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Chapter 1

Introduction

The present thesis covers several topics in industrial organization which can be basically divided into two parts. In the first part, we focus on managerial incentives in firms facing competition in the product market (chapters 2 and 3). In the second part, we examine the effectiveness of antitrust and regulation (chapters 4 and 5). In other words, we ask whether or not certain regulatory changes and antitrust rules were (are) successful to create and to ensure efficiency and competition in particular markets. In the following, the course of analysis and our main results are presented in more detail.

In chapter 2, we analyze the impact of partial public ownership (PPO) on managerial incentives. Thereby, we combine agency issues of a moral hazard type with a market game where firms are horizontally differentiated and compete à la Vickrey-Salop. A novelty of our framework is that it explicitly considers competition in the product market. We find that PPO negatively affects managerial incentives when all firms are partially owned by the government. When partially public firms compete with private firms, the effects on managerial incentives crucially depend on the degree of competitive pressure. Thereby, PPO induces either partially public firms or their private competitors to offer stronger managerial incentives. This result is essentially confirmed even if the government's primary concern is consumer protection rather than social welfare.[1]

In chapter 3, we analyze the effects of competition and indirect network externalities on managerial incentives within two-sided platforms. Using a moral hazard model, we

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[1] This chapter benefited a lot from comments of Justus Haucap, Yossi Spiegel, Irina Suleymanova, Tobias Wenzel, and Christian Wey.

specify that each platform consists of one principal and one agent. Thereby, managerial effort aims at increasing platform quality. First, we highlight that the effects of competition cannot be unambiguously characterized by the *business stealing effect* and the *rent reduction effect*. Second, we demonstrate that it is rather each platform's relative profitability and each group's adoption possibilities which shape managerial incentives when competition or indirect network externalities are varied.[2]

The fourth chapter is based on joint research with Christian Wey. We analyze the efficiency defence in merger control. Thereby, we especially focus on the criterion of merger specificity which plays a crucial role for an antitrust authority's decision whether or not to accept claimed efficiencies according to both the US merger guidelines and the EC merger guidelines.[3] First, we show that the relationship between efficiency gains and social welfare is non-monotone. Second, we analyze endogenous efficiencies and introduce a counterfactual to account for the criterion of merger specificity. It is demonstrated that most efficiencies are not merger specific, i.e., firms' incentives to implement the efficiency are typically larger without a merger. Finally, we take the merger decision as endogenous, and we show that welfare enhancing merger proposals are largely not accompanied by merger specific efficiencies. We take these results to cast serious doubts on the effectiveness of the current efficiency defence.[4]

Chapter 5 is based on joint research with Justus Haucap and Ulrich Heimeshoff. We apply econometric methods to examine recent regulatory changes in the German electricity

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[2]This chapter benefited a lot from comments of Simon P. Anderson, Michael Coenen, Justus Haucap, Hans-Theo Norman, Martin Peitz, Irina Suleymanova, Tobias Wenzel, Christian Wey, Yaron Yehezkel, and the seminar participants of the 9th IIOC in Boston, 2011.

[3]More specifically, claimed efficiencies have to be merger specific, verifiable and substantial, i.e., beneficial to consumers. If these criteria are cumulatively met, then claimed efficiencies will be accepted according to both the US merger guidelines and the EC merger guidelines.

[4]This chapter benefited a lot from comments of Tomaso Duso, John E. Kwoka, Stephen Martin, Hans-Theo Normann, Yossi Spiegel, Florian Szücz, the seminar participants at the CRESSE conference in Rhodes, 2011, and the seminar participants at the EARIE in Stockholm, 2011.

reserve power markets. The regulatory changes comprise nine reforms which led to a creation of a new market design through synchronization and interconnection of the four control areas. In this chapter, we analyze whether or not the reforms led to lower prices for minute reserve power (MRP). In contrast to existing works, we use a unique panel dataset to account for unobserved heterogeneity between the four German regional markets. Moreover, we control for endogeneity by using weather data as instruments for electricity spot market prices. Although we find that the reforms were jointly successful in decreasing MRP prices, the reforms' effects on both consumer surplus and welfare are rather ambiguous.[5]

Part I

Managerial Incentives and Competition

Chapter 2

Partial Public Ownership and Managerial Incentives

2.1 Introduction

Existing papers analyzing the impact of public ownership on firms' productive efficiency and managerial incentives rely on the comparison of two extremes: entirely private ownership and entirely public ownership.[1] In fact, many markets are characterized by firms exhibiting mixed ownership structures. In the European Union, it is especially the public utilities sector which reflects the phenomenon of partially public firms. Despite the substantial structural reforms including privatization of the formerly governmental-owned utilities, not all of the active firms have been transferred into entirely private ownership. For instance, in the German electricity market, two of the four largest firms are partially public, while one firm is entirely public, and the other entirely private.[2] A further example is the telecommunications market in Germany where the incumbent firm Deutsche Telekom AG is partially public, while its main competitors are entirely private.[3] This observation raises the question how partial public ownership (PPO) affects the firms' productive efficiency and managerial incentives. The present chapter addresses this issue.

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[1] Papers in this spirit are e.g., Laffont and Tirole (1991), and Roemer and Silvestre (1992) who explicitly account for regulation when firms are privatized. In addition, De Fraja (1993) tackles the role of "x-inefficiencies" in public firms compared with private firms. All these papers demonstrate that, in contrast to the claims by the proponents of the property rights approach (see Alchian, 1965, and Alchian and Demsetz, 1972), managerial effort is higher in public firms whose objective is social welfare rather than profits. It is worthwhile to note that Shleifer and Vishny (1994) build an exception who allow for partially public firms in their model. However, their setup can be rather classified as a political economics framework which differs form our paper in various respects.

[2] The four largest firms in the German electricity market are RWE, E.ON, Vattenfall and EnBW. While RWE and EnBW are partially public, E.ON is an entirely private firm. Note that the fourth competitor, Vattenfall, is entirely owned by the Swedish government. However, the present paper does not discuss the implications for the objective functions of public firms operating in foreign country.

[3] The German government owns directly 15% and indirectly 17% of Deutsche Telekom's shares. Another example is the German car market where the largest company, Volkswagen, is partially owned (20%) by the local government.

