high-cost) technologies are denoted as Π_L, and Π_H respectively. The monopolist will need to compare the "additional" profits gained from the new technology $\Pi_L - \Pi_H$ it will make against the fixed cost of investment F. He will only implement the new technology if $\Pi_L - \Pi_H > F$. Now let us assume that a competitive firm stuck in a highly competitive market, like a Bertrand paradox[3], faces the same choice. The current (old) technology enables a marginal cost c_H assuming the market has symmetric firms, the market price is $p = c_H$, and thus the per-firm profits equal $\Pi'_H = 0$. Now assume that one firm implements a new technology, reducing the marginal cost to c_L, while the other competing firms will operate with the old technology. The innovative firm can now make Π_L profits. Considering this, a firm in a competitive market will invest if $\Pi_L > F$, whereas a monopolist will only do so if $\Pi_L - \Pi_H > F$, a much stricter condition. Since the monopolist would only evaluate the "additional" profits brought by the new technology, as opposed to the competitive firm, which would consider the whole profit brought by it, the monopolist would be less motivated to innovate. Motta further shows that this argument holds for both a drastic and a non-drastic process innovation. Tirole named this effect the Arrow replacement effect.

Vives (2008), Aghion et al. (2001), and Aghion et al. (2005) uses an endogenous growth model, where firms either competed "neck-to-neck" or in a Stackelberg competition where one firm trailed the technological leader. They find that if the products have a small degree of differentiation, then in the Stackelberg model, the trailing firm has small incentives to innovate. At the same time, the neck-to-neck firms have a significant incentive to innovate, showing an "escape-competition effect[4]." However, if the opposite is true, that the degree of differentiation is significant, then the trailing firm will be more incentivized than the "neck-to-neck" firms to innovate (or catch up), known as the "Schumpeterian effect[5]."

[3] The Bertrand paradox states that the unique equilibrium has the firms charge the competitive price $p_i = p_j = c$ (Bertrand, 1889).

[4] In markets where firms operate at the same technological level, an increase in product market competition will reduce the pre-innovation rents, and thus increasing the incremental potential profits from inventing and becoming the leader in the market (Aghion & Howitt, 2008).

[5] In markets where the firms are not using the same technology, an increase in product market competition will tend to discourage innovation by low-technology firms as it will decrease the short run extra profits from catching up with the leaders (Aghion et al., 2015).

Shapiro (2011) evaluated whether the theories of Arrow and Schumpeter were genuinely conflicting. He eventually asserted that these viewpoints could harmoniously coexist and enhance each other through three key principles; Contestability, Appropriability, and Synergies. These principles are not meant to be applied collectively but serve as different factors under a ceteris paribus assumption.

The principle of contestability highlights how the potential to acquire or secure market shares from a better product can stimulate innovation. This resonated with Arrow's suggestion that a monopolist without competition lacks innovation motivation and Schumpeter's idea that a firm can earn larger market shares by investing in drastic innovation.

Appropriability examines the extent to which a firm can protect its innovative advantage. This principle corresponds with both theories; if competing firms can immediately imitate a new product, then the profits for a successful innovator would be marginal, discouraging substantial innovation.

Finally, the synergies principle underscores that firms typically do not innovate alone. Through these principles, Shapiro concludes that Arrow and Schumpeter were right, finding no discord between their fundamental insights. Hence, a firm interested in preserving the status quo is less inclined than a newcomer to invest in drastic innovation (Arrow). At the same time, the prospect of gaining market dominance serves as a critical incentive for innovation (Schumpeter).

Schmutzler (2013) identified four channels connecting competition and innovation using a general two-stage framework. Through the paper, Schmutzler looks at the effect of higher substitutability in different oligopoly models or what happens to the competition if we move from a Cournot to a Bertrand competition. Schmutzler concludes that: "competition reduces margins and increases the sensitivity of equilibrium output with respect to efficiency. Adding to these ambiguities, competition can have positive or negative effects on equilibrium output and the sensitivity of prices with respect to marginal costs. Together, this explains why the effects of competition on investment are ambiguous."

2.2 Innovation and mergers

As noted, there is no consensus among economists about a presumed (negative or positive) sign of a horizontal merger's impact on innovation (Jullien & Lefouili, 2018). However, there is a consensus that positive and negative forces are at play, and leading economists disagree on balancing these effects in merger analysis. The literature presented aims to provide some understanding regarding how a merger might impact the motivation to innovate.

Federico et al. (2018) use an oligopoly model with Bertrand competition, where firms can invest in stochastic product innovation, to investigate how a horizontal merger may affect product innovation through its effect on market power. They assume that a merger can have an impact via two channels, i) Price coordination and ii) innovation externality. The first channel refers to how the price level in the market would be affected by a merger. A merger can internalize the negative price externalities the rivals extract on each other pre-merger. Internalizing the price competition would result in a less competitive post-merger market where the firms can increase prices. If the firms can raise their prices, they will see an increased profit regardless of their innovation ability. Therefore, reduced-price competition would affect the extra gain from innovation and, thus, the incentive to innovate. The second channel, the innovation externality, refers to the effect of one firm innovating and how this would affect the profits of its merging partner. Innovation by one firm diverts post-merger sales from the other, reducing the incentive to innovate.

Motta and Tarantino (2021) study the competitive effects of a horizontal merger in a context where firms compete in both prices and cost-reducing investment. They use a Bertrand game with differentiated products and $n \geq 2$ firms in both a simultaneous game and a sequential moves game. Their analysis finds that if the firms are competing in a market where they are setting their cost-reducing investment and price simultaneously, the horizontal merger is anti-competitive if it does not entail any efficiency gain. Their analysis suggests that, under no efficiency savings, a merger will reduce aggregated investments and harm consumers. This net effect results from a decrease in investment and a rise in prices for the merging parties. Furthermore, Motta and Tarantino get the same outcome if the firms instead invest in product-enhancing R&D; without any spillover effect, the merger is anticompetitive. However, they also show there might be additional effects the firms need to consider. One of them is the knowledge spillover effect. The spillover effect could generate a countervailing effect significant enough to achieve an overall positive effect on innovation (Jullien & Lefouili, 2018). d'Aspremont and Jacquemin (1988) and Bloom et al. (2013) study the effect technological spillover can have on rival firms. A central problem with the spillover effect is that firms are affected by two countervailing forces. A firm is positively affected by the effect if they acquire more technology from a technological spillover in a rivaling firms' innovation, and negatively affected if the firm innovates and rivaling firms gain technology. Furthermore, Bloom et al.

(2013) identified that the socially optimal level of R&D investment is two-three times higher than the privately optimal level, implying an under-investment in R&D. This under-investment is observable from a market analysis where they find that the social rate of return is 55% whereas the private return is 22%.

In contrast to Motta and Tarantino (2021), Jullien and Lefouili (2018) present a contrasting view, suggesting that the overall effect of horizontal mergers on innovation can be either positive or negative. Their analysis demonstrates that this holds even in the absence of spillovers and efficiency gains in R&D. By emitting spillovers and efficiency gains in R&D, they identify three main effects of a horizontal merger on innovation incentives.

The first effect, the innovation diversion effect, refers to the impact on competing firms' demand if a merger results in a higher degree of product differentiation. This effect could be positive or negative for the merging firms, depending on the market and the product relationship.

The second effect, the margin expansion effect, studies the effect of a price change. If the firm knows that the post-merger price level for its product will increase, a merger could be motivated by a sufficient margin increase. When a firm can maintain its output while simultaneously increasing its margins (through either an increased price or reduced marginal cost), it is incentivized to finalize the merger to achieve the post-merger increased profits.

The third effect is closely related to the second effect. The demand expansion effect comes to light if the merging firm knows that post-merger margins are relatively stable but they will obtain an increased demand. While the second effect seeks to increase profits through a higher margin, the demand expansion effect on the other hand, seeks to increase profits by increasing the firms' demand. Both effects are usually present in a merger, but one will dominate the other, but which effect is the dominating one is ambiguous.

Jullien and Lefouili (2018) further argue that including spillovers in the analysis depends upon the nature of the spillover and the market conditions. They conclude that the effects of a horizontal merger on innovation can be positive and negative, but they highlight key factors that significantly influence the merger's impact. Specifically, a positive relationship between a merger and innovation is more likely to occur in the context of demand-enhancing innovation and an increased degree of differentiation.

Building on Jullien and Lefouili, Bourreau et al. (2021) identify four factors that affect the incentives for investing in demand-enhancing innovation in the case of horizontal mergers between symmetric firms. The first three effects are equal to the findings of Jullien and Lefouili

(2018). In addition, Bourreau et al. (2021) introduce the concept of the per unit return to innovation effect.

The per unit return to innovation effect estimates how much a firm can increase its price level following a marginal increase in R&D spending while holding its output constant. It can therefore be understood as the return on innovation for each unit of output. Through a Hoteling duopoly model that compares various standard models without spillover effects or efficiency gains in R&D, they reveal that a merger's impact heavily depends on comparing a price change/price diversion ratio and the innovation diversion ratio. Their study indicates that if the innovation diversion ratio exceeds the price diversion ratio, a merger will negatively affect a firm's incentive to finalize a P-neutral[6] and P-increasing merger[7]. However, if the price diversion ratio prevails, the incentives for P-neutral mergers will experience a positive change. Nonetheless, the total effect of P-increasing mergers can be positive or negative.

Haucap et al. (2019) utilized data from the European Commission to gather statistics on M&As involving companies with annual revenue above a given threshold, both globally and within the EU. In order to assess the level of innovation within a market, Haucap et al. (2019) employed a widely recognized indicator of innovation, namely patents, which is consistent with multiple recent studies ((Aghion et al., 2009; Bena & Li, 2014; Seru, 2014)). The study determined that the degree of R&D intensity in an industry significantly impacts the overall effect of a merger on innovation, both for the merging firm and the industry as a whole. In industries characterized by a high level of research intensity, a merger is likely to have a negative effect on both the merged firm and the incentive for outside firms to innovate. Conversely, in industries where R&D activities are less pronounced, the impact of a merger on the incentive for innovation among merged firms can be either positive or negative. However, it positively affects the incentive for innovation among outside firms. Lastly, the study revealed that if the products in the post-merger market are highly substitutable, there is a greater likelihood of reduced R&D activity.

[6] A merger would not affect the price level.
[7] A merger would increase the firms price level.

3. Linear Model

3.1 López and Vives

The model presented below is a modification of the framework presented by López and Vives (2019), which examines an industry characterized by a Cournot oligopoly with overlapping ownership. The firms compete in a simultaneous game, where they compete by setting their investment level and quantities in the same period without knowing what the other firms do. Each firm is a solo product producer. Their framework incorporates the assumption that firms can invest in cost-reducing R&D and accounts for the spillover effect, where a part of a firm's R&D investments would spillover to rivaling firms in the industry.

Additionally, where López and Vives mainly studied a Cournot competing industry, I will on the other hand, expand the framework to study both Cournot and Bertrand competition in my model. In a Cournot competing industry, firms compete through their quantity, and the market price is determined by the Nash equilibrium (NE) quantity (Cournot, 1838). Conversely, if the industry competes through price, the quantity would be given from the NE price level, known as Bertrand competition (Bertrand, 1883). The Nash equilibrium is a stable state where no firm will change its output (price) level given its R&D investments and rivaling firms' decisions (Nash Jr, 1950).

To model these competitive scenarios, my model will utilize the utility function from Singh and Vives (1984) in order to derive the direct and indirect demand functions the firm faces, in line with Choné and Linnemer (2020) summary of Spence (1976). These demand functions will be used to analyze the impact of a merger, which will be modeled as a reduction in the number of firms, n, on firms' price (quantities) and their R&D levels.

In order to make López and Vives model work, some modifications are needed. In contrast to López and Vives', I will reincorporate the parameter γ to account for the impact of differentiated products[8] on firms' decisions. The degree of product differentiation in markets is represented by $\gamma \in [0, 1]$. A higher value of γ signals more similar products, and conversely, low values would imply a greater differentiation among rival firms' products.

[8] Product differentiation can include a veraity of different inequalites i.e: quality, features, sustainability and design.

Furthermore, throughout the model, I will use the technological spillover in the same fashion as López and Vives. They assume that the industry they study could exhibit some degree of technological spillover among rival firms[9]. As such, if the industry has some spillover, the R&D investments of one firm would benefit the whole industry. Since I assume symmetric firms, the spillover level is also symmetric across all firms. Throughout the model, the degree of spillover is noted through the parameter $\beta \in [0, 1]$. A value of 0 implies no spillover among firms, and conversely, a spillover degree of 1 would mean a perfect R&D flow among rival firms.

3.2 Base model

The market I am analyzing contains $n \geq 2$ identical firms, where each firm $i = 1, \dots, n, i \neq j$, chooses their investment level, x_i, and their prices (output), p_i (q_i), (depending on whether I look at price or quantity competition). The marginal cost of production for firm i, $c_i(x_i, x_j)$ is a function of the heterogeneous constant marginal cost of production, c, own R&D x_i, and the aggregated R&D investments from all rival firms, multiplied by the degree of spillover in the industry, $\beta \sum_{j \neq i} x_j$. In the model, both own R&D and a share of rival firms' R&D will reduce the cost of production for firm i.

By increasing its investment level, the firm will reduce its marginal cost of production c_i, at the cost of an increase in investment costs $\Gamma(x)$. c_i is assumed to be linear, and the investment costs $\Gamma(x)$ the firm faces when its investing is assumed to be quadratic, based on the assumed diminishing returns of R&D investments[10]. The investment the firm chooses is multiplied by a variable that indicates how costly R&D is for a given industry $r \geq 1$.

Assumption 1: The cost of R&D level x_i is given by $\Gamma(x) = \frac{rx^2}{2} > 0$, $\frac{\partial \Gamma(x)'}{\partial x} = rx > 0$, *and* $\frac{\partial \Gamma(x)''}{\partial x''} = r > 0$.

Assumption 2: The marginal production cost of firm i, or c_i, is independent of output and is decreasing in both own and rivals' R&D, as follows: $c_i = \left(c - x_i - \beta \sum_{j \neq i} x_j\right) > 0$, *where* $\frac{\partial c'}{\partial x_i} = -1$, $\frac{\partial c'}{\partial x_j} = -\beta(n-1)$, $c'' = 0$

[9] This could be the result of lacking patenting rights, reverse engineering, etc.
[10] This assumes that the investments the firm can make are not equally cost-efficient, and thus, the firm would invest in the most efficient R&D investments, then the second most efficient investment, and so on.

For simplicity, I follow in the footsteps of López and Vives. In my model, the firms are assumed to be symmetric; thus, an increase in R&D by firm *i* will have the same effect on firm *i*'s margins as an increase in R&D for firm *j* would have on firm *j's* margin.

From assumptions 1 and 2, firm *i*'s general profit maximization problem can be formalized as:

$$\pi_i(p_i, q_i, x_i, x_j) = p_i q_i - \left(c - x_i - \beta \sum_{j \neq i} x_j\right) q_i - \left(\frac{r x_i^2}{2}\right)$$

The objective for firm *i* is to maximize its profit function by choosing the investment level x_i and the price (output) $p_i(q_i\ )$ simultaneously as all other firms. The model provides a tool to analyze the market for different values of β and γ. γ is introduced through the inverse[11] demand function (Cournot) and the direct demand function (Bertrand). The importance of this variable on firm i's price (quantity) is significant since it is a variable that signals how intensely the firms compete. A higher value would indicate fiercer competition, and one would generally assume a lower profit. It incentivizes the firms to differentiate. This general representation makes it possible to study the effect of a merger, modeled as a reduction in n, and how it would affect firms' decision-making in both the Cournot and Bertrand competing industries.

3.3 Utility function

To derive the firms direct and indirect demand function under Bertrand and Cournot competition, I would need to identify the utility function for the consumers in the market. The utility function I am basing my demands on is derived from Singh and Vives (1984) and is on the following form:

$$U(q_i, q_j, I) = a_1 q_1 + a_2 q_2 - \frac{1}{2}(\beta_1 q_1^2 + \beta_2 q_2^2 + 2\gamma q_1 q_2) + I$$

Let us assume that we are looking at one specific industry. The firms are thus affected by the same spillover values, $\beta_i = \beta_j = 1$. The utility is linear for the consumption of ordinary goods (I) and quadratic for the consumption of q-goods. In contradiction to Singh and Vives, who argues that the parameter $\gamma \in [-1, 1]$ measures how substitutable/complementary the products are, where a value of 0 implies monopolistic power to every firm. $\gamma = 1$ shows perfectly substitutable products, and $\gamma = -1$ represents perfectly complementary goods. My model only looks at substitutable products. Thus, I will only use the interval 0 to 1 for the differentiation

[11] The invers demand function determines the price of a good as a function of quantities (Anderson, 1980)

variable γ, as highlighted above. Furthermore, in the original utility function, the parameter *a* measure the vertical quality of the goods, while here, it is a heterogenous positive utility parameter showing the utility of consuming good q.