Using a principal-agent setting with ex post asymmetric information, we explicitly account for product market competition by considering an oligopolistic market structure. Thereby, we specify that the principals design the contracts for their respective agents and set the price non-cooperatively in the product market where they compete à la Vickrey-Salop. Moreover, it is assumed that each principal has private information on her firm's marginal costs. Given that the agent accepts the contract, she can exert unobservable effort to increase her firm's productive efficiency. Initially, we consider entirely private firms consisting of one private principal, e.g., a private investor or entrepreneur, and one agent. When analyzing partially public firms, we introduce a second principal into our model. Since we are interested in the effects of PPO on managerial incentives, we define that the second principal is a public principal, e.g., the government or a governmental institution. The public principal is assumed to be a minority shareholder whose share in firm i is given by $s_i \in (0, 1/2)$.[4],[5] As a consequence, we postulate that the public principal has only *limited* control over her firms. More precisely, it is involved in the decision on the incentive scheme, but it cannot decide on prices.[6] The pricing decision is rather exclusively made by the private principal.[7] To motivate this assumption, one should bear in mind that the private

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[4] Note that the term 'public' does not include private investors who are active in the (public) stock market. It rather exclusively indicates governmental ownership.

[5] By assuming that $s_i < 1/2$ suffices to guarantee that G is a minority shareholder, we implicitly apply a majority rule which specifies that a shareholder needs to have more than 50% of a firm's shares in order to get full control over it. Such a rule appears to be common, and is also used by e.g., Grossman and Hart (1988).

[6] Laffont and Tirole (1991) distinguish *internal* control and *external* control. It should be noted that we solely focus on internal control which comprises the design of the contract and the pricing decision. In this context, we can characterize the government as having limited internal control because it cannot decide on prices. However, external control is neglected, since we do not account for e.g., taxation or regulation.

[7] Thereby, we implicitly assume that the private investor and entrepreneur, respectively, is a manager at the same time. Alternatively, one could also think of a managing director whose interests are perfectly aligned with the private shareholders.

principal represents the majority shareholder whose share always satisfies $1/2 < (1-s_i) < 1$. Hence, we actually suppose that owning a minority share gives the principal the possibility to partially affect her firm's personnel decisions. To give an example, one can think of the public principal choosing one or more members of the supervisory board, and thereby affecting the firm's decision which managers to hire and how to reward them.

We analyze three cases. First, we presume that all firms are entirely private. This scenario serves as our benchmark case. Second, we suppose that the government holds identical minority shares in all firms (symmetric case). This case reflects a situation in which all firms are partially owned by the government with symmetric shares. Finally, we analyze the case in which only half of the firms are partially owned by the public principal, whereas the remaining firms are entirely private. Hereby, we specify that every partially public firm exclusively competes with entirely private firms and vice versa (asymmetric case). To simplify matters, we maintain the assumption that the public principal's shares are identical.

The substantial difference between a private investor and the government is that the former's objective is solely to maximize her firm's profit, while the latter additionally accounts for social welfare. In a second step, we will drop the welfare standard and presume instead that the public principal's objective is a linear combination of her firms' profits and consumer surplus. This modification allows us to analyze the effects of PPO given that the government's aim is to protect consumers.

We find that managerial incentives are always larger in the benchmark case than in the symmetric case of PPO. The fact that the public principal cares relatively more about all firms' profits in the market and, additionally, designs uniform contracts reduces managerial incentives finally given to the agents. As a consequence, firms exhibit lower productive efficiency and charge higher prices in equilibrium. Compared with the asymmetric case of PPO, our findings crucially depend on the level of competition in the market which is measured by the horizontal differentiation parameter. We demonstrate that managerial incentives either in partially public firms or in private firms can be higher than those in the

benchmark case. Given that the level of competition is above a certain threshold, partially public firms offer stronger incentives whenever competition is sufficiently low. Otherwise, entirely private firms in the benchmark case give their agents stronger incentives. The opposite holds when private firms in the asymmetric case are compared with those in the benchmark case. Hence, PPO exhibits positive effects on managerial incentives when not all firms in the market are partially public, i.e., private firms compete with partially public firms. Thereby, PPO induces either the partially public firms or the private competitors to push their agents to exert more effort compared to the full private scenario. Finally, we show that, when the government adopts a consumer surplus standard rather than a social welfare standard, the effects of PPO are reversed. We take this result to propose that the government should only care about consumer protection when it holds minority shares in all firms in the market. If partially private firms compete with private firms, then there is no essential effect of PPO on managerial incentives, and thus on productive efficiency.

The remainder is organized as follows. The related literature is discussed in Section 2.2. We present the model in Section 2.3. Sections 2.4 presents the equilibrium for the benchmark case, i.e., all firms in the market are entirely private. The equilibria for both cases of PPO as well as the effects of PPO on managerial incentives are studied in Section 2.5. Section 2.6 analyzes the implications of a government which cares about consumer protection rather than social welfare. A discussion is provided in Section 2.7. Section 2.8 concludes this chapter.

2.2   Related Literature

Our model is closely related to Raith (2003) whose paper is the first to explicitly model oligopolistic competition between firms following a contracting game where the principals face ex post asymmetric information.[8] Thereby, he focuses on a comparison between exoge-

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[8] Other papers with a similar modelling approach are Martin (2003) and, especially, Baggs and de Bettignies (2007). The latter rather use a Hotelling model with a fixed number of firms, and they provide some empirical evidence on the effects of competition on managerial incentives. In general, this literature builds

nous and endogenous market structures with respect to their effects on managerial incentives. Raith's basic setup with an exogenous market structure corresponds to our benchmark case. However, his paper focuses on firms which are inherently private. We are, on the contrary, interested in the effects of different ownership structures on managerial incentives where PPO with limited control is emphasized.

So far, the literature on partially public firms or, alternatively, partially private firms has not analyzed the effects on managerial incentives. As mentioned above, existing papers dealing with managerial incentives either compare private firms with entirely public firms (see e.g., De Fraja, 1993, and Corneo and Rob, 2003) or private regulated firms with entirely public firms (see e.g., Laffont and Tirole, 1991, and Roemer and Silvestre, 1992). In addition, they consider monopoly markets, and thereby do not allow for competition in the product market. In contrast, we rather focus on firms competing in an oligopolistic environment.

However, those papers on partially public firms, which allow for product market competition, do not analyze the consequences of agency issues within the firms; i.e., they suppose that firms are entrepreneurial. Two examples are Fershtman (1990) and Matsumura (1998) who use mixed Cournot duopoly models. The former shows that a partially public firm always realizes higher profits than its private competitor,[9] while the latter focuses on the degree to which public ownership is optimal. Thereby, Matsumura (1998) demonstrates that neither full public ownership nor full private ownership is optimal from a welfare perspective.

Finally, partially public firms are also analyzed by Cambini and Spiegel (2011) who study the strategic interactions between capital structure, investment decisions, and regulatory independence given a partially public firm which is price-regulated. They consider

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on the works by Hart (1983) and Schmidt (1997) who were among the first to formalize the relationship between managerial incentives and competitive pressure.