From this, I will follow in the footsteps of Häckner (2000) to get a utility function containing n firms producing one differentiated product each.

$$U(\boldsymbol{q}, I) = \sum_{i=1}^{n} q_i a_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + 2\gamma \sum_{i \neq j} q_i q_j\right) + I$$

When faced with a budget constraint of $\sum p_i q_i + I \leq m$, where m stands for the income, and the price of the composite good is normalized to one, all consumers will try to maximize their utility. To identify the optimal consumption of good q_i, I will solve the budget constraint for the ordinary good I and insert that into the utility function. This will provide me with a more accurate utility function. The F.O.C. for the consumer's optimal consumption of good q_i is thus:

$$\frac{\partial U}{\partial q_i} = a - q_i - \gamma \sum_{i \neq j} q_j - p_i = 0 \tag{1}$$

3.3.1 Indirect demand

Solving the equation for a consumer’s optimal consumption of good q_i above (1), for the price of good q_i, yields the inverse demand function for firm i.

$$p_i(q_i, q_j) = a - q_i - \gamma \sum_{i \neq j} q_j \tag{2}$$

3.3.2 Direct demand

Further calculations are needed to find the firms direct demand under Bertrand competition. Let us first assume that all firms will set their quantities such that they maximize profits while taking the quantity of other firms as given, when costs are normalized to zero, the firms' reaction function equals:

$$q_i(q_j) = \frac{a - \gamma \sum_{i \neq j} q_j}{2}$$

Summing over all firms, I get:

$$\sum_{i=1}^{n} Q = \frac{\sum_{i=1}^{n} a - \gamma(n-1) \sum_{i \neq j} q_j}{2}$$

(3)

Noting that:

$$\sum_{i=1}^{n} Q = q_i + \sum_{i \neq j} q_j$$

$$\sum_{i=1}^{n} a = a + \sum_{i \neq j} a$$

(4)

To find the direct demand under Bertrand competition, I need to summarize equation (1) overall firms:

$$\sum_{i=1}^{n} a - \sum_{i=1}^{n} Q - \gamma(n-1) \sum_{i=1}^{n} Q - \sum_{i=1}^{n} p_i = 0$$

(5)

Solving equation (1) by inserting (4) and (5) yields firm i's direct demand under Bertrand competition.

$$q_i(p_i, p_j) = \frac{\left([1 + (n-2)\gamma](a - p_i) - \gamma \sum_{j \neq i} (a - p_j)\right)}{(1-\gamma)[1 + \gamma(n-1)]}.$$

(6)

3.4 Cournot-competition

Before examining how a merger would affect an industry competing through output, I must determine the pre-merger NE investment and quantity levels. To find the optimal investment and quantity level for firm *i*, knowing the Cournot-market profit maximization problem is necessary.

To find the general maximization problem under Cournot competition, the inverse demand function for firm *i* is needed. Recalling chapter 3.3.1, I identified the inverse demand function (2) to be on the linear form: $p_i = a - q_i - \gamma \sum_{j \neq i} q_j$. This equation shows that the firms' price level, p_i, is determined by subtracting the firms' demand, both own demand, q_i, and a portion of the aggregated market demand through a differentiated product, $\gamma \sum_{j \neq i} q_j$, from a heterogenous positive utility parameter, a.

The profit-maximizing problem for firm *i* is given on the following form:

$$\pi_i = \left(a - q_i - \gamma \sum_{j \neq i} q_j \right) q_i - \left(c - x_i - \beta \sum_{j \neq i} x_j \right) q_i - \left(\frac{r x_i^2}{2} \right)$$

(7)

Firstly, I will maximize the profit function concerning firm *i's* quantity to find the NE production level.

Maximizing the Cournot profit function (7) w.r.t. q_i, while considering the assumption of symmetric firms, it is given that the per-firm investment level and output must be equal across firms. Therefore, the per-firm investment and output levels are replaced with: $q_i = q_j = q, and\ x_i = x_j = x$.

Solving the F.O.C. w.r.t. the symmetric quantity will give the optimal general quantity function for all firms with unknown investments.

$$q_C = \frac{A + x + \beta(n-1)x}{2 + E}, \qquad A \equiv a - c, \qquad E \equiv \gamma(n-1)$$

(8)

A and E are two self-defined variables. A is a variable containing the utility of firm *i's* product minus the marginal cost of production for the good. If A is negative, firm *i* will stop production and leave the market, following a negative production margin. From this, we can say that A is a non-negative parameter $A \geq 0$, and a necessary condition for this is: $a \geq c$. On the other hand, E measures how differentiated the firm's product is relative to all rivaling firms. An increase in n would increase the value of E, but how much this increase affects the total value depends on

γ. If γ is close to 0, the total effect of the variable (almost), regardless of the number of firms, is minimal.

To determine the per-firm quantity, the optimal investment level is also needed. From the assumption that the firms compete in a simultaneous game, the investment and the output levels are determined in the same period without observing competing firms' values. Maximizing (7) w.r.t. firm i's investment level, x_i, and solving the F.O.C for x, gives the general investment level:

$$x_C = \frac{q}{r} \tag{9}$$

Solving (8) by inserting the general investment function (9) gives the pre-merger NE optimal per-firm output level.

$$q_C^* = \frac{A\,r}{\beta\,(1-n) + r\,(E+2) - 1} \tag{10}$$

The firms' margin variables A and the investment cost r dictate the NE output level. With an increase of A, ceteris paribus, we would see a market-wide increase in output because the firms now have a higher per-firm output margin. The effect of a change in r is ambiguous since an increase in r would incentivize increased and decreased output levels. Both spillover and product differentiation work against increasing the overall output for the firm. Firstly, if there is no spillover, any spillover increase would decrease total output. Secondly, if γ decreases, the last term in the equation decreases, and thus an increase in demand. In the extreme case of no spillover effect and perfect differentiation $\beta = \gamma = 0$, the per-firm quantity would decrease by twice the value of r. Therefore, if spillover and differentiation are present, it tends to limit a possible increase in output.

Inserting the NE output level (10) into the general investment function (9), and solving for the investment level, gives the NE optimal per-firm investment level:

$$x_c^* = \left(\frac{A}{(\gamma r - \beta)(n-1) - 1 + 2r}\right)$$

(11)

As with the optimal quantity, the investment level directly relates to the per-unit margin. Furthermore, how much of the margin is transferred to the firms' investments is determined by the differential between the product differentiation factor scaled by r, and the market's spillover level multiplied by the total number of rivals. Moreover, the investment level is further reduced by twice the rate of r. From the second order derivative of the profit function w.r.t. the investment level $\frac{\partial \pi''}{\partial x_i''} = -r < 0$, implying that the profit function is concave in investment.

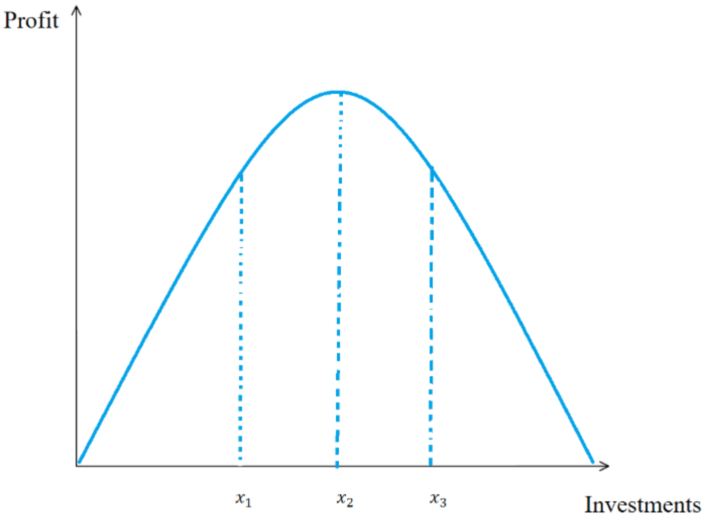

Figure 2: Implications of concave profit function w.r.t. investments

Figure 2 shows the implications of a concave profit function. As we can see, if the firms invest in R&D, they can move from $x_1 \rightarrow x_2$ and they would observe a decreasing effect of further increasing their R&D level. The effect on the firm's profits however is positive in x_2. If firms do not recognize this relationship, they could overinvest in R&D and move from $x_1 \rightarrow x_2 \rightarrow x_3$, in x_3 the cost of investing would negatively offset the gains of increased R&D. Thus, the firm would see a reduction in profits for higher investment levels, $x_2 \rightarrow x_3$. The adherent investment costs offset the increased revenue of the R&D entirely. For more concave profit functions, the curve would be steeper, implying that the firm is more sensitive to a change in investments, and thus a merger would have a more significant effect on the per-firm R&D levels.

How the investment level in the market would respond to a merger between two firms, assuming there are no R&D complementary between the two firms, could be viewed as a marginal reduction in n, on the optimal investment level. By differentiating (11) w.r.t. the number of firms, we can predict the change in post-merger investment levels.

$$\frac{\partial x_c^*}{\partial n} = -\frac{A(\gamma r - \beta)}{\left((\gamma r - \beta)(n-1) - 1 + 2rx\right)^2}$$

(12)

Earlier, I established that $A \geq 0$. Additionally, since the denominator is squared, we know intuitively that the denominator must be non-negative. That implies; that how the market responds to a change in firms is determined solely by the inequality: $\gamma r - \beta$. The inequality depends on whether the product differentiation scaled by the cost of investing or whether the spillover effect dominates. Let C_1 denote the region where $\frac{\partial x^*}{\partial n} \geq 0$, this is the region where the spillover effect dominates. C_1 is only possible if the spillover effect is sufficiently more prominent than the product differentiation in the market so that it satisfies $\beta \geq \gamma r$. Intuitively we know that this implies that the spillover effect will (almost) never dominate in the case of identical products ($\gamma = 1$). Conversely, the spillover effect will (almost) always dominate if the product differentiation is close to or equal to zero, given that the spillover effect is present. Keep in mind that the way I model a merger implies that if $\frac{\partial x^*}{\partial n}$ is positive, increasing the number of firms would increase the per-firm R&D level. Following this analogy, a reduction of firms and $\frac{\partial x^*}{\partial n} > 0$ would imply a reduction in the optimal per-firm R&D level. In region C_1 a merger would reduce the optimal R&D level in the market.

Proposition 1: If β_C is large enough, that is $\beta \geq \gamma r$ than for all values of n, and $\gamma \in (0, 1)$ a merger would reduce the optimal investment level.

If the industry however, does not fulfill proposition 1, meaning that a merger would increase the per-firm R&D level, the firm would be in region C_2. In C_2 the scaled product differentiation effect dominates $\frac{\partial x^*}{\partial n} < 0$, a reduction in firms would result in increased per-firm optimal R&D level; the associated spillover effect needs to be $\beta_C < r\gamma$ smaller than the scaled product differentiation effect. From this, it becomes clear that understanding the market dynamics is impeccable to regulate a market efficiently.

3.5 Bertrand competition

In the second game, I will look at the same industry. However, this time the competition revolves around pricing strategies rather than output levels. Moreover, it becomes necessary to make changes to the original Bertrand assumptions. Specifically, through product differentiation, the assumption that the lowest-priced firm will capture the entire market demand can be relaxed, ultimately eliminating the Bertrand paradox.

One must derive the direct market demand to establish the general Bertrand maximization problem. In this regard, I have used the approach presented by Majerus (1988) and later Häckner (2000) as presented in 3.3.2. The direct demand for firm *i* is on the following form:

$$q_i(p_i, p_j) = \frac{\left([1+(n-2)\gamma](a-p_i) - \gamma \sum_{j\neq i}(a-p_j)\right)}{(1-\gamma)[1+E]}$$

The demand function possesses appealing features through the properties of the own-price and the cross-price elasticities. The own-price elasticity measures how demand changes when the firms' price changes. On the other hand, cross-price refers to how interchangeable the product is and how a price change in a rivaling firm's product affects firm i's demand. Both elasticities are reducing in differentiation, implying that if firms have similar products, both the own-price and the cross-price elasticities will increase. See appendix for calculations. The firms will move towards a Bertrand paradox and limited profits when the industry is defined with nearly identical products. The more differentiated the products are, the less the own price and cross-price effects are, incentivizing higher prices and thus higher per-firm profits. Firm *i's* maximization problem can therefore be derived to be:

$$\pi_i(x_i, x_j, p_i, p_j) = \left(p_i - c + x_i + \beta \sum_{j\neq i} x_j\right) \frac{\left([1+(n-2)\gamma](a-p_i) - \gamma \sum_{j\neq i}(a-p_j)\right)}{(1-\gamma)[1+E]} - \left(\frac{r x_i^2}{2}\right) \tag{13}$$

Like the Cournot case, I need to identify a general equation for both the price and investment levels before solving the two equations and identifying the market-stable NE levels before determining how a merger will affect R&D spending. Firstly, firm i would want to maximize its price; which involves taking the partial derivative of (13) w.r.t. firm i's price, p_i. I then solve the F.O.C. while assuming symmetry between firms, $p_i = p_j = p$, and $x_i = x_j = x$ and solving for p.

$$p_B(x) = \frac{a\,(1-\gamma) + \big((n-2)\gamma + 1\big)(x\,(\beta\,(1-n) - 1) + c)}{(n-3)\gamma + 2}$$

(14)

Simultaneously, to identify the general investment level, I maximize (13) w.r.t. the firm's investment, x_i. From the F.O.C., I assume symmetry and solve for the symmetric per-firm R&D level.

$$x_B = \frac{a-p}{r(E+1)}$$

(15)

I am now ready to locate the pricing strategy for firm i in a given industry. This can be done by inserting the general investment level (15) into the general pricing strategy (14), then solving for the optimal price.

$$p_B^* = \frac{a\,\big((\beta\,(n-1)+1)\big)\big((n-2)\gamma+1\big) + r(E+1)\Big(a\,(\gamma-1) - c\,\big((n-2)\gamma+1\big)\Big)}{(\beta\,(n-1)+1)\big((n-2)\gamma+1\big) - \big((n-3)\gamma+2\big)\,r\,(E+1)}$$

(16)

Firm i's NE price is a complex and intriguing function where the product's utility significantly influences the pricing strategy. This utility is intricately linked to the spillover effect and the degree of product differentiation. Intriguingly, the first terms in both components of the pricing function are identical, except for the utility variable, a. The term for the investment cost: $r(E+1)\Big(a\,(\gamma-1) - c\,\big((n-2)\gamma+1\big)\Big)$ consistently yields a net negative value for all variable values, given that the lower limit for the market size is $n \geq 2$, and the upper limit for the product differentiation is 1.

Product differentiation has a threefold influence on the pricing function.

First, when products are more similar (high γ), the negative impact of the investment cost is reduced. Second, there is a decline in the utility of the product. Third, in markets with more than two firms, the last term in the pricing function $-\big((n-3)\gamma+2\big)\, r\,(E+1)$, always becomes negative for all values. Thus, the term would decrease, but if the degree of differentiation changes, the effect on price is ambiguous, following the counteracting forces identified.

Using (16), I can also find the optimal investment level for firm i, by inserting it into the general investment function (15).

$$x_B^* = \frac{A\big((n-2)\gamma+1\big)}{-(\beta\,(n-1)+1)\big((n-2)\gamma+1\big)+r(1+E)\big((n-3)\gamma+2\big)} \tag{17}$$

The margin between product utility and production cost heavily influences the optimal investment level for a firm. An increase in A would encourage a higher investment level in R&D. However, how much the firm would respond to an increased A depends on how differentiated the products are and how many rivals are in the industry. These two factors counteract each other; while a high number of rivals increases the effect of A, a highly differentiated product can counterbalance this effect.

Additionally, the firm's investment costs reduce the overall investment, as indicated by the last term in the denominator; how significant this effect is depends on the number of rivals and the product differentiation. Where a highly differentiated product reduces the effect of investment costs, the number of rivals increases it. Moreover, the degree of technological spillover between firms positively influences the optimal R&D investment for each firm. Similar to the margin and the cost of investment, the spillover effect is increasing in the number of firms in the market and reducing in differentiation.

The second-order derivative of the firms' profit function $\pi_i\big(x_i, x_j, p_i, p_j\big)$ w.r.t. own investment is negative: $\frac{\partial \pi''}{\partial x_i''} = -r$. Indicating that firm *i's* profit function is concave in its own investment level, that is, an increase in one unit of R&D will either; have a decreasing effect on the profit (less than one unit increase), no effect, or a negative effect on the firms' profit (see figure 2).

Additionally, I would assume that firms would not invest in negative R&D, implying that the sum of the denominator must be positive. In turn, the optimal investment level above must be positive. I am interested in how R&D in equilibrium will respond to a change in *n*. To predict the response, I will differentiate the firm's optimal investment level by n. This will yield the marginal change in x_B^* for a change in *n*.

$$\frac{\partial x_B^*}{\partial n} = \frac{A\left(\beta\left((n-2)\gamma+1\right)^2 - r\gamma\left(\gamma\left(\left((n-4)n+5\right)\gamma+2n-5\right)+1\right)\right)}{\left(\beta\,(n-1)\left((n-2)\gamma+1\right)-r\left((n-3)\gamma+2\right)\left((n-1)\gamma+1\right)+(n-2)\gamma+1\right)^2} \tag{18}$$

Both the first term in the nominator and the whole denominator is squared and therefore positive, regardless of $\beta, n, \gamma\ and\ r$. Additionally, we know that *A* is a non-negative variable. The last term, however, is negative for all values of γ and *n*. This conflict indicates that two effects are battling for how the industry will respond to a merger. On the increasing side, we have the spillover-driven effect; on the decreasing side, we have the differentiation-driven effect. The sign of $\frac{\partial x^*}{\partial n}$ is therefore ambiguous.

Let us first assume that the spillover-driven effects dominate, $\frac{\partial x^*}{\partial n} > 0$; this would imply that a reduction in the number of firms would lead to a reduction in optimal per-firm R&D level. Mark that this is not the same as the optimal per-firm R&D investment would increase.[12] Let us call the region $\frac{\partial x^*}{\partial n} \geq 0$ for B_1. The existence of B_1 would be for all values of $\beta,\ \gamma, r\ and\ n$ that satisfy the inequality:

$$\beta_B \geq \frac{r\,\gamma\left((n^2-4n+5)\gamma^2+(2n-5)\gamma+1\right)}{\left((n-2)\gamma+1\right)^2}$$

If β is sufficiently large, then the spillover-driven effect in $\frac{\partial x^*}{\partial n}$ will dominate the product differentiation-driven effect, and a merger would reduce the optimal per-firm R&D level post-

[12] Some of the increase in R&D would come from an increased spillover from the total R&D of the firms' rivals.

merger. Alternatively, if the differentiation-driven effect dominated the spillover effect, it would have to be:

$$\beta_B < \frac{r\,\gamma\left((n^2 - 4\,n + 5)\gamma^2 + (2\,n - 5)\gamma + 1\right)}{\left((n - 2)\gamma + 1\right)^2}$$

Let the region where the differentiation dominates the spillover $\frac{\partial x}{\partial n} < 0$, be denoted as B_2, that is, the region where a merger would incentives an increased optimal investment level $\frac{\partial x^*}{\partial n} < 0$ post-merger.