[9] This result holds if the "degree of nationalization", i.e., the share of public ownership, is strictly higher than zero and strictly lower than one. Moreover, if the government's share is below 60%, then the partially public firm's profit is higher than the Cournot equilibrium profit with exclusively private firms.

a regulator who is ex ante not able to fully commit to the price set at the initial stage of the game, and thus can appropriate some part of the firm's surplus via renegotiation. Nevertheless, the authors assume that the firm is entrepreneurial and does not face any competition in the product market which clearly distinguishes their work from the present chapter.

While there is empirical evidence on productive efficiency and profitability of public firms compared with private firms (see e.g., Caves and Christiansen, 1980, and Dewenter and Malatesta, 2001), there is only one empirical study by Gupta (2005) dealing with the effects of PPO on firms' performance. Gupta (2005) finds for India that, when initially public firms are partially privatized, profitability, productivity, and investments increase, although the firms completely remain under public control. However, there is no empirical evidence on the effects of PPO where the public owner has only limited control over its firm's (s'). The present analysis attempts to fill this gap using a theoretical framework.

2.3   The Model

We use the Vickrey-Salop setup[10] to model product market competition. For that purpose, we consider n firms indexed by $i = 1, 2, ..., n$ which are equidistantly located around a circle of circumference 1. When entering the market, each firm has to incur fixed costs of entry denoted by F. To simplify matters, we focus on an exogenous market structure where we set the number of firms in the market, n, to be fixed.[11]

Consumers of mass 1 are assumed to be uniformly distributed along the unit circle.

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[10]It should be noted that the circle model has been already analyzed by Vickrey (1964) where he, among other things, also compares the socially optimal number of firms with the market equilibrium number (see also Vickrey / Anderson and Braid, 1999).

[11]Raith (2003) focuses on the effects of competition on managerial incentives where he distinguishes exogenous and endogenous market structures. In contrast to this work, we concentrate on the effects of different ownership structures on managerial incentives and assumes, for simplicity, that the market structure is exogenous.

They exactly purchase one unit of the product offered either from firm i or from firm i's immediate neighbor firm $i-1$ and firm $i+1$, respectively. A consumer located at x derives utility of

$$v_i = v - p_i - t\left(z_i - x\right)^2 \tag{2.1}$$

from purchasing a product offered by firm i, where v denotes the utility of purchasing the most preferred product, t represents the horizontal product differentiation parameter, and z_i is firm i's location. It should be noted that due to the circle characteristic every firm i competes with two competitors, i.e., firms $i-1$ and $i+1$. Using (2.1) and determining the marginal consumers, it is straightforward to calculate firm i's demand which is given by

$$D_i = \frac{1}{n} + \frac{n\left[\left(p_{i+1} - p_i\right) + \left(p_{i-1} - p_i\right)\right]}{2t}, \tag{2.2}$$

where p_{i-1} and p_{i+1} denote the prices of firm i's immediate neighbors. Due to symmetry of the neighbors, $i-1$ and $i+1$, we can rewrite (2.2) as follows

$$D_i = \frac{1}{n} + \frac{n\left(p_j - p_i\right)}{t}, \tag{2.3}$$

where $p_j = p_{i-1} = p_{i+1}$.

Private firms. We assume that each firm consists of one risk-neutral private principal and one risk-averse agent. Firm i's private principal, labeled I_i, is assumed to maximize her (expected) profit given by

$$\pi_i = (p_i - c_i)D_i - F - w_i, \tag{2.4}$$

where p_i and D_i denote firm i's price and demand, respectively, and w_i denotes the wage. While I_i sets the price, p_i, and designs the incentive scheme, w_i, her agent can exert unobservable effort to reduce marginal costs, i.e., to increase firm i's productive efficiency. Marginal costs per firm are given by $c_i = c - e_i - \theta_i$, where c is a constant, e_i represents agent i's effort level, and θ_i denotes a normally distributed random variable with zero mean and variance σ^2, i.e., $\theta_i \sim N(0, \sigma^2)$ i.i.d. However, I_i offers her agent a wage of

$$w_i = d_i + b_i\left(c - c_i\right) \tag{2.5}$$

which comprises a (fixed) salary, d_i, and a variable component, $b_i(c - c_i)$, depending on the extent to which productive efficiency is increased. The piece rate, b_i, represents the incentive the principal gives her agent to reduce marginal costs which is termed managerial incentive. Throughout the entire analysis, we assume that marginal cost reductions are verifiable, and thus can be contracted upon.

The agent can accept or reject the contract which is a take-it-or-leave-it offer. If agent i rejects the contract, then she realizes her reservation utility which is normalized to zero, i.e., $\overline{u} = 0$. In contrast, if agent i accepts the offer, then she receives w_i and incurs costs of exerting effort which we denote by $ke_i^2/2$. For simplicity, we set $k = 1$ so that the disutility of effort can be written as $e_i^2/2$. Each agent is supposed to have a CARA utility function in the form of

$$u_i = -\exp\left(-r\left[w_i - e_i^2/2\right]\right),\tag{2.6}$$

where r denotes the agent's degree of risk aversion. It is straightforward that an agent only accepts the offer if $u_i \geq 0$ holds (participation constraint).

Partially public firms. When firms are partially owned by the government, then they consist of two principals. One principal is private and the other principal is a public principal labeled G. The public principal's share in firm i is given by $s_i \in (0, 1/2)$, i.e., G is a minority shareholder. We postulate that G is risk neutral and has only *limited* control over her firms. More precisely, it is involved in the decision on the incentive scheme, but it cannot decide on prices. It follows that firms are always privately managed with respect to product market decisions. Finally, given PPO, we presume that G has the same information about firm i as I_i. More specifically, G cannot observe its agents' effort levels, but it learns the marginal costs of the firms it owns.

We distinguish two cases. First, it is supposed that G holds an equal share in *all* firms in the market which is denoted by s^{SC} (symmetric case). Second, we presume that G owns only *half* of the firms in the market, whereas the remaining firms are entirely private (asymmetric case). Note that in this case every partially public firm exclusively competes with entirely private firms and vice versa. However, we maintain the assumption that G holds an equal

share in every partially owned firm which is labeled s^{AC}. It follows immediately that G observes the marginal costs of n firms and $n/2$ firms, respectively, while each I_i only knows the cost of her respective firm i.