Preposition 2: If β_B is large enough that it satisfies the B_1 conditions, a merger would reduce the optimal investment levels regardless of n for all values of γ.

Preposition 2 identifies the region where a possible merger, shown as a marginal reduction in n, would reduce the optimal per-firm investment levels. Furthermore, it also shows that if a merger does not fulfill the conditions necessary for B_1, a merger would result in an increased per-firm R&D spending post-merger.

4. Comparative analysis

Analyzing the difference in price, quantity, R&D levels, and R&D thresholds between the Bertrand and Cournot case is crucial from a competition policy perspective. Understanding the distinct characteristics of price and output competition and how a merger might affect innovation, consumer welfare, and competition post-merger is essential. In what markets would a merger positively affect the investment level, and how would this affect the consumers? Policymakers must comprehend whether one market structure typically fosters higher R&D investments and product differentiation.

Firstly, both Cournot and Bertrand competition has in the framework provided a concave profit function w.r.t. the firm's investment level, $\frac{\partial \pi''}{\partial x_{i_B}} = \frac{\partial \pi''}{\partial x_{iC}} = -r$. Not surprisingly, the two competitional forms have the same form on the profit function w.r.t. the investment level. See figure 2 for possible implications of a concave profit function.

To comprehensively analyze the Bertrand and the Cournot games, estimating non-competitive variables, such as the output level in Bertrand and the price level in Cournot, is essential. To identify the Cournot price equilibrium, I utilize the inverse demand function identified in equation 2: $p_i(q_i, q_j) = a - q_i - \gamma \sum_{i \neq j} q_j$. From the symmetry assumption, the total market demand is given on the form $Q = q_i + \gamma \sum_{j \neq i} q_j$, and thus the inverse demand function can be rewritten as: $P = a - Q$. From this, I determine the market price to be:

$$P_C^* = a - (1 + E) * q_C^* \tag{19}$$

The market clearing price is directly affected by the firms' demand and how differentiated the products are. Furthermore, since the horizontal merger also affects the price level, we know the margin and demand expansion effects are at play. If the degree of spillover in the market is significant enough to fulfill Proposition 1, the market would be in region C_1. In C_1 we know that a merger would reduce the optimal investment level, and from the general output setting function (14): $q_C = \frac{A + x + \beta(n-1)x}{2+E}$, a reduced per-firm R&D level would imply a lower quantity. Furthermore, if the firm is incentivized to reduce its output, we can from (19) see that this would also imply an increased price level for the Cournot competing firm. Suppose the firms would be incentivized to increase their price level while decreasing their output level. In that case, this suggests that one of the drivers behind a post-merger firm's motivation to innovate would be the margin expansion effect identified by Jullien and Lefouili (2018) and Bourreau et al. (2021).

However, if the opposite is true, and the market spillover is not sufficiently large so that Proposition 1 is not fulfilled, then the firms would be in region C_2. In C_2 a merger would positively affect the per-firm R&D level, and a merger would thus increase the outputs while at the same time reducing the market price. If this is the case, the demand expansion effect would be more significant than the margin expansion effect for the firms.

Additionally, the innovation diversion effect would be present for the firms in the market. This effect refers to how a change in the differentiation in the firms' product would affect the firm's sales. Suppose we consider incorporating this effect into the model by reducing γ. If the firm manages to increase its differentiation, it will relax the quantity competition in the market and increase its market power. From (10): $q_C^* = \frac{A\,r}{\beta\,(\,1-n) + r\,(E + 2) - 1}$, we can see that if the firm manages to become more differentiated, it will see an increase in its output. However, the effect on the price would be ambiguous. From (19), one can see that when the output and the differentiation increase, these changes would counteract each other. Further calculations are needed to predict the full effect. The optimal Cournot price can be expressed on the form: $p_C^* = a + \frac{(1+E)Ar}{b(n-1)-(2+E)r+1}$ while this does provide us with a concrete price in the Cournot market, it does not give us a clear-cut answer to what happens if the firm manages to increase its differentiation. The effect is still ambiguous.

The Bertrand quantity level is given from the direct demand function as identified through equation 6 to be: $q_i\left(p_i, p_j\right) = \frac{\left([1+(n-2)\gamma](a-p_i)-\gamma\sum_{j\neq i}\left(a-p_j\right)\right)}{(1-\gamma)[1+\gamma(n-1)]}$, like for the Cournot market, by assuming symmetric prices among rivaling firms, the firms' quantity is:

$$q_B^* = \frac{a - p_B^*}{E + 1}$$

(20)

The firm's output is dictated by the product's utility and the market price. A price increase will reduce the demand, as predicted by the shape of the demand function. Additionally, firms with more differentiated products will have a higher demand.

However, when considering a Bertrand market structure, the response to a horizontal merger in a setting with significant technological spillover between firms so that it satisfies proposition 2, and they are in region B_1. In B_1 a merger would negatively affect the per-firm R&D level. If the R&D level drops post-merger, we would from (14): $p_B(x) = \frac{a\,(1-\gamma) + ((n-2)\gamma + 1)(x\,(\beta\,(1-n) - 1) + c)}{(n-3)\gamma + 2}$, also expect a reduction in the NE price. Furthermore, if the firms were to reduce their prices, we can from (20), ceteris paribus, expect an increase in the per-firm NE output. Signaling a demand expansion effect.

Conversely, if the market does not fulfill proposition 2, then $\Delta x > 0$, and we would see a decrease in output and a price increase. This suggests that the margin expansion effect would be the more significant effect. As for the Cournot market, the Bertrand competing firms would be affected by the innovation diversion effect, which can be viewed as a change in product differentiation. Let us first assume that a firm manages to increase its product differentiation, $\Delta\gamma < 0$. From the optimal pricing equation (14), it becomes evident that an increase in product differentiation would incentivize an increase and a decrease in the NE price, thus making the total effect ambiguous. Also, there are some uncertainties regarding the post-merger per-firm output level in the quantity function. Firstly, assume that the increased differentiation would affect the price level negatively, yielding a lower price. This price reduction, combined with $\Delta\gamma < 0$, would affect the optimal output positively. Yielding an increased NE output. Secondly, if the pricing function changes positively, the two effects would counteract each other, and the total effect would be uncertain.

How a merger could motivate innovation differs significantly between the two markets. In the region where one would increase prices and reduce output, the other market would do the complete opposite, highlighting the importance for competitional authorities to know their market. If they incorrectly identify the market by chance, the regulations imposed could devastate consumer welfare.

4.1 Price levels

To compare the price levels in the two markets, I use the Cournot price function identified above and subtract the optimal price level under Bertrand competition (16).

$$p_c^* - p_B^* = \frac{A\,(n-1)r^2y^2(E+1)}{(\beta(1-n) + r(E+2) - 1)\left(-\beta\,(n-1)\left((n-2)\gamma + 1\right) + r\left((n-3)\gamma + 2\right)(E+1) - (n-2)\gamma - 1\right)}$$

In all scenarios and for any combination of variables, the Cournot competition consistently results in a higher price than the Bertrand case. Regardless of how differentiated the products are or how much spillover between firms, the Cournot competition is more "monopolistic" than Bertrand (Amir & Jin, 2001). When the firms are not competing through prices, the firms have an opportunity to take higher margins and, thus, a higher market price. Furthermore, the more differentiated the products are, the smaller the difference will be. In the extreme case of perfectly differentiated products, the difference would be nullified, and the type of competition will not matter, in line with the findings of Singh and Vives (1984).

4.2 Quantity

I use the NE Bertrand price (16) to solve the Bertrand quantity (20). Making it possible to analyze the difference between the two competitive forms by subtracting the Cournot quantity (10).

$$q_B^* - q_C^* = \frac{A\,(n-1)r^2\gamma^2}{\big(\beta\,(n-1)\big((n-2)\gamma+1\big) - r\,\big((n-3)\gamma+2\big)(E+1) + (n-2)\gamma+1\big)\big(\beta\,(n-1) + r\,(E-2)+1\big)}$$

In terms of quantity, we can see that if the Bertrand firm obtains a margin, this margin will increase the difference between the Bertrand and the Cournot outputs. This is true irrespective of the degree of product differentiation, given at least two competing firms in the market, assuming the products are not perfectly differentiated.

The spillover effect would increase the difference in output for markets characterized by low spillover values without altering the relationship between them. Regardless of the extent of spillover, this indicates that the model that produces the highest output would remain unchanged, although the magnitude of the output gap may vary. On the other hand, the effect of differentiation is harder to interpret. While the difference between the Bertrand and Cournot outputs can, through one channel, decrease in more differentiated products, they can, through others, increase the difference between them, making the overall impact ambiguous.

Despite the ambiguity, it is essential to note that the overall output for a Bertrand firm will never (in this model) be exceeded by the Cournot firms' output; this holds for all levels of differentiation and spillover. They can however, be equal. This is only possible if the products are perfectly differentiated, then the competitive form is irrelevant.

My findings of the Bertrand-Cournot comparison of price and quantity are in line with economic literature on the competitiveness between Bertrand and Cournot markets Singh and Vives (1984), Vives (1985), Cheng (1985), Okuguchi (1987), and others.