In contrast to the private principal, G's objective function encompasses both the (expected) profits of her firms and social welfare. Let $l = SC, AC$ indicate the symmetric case (SC) and the asymmetric case (AC), respectively. Thus, G maximizes

$$U^l = s^l \Pi^l + W^l, \tag{2.7}$$

where Π^l is the sum of all the firms' profits in the market owned by G, i.e.,

$$\Pi^l = \sum_{i \in O^l} \pi_i^l,$$

and W^l is social welfare defined as

$$W^l = \sum_{i=1}^{n} \pi_i^l + n \left[\int_0^{y^l} v - p_i^l - tx^2 dx + \int_{y^l}^{1/n} v - p_j^l - t\left(1/n - x\right)^2 dx \right],$$

i.e., the sum of consumer surplus and producer surplus. Note that y^l indicates the marginal consumer and O^l denotes the set of firms partially owned by G.[12] Obviously, both y^l and O^l depend on whether the symmetric case or the asymmetric case is analyzed. The public principal cares about her partially owned firms' profitability because it benefits from their profits via e.g., dividends. Moreover, it is concerned with W^l. Taking social welfare into account appears to be a natural assumption, if we consider a government which cares about being reelected given that voters can be influenced by creating a higher social standard.[13]

For a partially public firm, the wage function changes to

$$w_i^l = d_i^l + b_i^l \left(c - c_i^l \right), \tag{2.8}$$

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[12] O^l contains all n firms in the symmetric case, whereas it 'only' contains half of the firms, $n/2$, in the asymmetric case.

[13] Maximization of social welfare is a standard assumption for a public principal's objective (see e.g., De Fraja, 1993, Matsumura, 1998, Francois, 2000, and Corneo and Rob, 2003). Our specification of the government's (linear) objective function is rather based on Grossman & Helpman (1994). In their setup, the government values political contributions made by (sector specific) lobby groups in addition to social welfare.

where we assume that $d_i^l = s^l d_{G,i}^l + (1-s^l)d_{I,i}^l$ and $b_i^l = s^l b_{G,i}^l + (1-s^l)b_{I,i}^l$. Hence, the incentive scheme is a weighted average of each principal's optimal offer, where s^l and $(1-s^l)$ represent (exogenous) measures of the principals' bargaining power when designing the agents' contracts. Based on the assumption that G always holds equal shares in its firms, it follows that it designs a uniform contract characterized by (d_G^l, b_G^l).

Sequence of Events. In the first stage, the principals simultaneously maximize their expected utility given in (2.4) ((2.7)) by offering their agents a contract (d_i, b_i) $((d_i^l, b_i^l))$. In doing so, the principals explicitly take their agent's reservation utility into account (participation constraint) as well as the incentive compatibility constraint. Given that the agents accept the offer, they simultaneously choose effort levels maximizing (2.6). Note again that each agent's effort level is not contractible. In the third stage, uncertainty is resolved, and each firm learns its marginal cost, c_i (c_i^l), which is private information. Subsequently, the private principals simultaneously and non-cooperatively set prices, p_i (p_i^l). In the last stage, prices are common knowledge and consumers make their purchasing decisions.

To ensure that each firm i only competes with its immediate neighbors, we suppose that the sufficient condition $t < (2p_i - c_i)n^2$ holds.[14] Thereby, the possibility of market monopolization by any firm can be neglected. Moreover, we have to make sure that a unique market-sharing equilibrium exists. Therefore, we invoke the following assumptions.

Assumption 2.1a. *In the benchmark case and in the symmetric case, $t > n/2\left(1 + r\sigma^2\right)$ must hold for an equilibrium to exist.*

Assumption 2.1b. *In the asymmetric case, $t > n\left(4s^{AC} + 9\right)/18\left(1 + s^{AC}\right)\left(1 + r\sigma^2\right)$ must hold for an equilibrium to exist.*

To avoid too large random cost differences, we have to restrict the variance of θ_i to be sufficiently small:[15]

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[14] The sufficient condition is based on the first derivative of firm i's profit given that one of its rival firms, say firm $i+1$, is not active in the market: $\frac{\partial \pi_i}{\partial p_i}\big|_{p_{i+1}=0} < 0$. Applying simple algebra, this condition can be rewritten as $t < (2p_i - c_i)n^2$.

Assumption 2.2. $\sigma^2 < t^2/3n^4$.

We explicitly take assumptions 2.1a to 2.2 into account by allowing only for solutions if the parameters are within the feasible regions. Moreover, we focus on non-negative managerial incentives throughout the entire analysis.[16]

The game is solved via backward induction looking for subgame perfect Bayesian-Nash equilibria. We begin our analysis with he benchmark case where firms are entirely private, i.e., $s^l = 0$ holds. Then, we focus on partially private firms and derive the equilibria for both cases of PPO. Finally, we examine the effects of PPO on managerial incentives.

2.4 Entirely Private Firms

Our benchmark case corresponds to Raith's (2003) analysis with an exogenous market structure. Given consumer demand in (2.3), principals simultaneously set prices, p_i, to maximize profits presented in (2.4). The first order condition is

$$p_i = \frac{t}{2n^2} + \frac{c_i + E(p_j)}{2},$$

where $E(p_j)$ denotes the expected value of the rivals' price. Note that, at this stage of the game, I_i does not know her rivals' price due to private information. Making use of the symmetry specification, which is based on $\theta_i \sim N(0, \sigma^2) \forall i$ as well as on identical objectives, we know that in equilibrium $E(p_i) = E(p) \forall i$, where $E(p) = t/n^2 + E(c)$ with $E(c)$ denoting expected marginal costs in the market. Hence, equilibrium demand and equilibrium prices are given by

$$p_i = \frac{t}{n^2} + \frac{c_i + E(c)}{2} \text{ and } D_i = \frac{1}{n} + \frac{n(E(c) - c_i)}{2t}. \tag{2.9}$$

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[15] As in Raith (2003), a confidence interval of $[0 - 2\sqrt{3}\sigma; 0 + 2\sqrt{3}\sigma]$ is supposed which contains $99,94$ per cent of all possible cost realizations, c_i. Hence, the probability that c_i deviates from its mean (given by $c - e_i$) by more than $2\sqrt{3}\sigma$ is below 0.1 per cent.

[16] Whereas, by Assumption 2.1a, managerial incentives in the benchmark case and in the symmetric case are always positive, we need to impose additional requirements for the asymmetric case. A more detailed argumentation is offered in the Proof of Proposition 2.3 (see the Appendix).

Both equilibrium values depend on firm i's realized marginal costs, c_i, and on the rivals'
expected costs, $E(c)$, which are identical for all firms in the market.

In the contracting phase, uncertainty prevails so that both agents and principals rely on
expectations with respect to their own marginal costs. At stage two, agents simultaneously
choose their optimal effort levels given the incentive scheme in (2.5). Maximization of the
certainty equivalent derived from (2.6) leads to the following lemma.[17]

Lemma 2.1. *Each agent's optimal effort level is given by* $e_i^* = b_i$.

Lemma 2.1 demonstrates that there is a direct link between the agents' optimal effort
choice and the managerial incentive set by I_i. This is a standard result of moral hazard
models where $e_i^* = b_i$ represents the principal's incentive compatibility constraint.

At the initial stage of the game, principals offer their respective agents a contract,
(d_i, b_i), without being able to monitor their agents effort. In doing so, each principal faces
the following optimization problem

$$\underset{d_i, b_i}{Max} E(\pi_i) = (p_i(e_i^*, E(c)) - E(c_i)) D_i(e_i^*, E(c)) - (d_i + b_i e_i^*) - F \qquad (2.10)$$

$$s.t. \ e_i^* = b_i \text{ and } u_i \geq 0,$$

where the participation constraint becomes binding, i.e., $u_i = 0$ holds. The expression in
(2.10) says that every I_i maximizes her expected profit explicitly taking into account that
her agent realizes at least her reservation utility and is provided with the incentive to choose
her effort level optimally. Solving (2.10) and imposing symmetry, i.e., $b_i = b \forall i$, leads to the
following proposition.

Proposition 2.1. *Given that firms are entirely private, managerial incentives are*

$$b^* = \frac{1}{n\gamma}$$

in equilibrium, where $\gamma = (1 + r\sigma^2)$.

The equilibrium incentive does not depend on the differentiation parameter, t. It is
rather shaped by the (exogenous) number of firms in the market, n, and the agents' risk

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[17] All proofs are provided in the Appendix.

aversion reflected by γ. It is worthwhile to note that managerial incentives decrease in equilibrium when the number of firms marginally increases. With exogenous market structure, an increase in n can be interpreted as a decrease in market size. One implication is that I_i gives her agent stronger (weaker) incentives to reduce marginal costs when the market is declining (growing). Furthermore, it can be immediately checked that risk measured by σ^2 has a negative impact on equilibrium incentives.

In the next section, we shift our focus to firms which are partially public. Compared with our benchmark case, we ask how managerial incentives are affected when the ownership structure changes such that the government G becomes a minority shareholder with limited control.

2.5 Partially Public Firms

2.5.1 Equilibrium Analysis

Symmetric case. We begin our analysis with the symmetric case (SC) where G partially and symmetrically owns all firms in the market. Prices are continued to be set by I_i in the fourth stage of the game; i.e., the first order condition fulfills $p_i^{SC}\left(c_i^{SC}, E(p_j^{SC})\right) = \arg\max \pi_i^{SC}\left(p_i^{SC}, c_i^{SC}, E(p_j^{SC})\right)$. Under symmetry, which implies $E(p_i^{SC}) = E(p^{SC})\forall i$, we get the following expression for the equilibrium prices and the equilibrium demand, respectively,

$$p_i^{SC} = \frac{t}{n^2} + \frac{c_i^{SC} + E\left(c^{SC}\right)}{2} \text{ and } D_i^{SC} = \frac{1}{n} + \frac{n\left(E\left(c^{SC}\right) - c_i^{SC}\right)}{2t}. \qquad (2.11)$$

As before, in the benchmark case, the equilibrium values depend on each firm's own realized marginal costs, c_i^{SC}, and on the expected marginal costs in the market, $E(c^{SC})$. Note that $c_i \neq c_i^{SC}$.[18]

---

[18] Although the distribution of the random variable θ_i is identical for all firms, we have $c_i \neq c_i^{SC}$ which implies $E(c) \neq E(c^{SC})$. The reason is that, unlike in the benchmark case, G, who has a different objective than I_i, appears as a second principal, and thereby partially affects the incentive scheme.

In the second stage, agents simultaneously choose effort levels given (2.8). Using the same procedure as in Lemma 2.1, agent i's optimal effort choice becomes $e_i^{SC} = b_i^{SC}$. Principal I_i faces the same problem presented in (2.10) when designing the contract $(b_{I,i}^{SC}, d_{I,i}^{SC})$. In contrast to that, G offers (d_G^{SC}, b_G^{SC}) maximizing (2.7) subject to both the incentive constraint and the participation constraint. In equilibrium, managerial incentives are calculated based on $b_i^{SC} = s^{SC} b_G^{SC} + (1 - s^{SC}) b_{I,i}^{SC}$. Imposing symmetry, i.e., $b_i^{SC} = b^{SC} \forall i$, we obtain the following result.

Proposition 2.2. *In the symmetric case of PPO, managerial incentives are given by*

$$b^{SC} = \frac{4\gamma \left(1 + \frac{1}{2} s^{SC} - \left(s^{SC}\right)^2\right) - s^{SC} n}{n \left(1 + s^{SC}\right) \gamma \left[2t\gamma - s^{SC} n\right]}$$

in equilibrium, where $\gamma = \left(1 + r\sigma^2\right)$. Furthermore, $\partial b^{SC} / \partial s^{SC} < 0$ always holds.

Proposition 2.2 highlights that an equal governmental minority share in all n firms reduces managerial incentives when s^{SC} is increased. That is, the higher G's share, the lower managerial incentives in equilibrium. The reason can be found in G's objective function. Although G accounts for social welfare, W^{SC}, it puts relatively more weight on all firms' profitability which induces G to offer lower incentives than I_i. In addition, the fact that G partially owns all firms in the market eliminates any strategic behavior when it decides on its individual offer, b_G^{SC}. Hence, it is straightforward that the managerial incentive finally given to the agent decreases with increasing s^{SC}.

Asymmetric case. We now derive the equilibrium incentives for the asymmetric case (AC). The first order conditions as of stage four satisfy

$$p_i^{AC} = \frac{t}{2n^2} + \frac{c_i^{AC} + E(p_j^{AC})}{2},$$

where symmetry cannot be imposed, since firm i's immediate neighbors differ from i in terms of ownership structure, i.e., $E(p_i^{AC}) \neq E(p_j^{AC})$. Put another way, if firm i is private (partially public), then both immediate neighbors j are partially public (private). Hence, immediate competitors are asymmetric which necessitates a solution procedure accounting

for asymmetric oligopolies with private information (see Basar and Ho, 1974).[19] Solving simultaneously gives the following equilibrium prices and equilibrium demand

$$p_i^{AC} = \frac{t}{n^2} + \frac{3c_i^{AC} + E\left(c_i^{AC}\right) + 2E\left(c_j^{AC}\right)}{6} \text{ and } D_i^{SC} = \frac{1}{n} + \frac{n\left(E\left(c_i^{AC}\right) - 3c_i^{AC} + 2E(c_j^{AC})\right)}{t}.$$

(2.12)

Note that the asymmetry arises from different incentive schemes which are due to I_i's and G's differing objectives. All other things are kept equal. Firm i's equilibrium values in (2.12) do not solely depend on its own realized marginal costs, c_i^{AC}, and the rivals' expected marginal costs, $E(c_j^{AC})$, but also on the expectation of its own marginal costs, $E(c_i^{AC})$.