4.3 R&D level

Using the previously obtained NE investment levels, the R&D difference can be formalized on the form:

$$x_B^* - x_C^* = \frac{A\,r\big((n-2)\gamma+1\big)\big(-(1+E)r\big((n-3)\gamma+2\big)+E+2\big)}{\Big((\beta(n-1)+1)\big((n-2)\gamma+1\big)-(1+E)r\big((n-3)\gamma+2\big)\Big)\big(\beta(n-1)+r(E-2)+1\big)}$$

The optimal R&D levels for firms in price and quantity competition are almost identical for a wide range of variables. However, the investment level in price competition is consistently higher than output competition, with only one exception. The only exception is the instance where the product is perfectly differentiated. In this instance, the market's optimal investment level is identical across all market sizes, degrees of spillover, investment costs, and margins.

This consistently higher investment level can be attributed to the strategic nature of price competition compared to output competition. The possible gain from a higher margin and a reduced-price level supersedes the gains output-driven competition can achieve.

4.4 Threshold

The threshold values represent the minimum degree of spillover that is required for the marginal investment w.r.t. the number of firms to become positive, $\frac{\partial x^*}{\partial n} > 0$. That is, a merger would reduce the optimal per-firm R&D level. Figure 3 below shows the Cournot and the Bertrand threshold values graphically with the spillover value on the y-axis and the number of firms on the x-axis. The values are modeled with a presumed investment cost of one and product differentiation equal to 0.4.

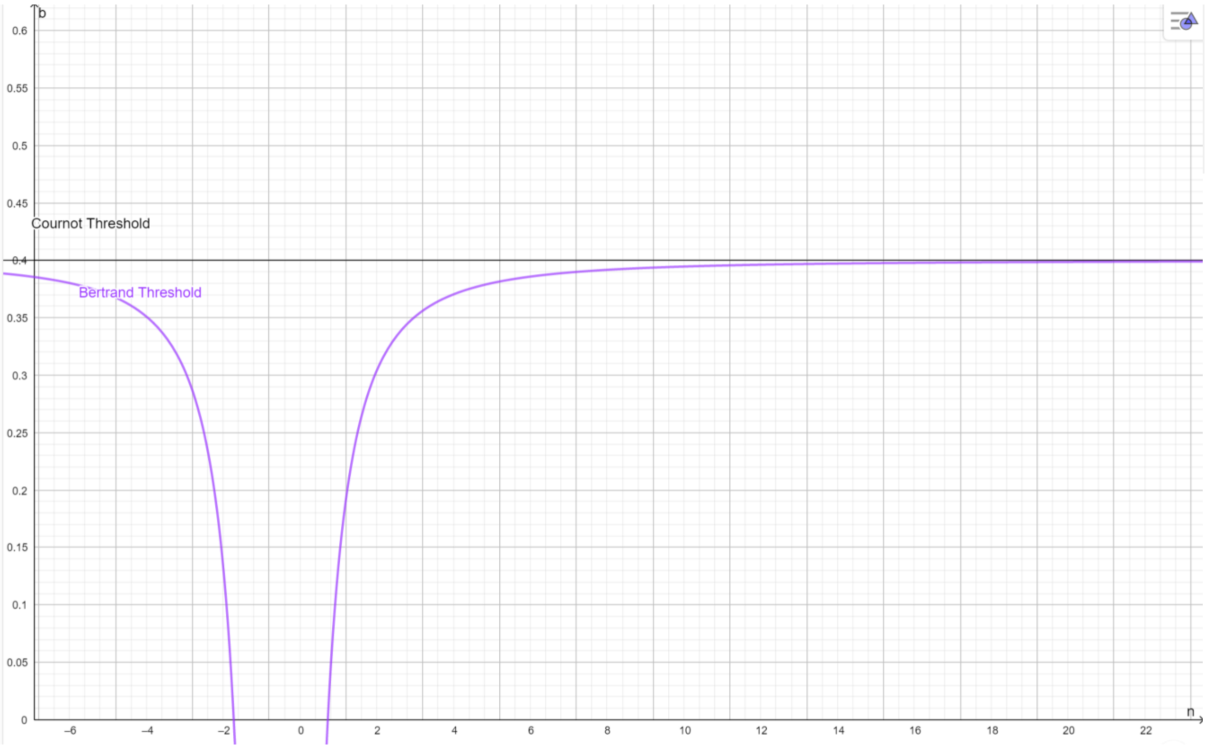

Figure 3: Threshold values, r=1 and γ=0.4

Figure 3 shows that the degree of product differentiation is essential for the likelihood that a merger would result in increased R&D levels post-merger. With the given investment cost of 1, the Cournot threshold, $\beta_C \geq r\gamma$, is equal to the degree of product differentiation for all values of n, and any spillover value over 0.4 would result in reduced per-firm R&D post-merger. Furthermore, it becomes evident that industries characterized by loose patent rights and a significant spillover have a high chance of negatively affecting the post-merger innovation level.

Regarding price competition, the threshold is not linear as it was under output competition: $\beta_B \geq \frac{r\,\gamma\left((n^2 - 4n + 5)\gamma^2 + (2n - 5)\gamma + 1\right)}{\left((n-2)\gamma + 1\right)^2}$. Figure 3 shows that the likelihood of a positive shift in the firm's investment level is reduced in highly concentrated markets. The U-shaped Bertrand threshold will, for an increase in γ shift upwards and to the right. Implying that when merging into a monopoly/duopoly, the likelihood of increased R&D is reduced. However, in low-concentrated industries, there is an increasing probability that a possible merger will increase the investment level. Lastly, the Bertrand threshold holds an interesting trait in low-concentrated markets. It converges towards $r\gamma$, the Cournot threshold.

This insight can be detrimental to policymakers. When only a few key players dominate a market, the threshold for reduced R&D investments, given price competition, is lower than what it would have been in a less concentrated market.

Proposition 3: The Bertrand threshold is lower than the Cournot threshold in all markets. However, in highly concentrated markets, Cournot and Bertrand thresholds will converge to $r\gamma$.

Proposition 3 supports the well-known assumption that price competition is more competitive than quantity competition. This assumption typically relays on the following: "Firms have less capacity to raise prices above marginal cost in Bertrand competition because the perceived elasticity of demand of a firm when taking the price of the rival as given is larger than that which the firm perceives when taking the quantity of the rival as given" (Singh & Vives, 1984). This assumption holds for my model.

5. Discussion

How firms react to a merger can have implications for the industry for decades, making it of utmost importance that policymakers correctly identify how firms compete and how a given industry would react to a merger. How would a merger impact the consumers, and how realistic is it that a market can have a high degree of spillover?

5.1 Consumer surplus

One of the main goals for policymakers is to facilitate firms to develop and thrive while maximizing consumers' utility. This is not an easy task since a thriving firm depends on bringing in a profit directly from the consumer surplus and negatively offsets the consumers. While a price increase might increase the firms' profits, it will reduce the consumer surplus, and vice versa, a price reduction will increase the consumer surplus, but the profits will fall.

REGION	$\boldsymbol{\Delta p}$	$\boldsymbol{\Delta q}$	$\boldsymbol{\Delta x}$
$\boldsymbol{C_1}$	$p_C^* > 0$	$q_C^* < 0$	$x_C^* < 0$
$\boldsymbol{C_2}$	$p_C^* < 0$	$q_C^* > 0$	$x_C^* > 0$
$\boldsymbol{B_1}$	$p_B^* < 0$	$q_B^* > 0$	$x_B^* < 0$
$\boldsymbol{B_2}$	$p_B^* > 0$	$q_B^* < 0$	$x_B^* > 0$

Table 1: Summary of changes

Table 1 summarizes the different regions a post-merger market can be in for Cournot and Bertrand competition. We can see that for the regions that will observe an increased R&D level post-merger (C_2 and B_2), the price and output change is opposite. Similarly, the regions where a merger would reduce the per-firm R&D levels (C_1 and B_1) are also opposite. As such, if the price level would drop following increased R&D for a Cournot firm, a reduction in R&D by a Bertrand firm would have the same effect. By inserting the budget function into the consumer utility, I get the following:

$$U(q, I) = \sum_{i=1}^{n} q_i a_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + 2\gamma \sum_{i \neq j} q_i q_j\right) + I, \qquad I = m - \sum p_i q_i$$

$$U(q, m) = \sum_{i=1}^{n} q_i a_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + 2\gamma(n-1) q_i q_j\right) + m - \sum p_i q_i$$

(21)

Based on Equation 21, it is evident that a higher value of p_i, leads to a decrease in the overall utility experienced by the consumer. In sections 4.1 and 4.2 of the analysis, I proved that the price level remains higher under Cournot than Bertrand competition, regardless of spillover effects or product differentiation. Additionally, the output level is consistently lower under Cournot competition across all scenarios, except when the products are perfectly differentiated, where the competitive form becomes irrelevant.

The findings of Sing and Vives, as well as Häckner, align with the analysis, demonstrating that Cournot competition exhibits greater monopolistic tendencies compared to comparable Bertrand industries. Although an increased level of R&D post-merger has inherent market benefits, it should be noted that under Cournot competition, higher R&D levels contribute to an increase in the overall price level, consequently reducing the consumer surplus. This outcome results in higher profits for firms but a lower consumer surplus. From a policy perspective, the identified regions highlighted in table 1 can be ranked in terms of consumer surplus as follows: $B_1 < B_2 < C_2 < C_1$.