Given agents' optimal effort choices, $e_i^{AC} = b_i^{AC}$, the incentive schemes are designed in the first stage of the game based on $b_i^{AC} = s^{AC} b_G^{AC} + (1 - s^{AC}) b_{I,i}^{AC}$ and b_j^{AC} maximizing (2.10), respectively. Say firm i is partially public, while its immediate competitors j are entirely private. Then the equilibrium is presented as follows.

Proposition 2.3. *In the asymmetric case of PPO, firm i's and firm j's equilibrium incentives are given by*

$$b_i^{AC} = \frac{1}{18} \frac{243\gamma^2 t^2 \left(\frac{4}{3} + s^{AC}\right) - 180\gamma nt \left(\frac{17}{10} + s^{AC}\right) + 8n^2 \left(9 + s^{AC}\right)}{\left[27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right)\right]\gamma n},$$

and

$$b_j^{AC} = \frac{1}{18} \frac{324\gamma^2 t^2 \left(1 + s^{AC}\right) - 198\gamma nt \left(\frac{17}{11} + s^{AC}\right) + 8n^2 \left(9 + s^{AC}\right)}{\left[27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right)\right]\gamma n},$$

where $\gamma = \left(1 + r\sigma^2\right)$, and $b_i^{AC} = b_j^{AC} = 2/3n\gamma$ if $s^{AC} = 0$. Firm j gives her agent stronger (weaker) incentives to reduce marginal costs than firm i if $t > t^H$ ($t < t_D$). Furthermore, given $s^{AC} > 1/4$, $\partial b_i^{AC}/\partial s^{AC} > 0$ holds whenever $\bar{t} < t < \bar{\bar{t}}$, while $\partial b_i^{AC}/\partial s^{AC} < 0$ holds whenever $t < \bar{t}$ or $t > \bar{\bar{t}}$. Given $s^{AC} < 1/4$, $\partial b_i^{AC}/\partial s^{AC} > 0$ ($\partial b_i^{AC}/\partial s^{AC} < 0$) holds whenever $t < \bar{\bar{t}}$ ($t > \bar{\bar{t}}$). The same is true for $\partial b_j^{AC}/\partial s^{AC}$.

It is shown that the private firm j induces its manager to exert more effort in equilibrium than its partially public competitor i if competition is sufficiently low, i.e., $t > t^H$ holds.

---

[19] See also Sakai (1985) who examines the value of information in a Cournot duopoly based on the procedure proposed by Basar and Ho (1974). Thereby, the case of private information with asymmetric oligopolies is also analyzed.

The opposite is true for $t < t_D$. It is surprising that partially public firms impose stronger incentives on their agents than private firms when product market competition is sufficiently fierce. However, a case is found for which PPO results in stronger managerial incentives than private ownership, i.e., $b_i^{AC} > b_j^{AC}$ holds. Moreover, we demonstrate that the equilibrium incentives in the asymmetric case are not monotonically decreasing in G's minority share s^{AC}. Given a relatively large initial public share, i.e., $s^{AC} > 1/4$, for intermediate levels of competition ($\bar{t} < t < \bar{\bar{t}}$) both equilibrium incentives increase if s^{AC} is marginally increased. If the initial public share is relatively small, i.e., $s^{AC} < 1/4$, then the level of competition has to be sufficiently high ($t < \bar{\bar{t}}$) for managerial incentives to increase when s^{AC} is marginally increased. Under these conditions, expanded governmental ownership induces all firms in the market to give their managers stronger incentives to increase productive efficiency.

2.5.2   The Effects of Partial Public Ownership

In this subsection, we analyze how a change in the firms' ownership structure affects managerial incentives. Therefore, we compare both cases of PPO with our benchmark case where all firms are entirely private. Note again that in the asymmetric case firm i is the partially public firm, and firm j is the private firm.

The following proposition presents our results.

Proposition 2.4. *Managerial Incentives are always lower in the symmetric case than in the benchmark case, i.e., $b^* > b^{SC}$ always holds. In the asymmetric case, the effects of PPO depend on the level of competition as follows:*
If $\tilde{t} < t < t_D$, then $b_i^{AC} > b^* > b_j^{AC}$ holds. If $t_H < t < \hat{t}$, then $b_j^{AC} > b^* > b_i^{AC}$ holds. Otherwise, managerial incentives are always higher in the benchmark case than in the asymmetric case.
Note that the following ordering holds $\tilde{t} < t_D < t_H < \hat{t}$.

Since G puts relatively more weight on its firms' profitability than on consumer surplus, it is less tempted to give its agents strong incentives to reduce marginal costs. Thereby, the fact that G symmetrically owns all firms in the market plays a crucial role. It strictly

prevents G from strategically inducing one of its managers to exert more effort because it would hurt the competitors which it also partially owns. It follows immediately that managerial incentives are always higher in the benchmark case compared with the symmetric case. The results in the asymmetric case depend on the level of competition. For relatively high levels of competition, i.e., $t < t_D$ holds, the partially public firm offers stronger incentives than any firm in the benchmark case if t is sufficiently high. At the same time, firms in the benchmark case always give their agents stronger incentives than any private firm in the asymmetric case. If, on the contrary, the level of competition is relatively low, i.e., $t > t_H$ holds, then the results are reversed. The firms in the benchmark case always offer higher incentives than the partially public firms in the asymmetric case. Compared with the private firms in the asymmetric case, managerial incentives are only lower in the benchmark case if t fulfills $t_H < t < \widehat{t}$. Otherwise, $b^* > b_j^{AC}$ always holds.

Proposition 2.4 highlights the idea that managerial incentives are not necessarily larger when all firms are fully private. Thereby, depending on the level of t, PPO induces either the partially public firms or their private competitors to offer stronger managerial incentives than any firm in the benchmark case. We conclude that the level of competition has to be explicitly taken into account when evaluating which ownership structure is accompanied by the strongest managerial incentives. This is especially supported by the fact that in most markets, where mixed ownership structures prevail, partially public firms compete with private firms as in e.g., the German electricity market.

Our findings in Proposition 2.4 can be directly transferred to the firms' (expected) productive efficiency. For that purpose, note that $E(c^*) = c - b^*$, $E(c^{SC}) = c - b^{SC}$ and $E(c_{i/j}^{AC}) = c - b_{i/j}^{AC}$ hold in equilibrium. Corollary 2.1 summarizes our results.

Corollary 2.1. *Productive efficiency is always higher in the benchmark case than in the symmetric case. In the asymmetric case, the results depend on the level of competition as follows:*

Partially public firms are more efficient than any firm in the benchmark case whenever $\widetilde{t} < t < t_D$. Private firms are more efficient than any firm in the benchmark case whenever

$t_H < t < \hat{t}$. *Otherwise, productive efficiency is higher in the benchmark case.*

Furthermore, it is straightforward to extend our findings to the level of expected equilibrium prices, since there is a direct link from managerial incentives over productive efficiency to equilibrium prices. Therefore, it is worthwhile to recall that, in all three cases, equilibrium prices depend on the level of competition and the number of firms in the market, i.e., t/n^2, as well as on the own and the rivals' expected marginal costs. The results are correspondent to our findings on productive efficiency in Corollary 2.1 and are left to the reader to check.

When PPO is analyzed where the government has only limited control over its firms' decisions, then the general claim, which associates lower productive efficiency with public ownership, does not hold true. We demonstrate that, under certain conditions, public ownership induces firms to give their managers stronger incentives to reduce marginal costs than entirely private ownership structures. The bottom line is that there is no per se rule for evaluating which ownership structure is superior in terms of managerial incentives, and thus creates higher productive efficiency. The level of competition measured by the product differentiation parameter is rather crucial, and therefore, it has to be explicitly taken into account.

2.6 Consumer Protection and Partial Public Ownership

We now consider a government which is rather concerned with consumer protection than with social welfare. For that purpose, we introduce consumer protection by simply modifying the government's objective function which is now given by

$$\overline{U}^l = s^l \overline{\Pi}^l + \overline{CS}^l. \tag{2.13}$$

In contrast to the objective function used before in (2.7), we postulate now that G does not care about social welfare, but rather about consumer surplus, $\overline{CS}^l$, in addition to its firms' profits.

We do not derive the equilibria resulting from the modification of G's objective function.

The equilibrium analysis is rather left to the Appendix. Instead, we directly compare both cases of PPO with the benchmark case. Note again that firm i is the partially public firm, whereas firm j is the private firm. Our results are presented in the following proposition.

Proposition 2.5. *Managerial Incentives are always higher in the symmetric case than in the benchmark case, i.e., $\bar{b}^{SC} > b^*$ always holds. In the asymmetric case, the effect of PPO depends on the level of t and s^{AC} as follows:*

a) Given $s^{AC} < s_1$, the ordering $\bar{b}_i^{AC} > b^* > \bar{b}_j^{AC}$ holds if $t > \bar{t}_H$. Otherwise, i.e., if $t < \bar{t}_D$, we get $b^* > \bar{b}_j^{AC} > \bar{b}_i^{AC}$.

b) Given $s^{AC} > s_2$, the ordering $\bar{b}_i^{AC} > b^* > \bar{b}_j^{AC}$ holds if $t > \bar{t}_H$. If, on the contrary, $t < \bar{t}_L$, then $\bar{b}_j^{AC} > b^* > \bar{b}_i^{AC}$.

Note that the following ordering holds $\bar{t}_D < \bar{t}_L < \bar{t}_H$.

When G cares about consumer surplus instead of social welfare, then the impact of PPO on managerial incentives changes. We find that managerial incentives in the symmetric case are strictly higher than in the benchmark case. This result is not surprising, since G is pushed to provide its agents with stronger incentives in order to increase consumer surplus. However, it should be noted that the difference $b^{SC} - b^*$, though positive, is monotonically decreasing in s^{SC}. Thereby, an increased public share implies that G puts more weight on its firms' profits, and thus is less tempted to push its agents to lower prices. Compared with our analysis in the previous section, we find again that PPO may induce either firm i or firm j to give their agents stronger incentives than any firm in the benchmark case. Nevertheless, the impact of competition is reversed when G's primary concern is consumer protection. Whereas firm i has only offered stronger incentives when competition in the product market was relatively fierce, it now offers stronger managerial incentives when the level of competition is relatively low. A similar reasoning holds for the private firm, j. Now, given $s^{AC} > s_2$, firm j offers its agent stronger incentives only if the level of competition is relatively high. However, for a relatively low public share ($s^{AC} < s_1$), firm j never gives its agent stronger incentives, irrespective of the level of competition.

While it appears to be rather plausible that consumer protection has a positive effect

on managerial incentives in the symmetric case, it is surprising that there is no substantial effect in the asymmetric case. Though in reversed order, we still observe that the effect of PPO depends on the level of competition. We conclude that consumer protection does not have a significant effect on managerial incentives when partially public firms compete with private firms. It should be noted that this case seems to be predominant in markets where firms with mixed ownership structures compete for consumers. While some firms are partially public, their competitors are rather entirely private. Our examples, comprising the electricity market, the telecommunications market, and the car market in Germany, confirm this view. Hence, irrespective of the government's objective, we suggest to explicitly consider the level of competition when evaluating managerial incentives in markets with mixed ownership structures.

2.7 Discussion

The wage function assumed in our setup is linear and continuous in (expected) productive efficiency. Moreover, we presume that both types of principals, I_i and G, use this specification for rewarding their agents. It could be claimed that especially the public principal uses some other form of incentive scheme which is closer to directly push the agent to enhance welfare or consumer surplus. Our model does not account for such instances. But it considers differences between private shareholders and the government by assuming different objectives which, finally, affect the incentive schemes. This seems to be a good compromise, although the presumed wage function remains identical for both principals. However, it should be noted that it is at least very difficult to contract upon social welfare and consumer surplus, respectively. This view in turn favors our assumption that both principals use the same wage function to incentivize their agents.

Moreover, it can be claimed that productive efficiency gains are not verifiable, and thus the principals cannot contract upon. In this case, we could make use of output measures such as profits or sales. Alternatively, we could compare different types of performance measures with regards to their effects on managerial incentives. Such an analysis is performed by

e.g., Raith (2008) who compares the effects of "input" measures and "output" measures when agents have specific knowledge of the output levels. For now, we neglect the effects of different types of incentives schemes, and leave this task for further research.

For the sake of simplicity, we assume that, provided PPO, managerial incentives are designed as the weighted sum of each principal's individual offer, i.e., $b^l = s^l b_G^l + (1 - s^l) b_{I,i}^l$. Thereby, the respective shares, s^l and $(1 - s^l)$, mirror the exogenous bargaining power parameters. It could be claimed that the bargaining process should have been explicitly modelled as in e.g., Shleifer and Vishny (1994), instead of treating it as exogenous. This property of our approach could be classified as a shortcoming. However, we do not focus on the process how the government and the private investor, respectively, create and exert their influence on the firm's decision. We rather focus on the consequences of a governmental minority share on managerial incentives which can vary within the (open) interval of $(0; 1/2)$. Therefore, we believe that it is adequate to treat the governmental influence on the firms' personnel decisions as exogenous.