In the regions that incentivize an increased price level post-merger (C_1 and B_2) a merger would be anti-competitive from a consumer point of view. However, if the goal of the policymakers is to increase R&D, then B_2 would be preferred compared to B_1 since the firms would increase their R&D spending.

This finding that B_1 is to be preferred to B_2 even though B_2 gives an increased R&D level is in line with the findings of Motta and Tarantino (2021). They identified that a merger would be anti-competitive following a rise in prices and reduced aggregated investments in the absence of efficiency gains.

5.2 Degree of spillover

While there are multiple ways a firm can acquire technological spillover from rivaling firms, from a policy viewpoint, some are preferred to others. The possible gains are enormous if the spillover results from employee movement, meetings, or other face-to-face interactions. The effect of face-to-face interactions is the cornerstone of the argument for creating knowledge clusters[13]. A well-designed cluster can bring academia and the private sector together and significantly increase output and productivity. In knowledge clusters like Silicon Valley, firms

[13] Clusters are geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate (Porter, 1998).

often operate close to one another, creating opportunities for employees to interact and exchange ideas outside their formal work settings. These informal interactions can lead to the diffusion of knowledge and technological advancements among firms. As a result, firms within the cluster can experience technology spillover, superseding the spillover firms that are not in the cluster faces. UiB is no exception to this mindset. In the strategy for 2023-2030, the university will focus on establishing six knowledge clusters to achieve its goal of "… develop outstanding research and education environments of excellence." (University Of Bergen, 2019). A cluster's effects can potentially change the global economy, as Silicon Vally has done in later decades[14]. Also, Bloom et al. (2013) and Jaffe et al. (1993) identified the importance of geographical closeness and knowledge spillovers.

Policymakers should recognize the value of the spillover effects that arise from industry clusters. They should strive to create an environment that fosters and facilitates such spillovers. By promoting collaboration, knowledge exchange, and innovation within clusters, policymakers aim to maximize the positive impact of technological spillover on regional economic growth and development.

While clusters are generally regarded as a desirable means of fostering spillovers, it is important to recognize that imperfect patents and reverse engineering can facilitate technological spillover among firms following successful innovation. Firms heavily rely on patents to protect their intellectual property and gain a competitive advantage. However, patents are not always foolproof, and if a patent is imperfect, firms can, from patents, gain insight into the technological improvement of a rival. However, is the possibility of an imperfect patent bad? According to Bloom et al. (2013), the socially optimal R&D level is twice as high as the private optimal R&D level, implying that even if private firms invest optimally in R&D, socially, we are still way too low. Patents, while intended to protect innovation and provide incentives for firms to innovate, have also been found to result in monopoly allocations (Gupta, 2023). It brings us back to the long-standing debate between Arrow and Schumpeter regarding the driving force behind innovation: large firms or competition. The nature of spillover works quite nicely with the three principles highlighted by Shapiro (2011). In a knowledge cluster, and through Table 2 below, it is hard to argue that a firm innovates alone. There are spillovers from the industry that the firm utilizes, in line with the synergies principle. The principle regarding contestability revolves around acquiring market shares, which with a patent, can create a

[14] See Atkin et al. (2022) For further understanding of knowledge spillover in Silicon Vally and the importance of face-to-face interactions.

monopolist, and with an imperfect patent, might increase the contestability in the market. Lastly, the appropriability principle revolves around how well a firm can guard their innovation and keep its competitive advantage. One factor surrounding this is patents, and how well they are designed, another is reverse engineering. Reverse engineering is a process where competitors analyze and replicate a product to gain insights into its technology, design, and functionality. Reverse engineering can occur in industries where product imitation is feasible. When reverse engineering occurs, it can lead to spillover effects as the imitating firms acquire knowledge and expertise from the original product.

The presence of technological spillover in almost (if not all) industries is undeniable. To study the degree of technological spillover, Tseng (2022) used patent data obtained from the National Burau of Economic Research (NBER), Kogan et al. (2017), and Google Patent to look at the degree across different industries. Table 2 is, in its entirety, taken from Tseng (2022).

Technology spillover of industries.

Industry	Mean	Median	Stdev	P1	P5	P25	P75	P95	P99
Food	15.08	9.84	16.68	0.40	1.16	5.67	17.26	53.32	89.90
Mining and minerals	12.65	8.48	12.90	0.47	1.66	4.71	14.28	41.33	64.69
Oil and petroleum products	18.93	13.73	16.42	0.58	2.04	6.23	26.52	52.23	72.73
Textiles, apparel, and footwear	7.06	2.94	10.30	0.04	0.28	1.08	8.56	25.60	52.62
Consumer durables	11.19	5.84	15.88	0.32	0.85	2.58	13.56	38.22	77.45
Chemicals	32.09	25.83	26.45	0.94	3.86	11.65	44.66	81.62	120.50
Drugs, biological, and medical products	46.34	34.83	35.59	1.15	4.24	16.33	75.01	111.24	132.46
Construction and construction materials	14.67	8.73	16.29	0.78	1.62	4.64	17.19	50.59	80.55
Steel Works	11.77	7.80	12.81	0.75	1.46	4.17	14.38	34.10	69.19
Fabricated products	14.76	8.77	20.31	0.27	1.28	4.12	17.09	49.46	105.25
Computers and business equipment	29.53	15.41	35.47	0.69	2.19	7.08	38.00	103.29	166.52
Automobiles	19.65	12.85	20.19	1.32	2.72	6.94	23.73	66.62	100.81
Transportation	28.64	17.92	34.67	0.65	1.87	6.26	34.81	106.17	171.86
Retail stores	15.60	7.19	20.46	0.15	0.56	2.50	20.33	59.40	100.21
Other	29.57	16.41	32.55	0.61	2.12	6.97	40.70	100.21	137.64

Table 2: This table reports the pooled mean (Mean), median (Median), standard deviation (Stdev), 1st percentile (P1), 5th percentile (P5), 25th percentile (P25), 75th percentile (P75), 95th percentile (P95), and 99th percentile (P99) of the technology spillover measure for firms in industries based on the Fama-French 17 industry classification system. Financial and utility firms are excluded. (Tseng, 2022).

Table 2 provides clear evidence of significant variations in the extent of technological spillover across different industries. The double-digit standard deviation within each industry further emphasizes the substantial differences within sectors. Moreover, the data highlights that it is unlikely that a spillover ratio close to one can be achieved in any industry. Even in the industries with the highest mean spillover values, namely pharmaceuticals (46%), chemicals (32%), and computers (30%), these relatively "low" spillover values suggest a high likelihood that mergers within these industries would result in a reduction in the per-firm R&D investments. While the probability of a reduction in investment levels is high, the considerable variation, as evidenced by the mean and standard deviation across and within industries, presents an opportunity for a positive shift in post-merger NE investment levels. The observed disparities imply that some firms within any industry may possess the characteristics that would incentivize an increased R&D level. This could be within a cluster or the combination of market concentration and differentiation.

In light of the data, policymakers should recognize the importance of carefully assessing each industry's specific dynamics and characteristics when considering mergers. Rather than assuming a uniform impact, understanding the nuances of technological spillover and the heterogeneity within and across industries can inform targeted strategies to maximize the potential benefits of post-merger NE levels.

6. Conclusion

My thesis is meant to develop further the existing literature surrounding the relationship between a horizontal merger and innovation. The model presented aligns with existing literature and proves that Bertrand competition is more competitive than an identical Cournot competition. Furthermore, the thesis aligns with the conclusion presented by Jullien and Lefouili (2018): The overall impact of a horizontal merger on innovation may be either positive or negative. Through this study, I find a negative relationship between technological spillover and firms' investments in R&D. This relationship is held regardless of if the firms compete through price or quantity. Thus, policy interventions in high spillover markets may be advisable.

Through my model, I find that the R&D threshold in price and output competition converge in low-concentrated markets. However, the Bertrand threshold is lower for all market concentration, although this is marginally in low concentrated markets, implying a lower probability of an increase in R&D post-merger. Despite this, Bertrand market yields higher per-firm R&D investments in all scenarios.

The competition and welfare-reducing effects that can occur post-merger in both price and output competition can justify policy intervention. Horizontal mergers may suppress negative pricing externalities between rivaling firms and negative innovation externalities. Therefore, mergers between rival innovators tend to reduce innovation incentives if there are sufficient knowledge spillovers.

6.1 Further research

One exciting development in the framework used in this thesis is how the comparison between Bertrand and Cournot competition would be if the firms were competing in a two-stage game, compared to the simultaneous game presented here. In a two-stage game, the firms choose their investment level in the first period and their prices (outputs) in the second period. Expanding the model into a two-stage game would make it possible to reflect the firms' sequential decision-making more accurately by observing rival firms' R&D investments.

It would be interesting to see if the results from my thesis would hold under a two-stage game, mainly proposition 3. Are there scenarios under this game form where the Cournot competing industries have higher competitiveness than Bertrand industries, contradicting standard economic theory? Alternatively, would this extension fix some of the simplifications needed for a simultaneous game to be modeled? Or will the outcome again align with standard economic theory: Bertrand competition is more competitive for all market variables. Further research is needed to determine this.

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Appendix

Direct demand elasticity

Own price elasticity	$\epsilon_{11} = \left\lvert\frac{p_i}{q_i} * \frac{\partial q_i}{\partial p_i}\right\rvert = \left\lvert\frac{p_i\big((n\,-\,2)y\,+\,1\big)}{a\,(-n\,y\,+\,2\,y\,+\,e\,-\,1) -\,e\,p_j +\,p_i\big((n\,-\,2)y\,+\,1\big)}\right\rvert$
Cross-price elasticity	$\epsilon_{12} = \left\lvert\frac{p_j}{q_i} * \frac{\partial q_i}{\partial p_j}\right\rvert = \left\lvert\frac{E\,p_j}{a\,(-y) +\,a\,+\,E\,p_j -\,p_i\big((n\,-\,2)y\,+\,1\big)}\right\rvert$

First order derivatives

Cournot price	$\frac{\partial \pi_i}{\partial q_i} = a - 2q_i - \gamma \sum_{j \neq i} q_j - c + x_i + \beta \sum_{j \neq i} x_j = 0$
Cournot investments	$\frac{\partial \pi_i}{\partial x_i} = q_i - rx_i = 0$
Bertrand price	$\frac{\partial \pi}{\partial p_i} = -\frac{-(\mathrm{n}\,-\,1)\gamma\,(\mathrm{a}\,-\,\mathrm{p_j}) +\,(\mathrm{a}\,-\,\mathrm{p_i})\big((\mathrm{n}\,-\,2)\gamma\,+\,1\big) +\,\big(-(\mathrm{n}\,-\,2)\gamma\,-\,1\big)\big(\beta(\mathrm{n}\,-\,1)\mathrm{x_j} -\,\mathrm{c}\,+\,\mathrm{p_i} +\,\mathrm{x_i}\big)}{(1\,+\,\mathrm{E})(\gamma\,-\,1)} = 0$
Bertrand investments	$\frac{\partial \pi_i}{\partial x_i} = \frac{a(\gamma - 1) + p_j(\gamma - n\gamma) + p_i\big((n-2)\gamma + 1\big)}{(\gamma - 1)(E + 1)} - rx_i = 0$

Non-competitive variable

Cournot

$$p_C^* = \,a\,+ \frac{A\,r\,\big((n\,-\,1)y\,+\,2\big)(y(n\,-\,1) +\,1)}{(y(n\,-\,1) +\,2)\big(b\,(n\,-\,1) +\,r\,\big((1\,-\,n)y\,-\,2\big) +\,1\big)}, \qquad E \equiv (n-1)\gamma$$

$$P_C^* = a\,+ \frac{(1\,+\,E)A\,r}{b\,(n\,-\,1) +\,r\,\big((1\,-\,n)y\,-\,2\big) +\,1}$$

Multiplying the last term with -1 on both sides of the equation.

$$\frac{A\,(1\,+\,e)r}{+\,b(1-n) +\,2\,r +\,ry(n-1) - 1}$$

$$P_C^* = a - \frac{Ar\,(1\,+\,E)}{b(1-n) +\,r(E+2) - 1}$$

$$P_C^* = a - (1 + E) * q_C^*$$

Bertrand

$$q_i(p_i, p_j) = \frac{\left([1 + (n-2)\gamma](a - p_i) - \gamma \sum_{j \neq i}(a - p_j)\right)}{(1-\gamma)[1+E]}$$

Assuming symmetry.

$$q_B = \frac{([1 + (n-2)\gamma](a - p) - \gamma(n-1)(a - p))}{(1-\gamma)[1+E]}$$

$$q_B^* = \frac{a - p_B^*}{E + 1}$$

Bertrand investment

x_B

$$= \frac{a - \left(\frac{a\,(b\,(n-1)+1)\left((n-2)y+1\right) + r(e+1)\left(a\,(y-1) - c\left((n-2)y+1\right)\right)}{(b\,(n-1)+1)\left((n-2)y+1\right) - \left((n-3)y+2\right)r(e+1)}\right)}{r(E+1)}$$

$$x_B^* = -\frac{(a-c)\left((n-2)y+1\right)}{(b\,(n-1)+1)\left((n-2)y+1\right) - r(1+e)\left((n-3)y+2\right)}$$

$$x_B^* = \frac{A\left((n-2)y+1\right)}{-(b\,(n-1)+1)\left((n-2)y+1\right) - r(1+e)\left((n-3)y+2\right)}$$

Price difference

$$p_c - p_B = (1+e)r\left(\frac{A}{b\,(n-1) - (2+e)r + 1} - \frac{(a-c)\left((n-2)y+1\right)}{b\,(n-1)\left((n-2)y+1\right) - (1+e)r\left((n-3)y+2\right) + (n-2)y+1}\right)$$

$$\frac{A\,r^2(y(n-1)+1)(n\,y + y\,y(n-1) - y(n-1) - y)}{(b\,(-n) + b + r\,y(n-1) + 2\,r - 1)(-b\,n^2y + 3\,b\,n\,y - b\,n - 2\,b\,y + b + n\,r\,y + n\,r\,y\,y(n-1) + 2\,r\,y(n-1) - 3\,r\,y\,y(n-1) - n\,y - 3\,r\,y + 2\,r + 2\,y - 1)}$$

$p_c - p_B$

$$= \frac{A\left(n-1\right)r^2y^2\left(n\,y - y + 1\right)}{\left(b\left(-n\right) + b + n\,r\,y - r\,y + 2r - 1\right)\left(-b\,n^2y + 3\,b\,n\,y - b\,n - 2\,b\,y + b + n^2r\,y^2 - 4\,n\,r\,y^2 + 3\,n\,r\,y - n\,y + 3\,r\,y^2 - 5\,r\,y + 2\,r + 2\,y - 1\right)}$$

Rewrites and shortens

$$\frac{A\,(n-1)r^2y^2(E+1)}{(b(1-n) + ry(n-1) + 2\,r - 1)\left(-b\,(n-1)\left((n-2)y+1\right) + r\left((n-3)y+2\right)\left((n-1)y+1\right) - (n-2)y - 1\right)}$$

Quantity difference

$$q_B^* = \frac{a - p_B^*}{E + 1}$$

$$q_C^* = \frac{A\,r}{\beta\,(1-n) + r\,(E+2) - 1}$$

$$p_B^* = \frac{a\,(\beta\,(n-1)+1)\big((n-2)\gamma+1\big) + r(E+1)\Big(a\,(\gamma-1) - c\,\big((n-2)\gamma+1\big)\Big)}{(\beta\,(n-1)+1)\big((n-2)\gamma+1\big) - \big((n-3)\gamma+2\big)\,r\,(E+1)}$$

$$q_B^* = \frac{a - \left(\frac{a\,(\beta\,(n-1)+1)\big((n-2)\gamma+1\big) + r(E+1)\Big(a\,(\gamma-1) - c\,\big((n-2)\gamma+1\big)\Big)}{(\beta\,(n-1)+1)\big((n-2)\gamma+1\big) - \big((n-3)\gamma+2\big)\,r\,(E+1)}\right)}{E+1}$$

Simplifying the term first

$$q_B^* = \frac{r\,(A)\big((n-2)y+1\big)}{-b\,(n-1)\big((n-2)y+1\big) + (1+e)r\,\big((n-3)y+2\big) - n\,y + 2\,y - 1}$$

$$q_B^* - q_C^* = \frac{A\,r^2\big((n+e-1)y-e\big)}{(b\,(n-1) - (2+e)r+1)\big(b\,(n-1)\big((n-2)y+1\big) - (1+e)r\,\big((n-3)y+2\big) + (n-2)y+1\big)}$$

Inserting for E and rewrites

$$q_B^* - q_C^* = \frac{A\,r^2\big((n+y(n-1)-1)y - y(n-1)\big)}{\big(b\,(n-1) - \big(2+y(n-1)\big)r+1\big)\big(b\,(n-1)\big((n-2)y+1\big) - \big(1+y(n-1)\big)r\,\big((n-3)y+2\big) + (n-2)y+1\big)}$$

$$\frac{A\,r^2\big(y\,(y(n-1)+n-1) - y(n-1)\big)}{\big(b\,(n-1)\big((n-2)y+1\big) - r\,\big((n-3)y+2\big)(y(n-1)+1) + (n-2)y+1\big)(b\,(n-1) - r\,(y(n-1)+2)+1)}$$

Inserting E

$$\frac{A\,r^2(y\,(E+n-1) - E)}{\big(b\,(n-1)\big((n-2)y+1\big) - r\,\big((n-3)y+2\big)(E+1) + (n-2)y+1\big)(b\,(n-1) - r\,(E+2)+1)}$$

$$\frac{A\,r^2\big((n+e-1)y-e\big)}{(b\,(n-1) - (2+e)r+1)\big(b\,(n-1)\big((n-2)y+1\big) - (1+e)r\,\big((n-3)y+2\big) + (n-2)y+1\big)}$$