We do not account for regulation, although it is usually a feature of markets exhibiting mixed ownership structures (see e.g., Cambini and Spiegel, 2011). One extension could be, therefore, to introduce price regulation by an regulatory authority and examine the interplay between regulation, ownership structure, and managerial incentives.

Finally, it should be noted that our model could be extended by adopting a framework where consumers continue to make discrete choices, but all differentiated firms compete with each other, and not solely immediate neighbors (see Chen and Riordan, 2008). However, we do not account for 'multilateral competition' with differentiated products, and rather leave this task for further research.

2.8   Conclusion

In this chapter, we analyze the effects of PPO on managerial incentives to increase productive efficiency. In contrast to existing works, we explicitly consider competition in the product market by introducing an oligopolistic environment à la Vickrey-Salop. Through-

out the entire analysis, we assume that the government is a minority shareholder who is only able to exert limited control over her firms', i.e., she decides on the contractual design, but has no control over the pricing decision. We demonstrated that PPO always triggers agents to exert less effort in equilibrium when the public principal symmetrically owns all firms in the market and cares about social welfare. This negative effect of PPO is reversed if the government's primary goal is consumer protection. The result appears to be straightforward, since the government is always tempted to offer its agents strong incentives to decrease prices, and thereby to increase consumer surplus. So far, a policy implication could be not to permit PPO if the government owns symmetric minority shares of all competitors in the market, unless it does not pursue consumer protection in the first place.

However, if the public principal only owns half of the firms in the market, so that a partially private firm always competes with a private firm and vice versa, the effect of PPO crucially depends on the level of competition. Keep in mind that we use the degree of horizontal product differentiation (product substitutability) as the measure of competition. More precisely, PPO induces either partially public firms or their private competitors to give their managers stronger incentives to reduce marginal costs than any firm in the benchmark case. Though in reverse order, this result essentially holds even if the government's objective is to maximize consumer surplus rather than social welfare. We take this result to claim that there is no per se rule in evaluating the effects of PPO on productive efficiency. Rather, the level of competition has to be explicitly taken into account, irrespective of the government's primary objective.

Appendix

In this Appendix we provide the omitted proofs.

Proof of Lemma 2.1. We apply the μ-σ-principle for the CARA utility function with a normally and independently distributed random variable θ_i. Then agent i's expected utility, $E(u_i)$, can be calculated as $E(u_i) = u_i(\mu_i - (1/2)r\sigma_i^2)$, where μ_i and σ_i^2 denote the expected value of w_i and the variance of w_i, respectively. This approach significantly simplifies the derivation of the certainty equivalent.

The agents simultaneously choose effort levels to maximize their expected utility which is identical with maximizing their certainty equivalent given by

$$C_i = d_i + b_i e_i - \frac{1}{2}e_i^2 - \frac{1}{2}rb_i^2\sigma^2, \tag{2.14}$$

where $(1/2)rb_i^2\sigma^2$ represents agent i's risk premium. Maximizing (2.14) over e_i gives an optimal effort level of $e_i^* = b_i$. It can be immediately checked that the structure of the optimal effort level holds irrespective of which of the three cases is analyzed. However, one should keep in mind that b_i differs, dependent on which ownership type is supposed.

This proves our result in Lemma 2.1.

Proof of Proposition 2.1. In the fourth stage of the game, principals choose prices to maximize their profits given by

$$\pi_i = (p_i - c_i)(\frac{1}{n} + \frac{n\left(E(p_j) - p_i\right)}{t}) - w_i - F$$

which yields equilibrium prices presented by (2.9). In the first stage, principals simultaneously maximize their expected profits subject to the participation constraint and incentive constraint (see (2.10)). Using Lemma 2.1, we can express principal i's expected profit by

$$E(\pi_i) = \frac{\left[n^2\left(E(c) + b_i - c\right) + 2t\right]^2}{n^3 t} + \frac{n\sigma^2}{4t} - (d_i + b_i^2) - F.$$

Maximization yields the following first order condition

$$b_i^* = \frac{n^2\left(E(c) - c\right) + 2t}{n\left[2t\left(1 + r\sigma^2\right) - n\right]}.$$

Imposing symmetry, i.e., $b_i = b_j = b^*$ for $i \neq j$, and using $E(c) = c - b$, we can calculate the equilibrium values b^* and $E(\pi^*)$ presented in Proposition 2.1. In addition, we ensure with Assumption 2.1a that the symmetric equilibrium is unique and that it exists. However, it can be immediately checked that the first derivative of b^* with respect to n, i.e.,

$$\frac{\partial b^*}{\partial n} = -\frac{1}{n^2 (1 + r\sigma^2)},$$

is strictly negative. The same is true for the marginal effect of σ^2 on b^* which is given by

$$\frac{\partial b^*}{\partial (\sigma^2)} = -\frac{r}{n (1 + r\sigma^2)^2}.$$

This completes the proof of Proposition 2.1.

Proof of Proposition 2.2. Since each firm's private principal I_i continues to have exclusive control over the pricing decision despite G's minority share in firm i, prices are set by maximizing

$$\pi_i^{SC} = (p_i^{SC} - c_i^{SC})(\frac{1}{n} + \frac{n \left(E(p_j^{SC}) - p_i^{SC} \right)}{t}) - w_i^{SC} - F.$$

The first order condition is given by

$$p_i^{SC} = \frac{t}{2n^2} + \frac{c_i^{SC} + E(p_j^{SC})}{2}.$$

Making use of symmetry gives the equilibrium values presented in (2.11). Based on the following optimization problem

$$
\begin{aligned}
\underset{d_{I,i}^l, b_{I,i}^l}{Max}\, E\left(\pi_i^l\right) &= (p_i^l(e_i^l, E(c^l)) - E(c_i^l))D_i^l(e_i^l, E(c^l)) - (d_{I,i}^l + b_{I,i}^l e_i^l) - F \quad (2.15) \\
s.t.\ e_i^l &= b_{I,i}^l \text{ and } u_i = 0,
\end{aligned}
$$

firm i's private principal, I_i, makes her offer in the first stage of the game which is given by

$$b_{I,i}^{SC} = \frac{2t + n^2 \left(E(c^{SC}) - c \right)}{n (2t + 2tr\sigma^2 - n)}.$$

Due to its objective, given in (2.7), G faces a different optimization problem presented by

$$
\begin{aligned}
\underset{d_G^l, b_G^l}{Max}\, U^l &= s^l \Pi^l + W^l \quad (2.16) \\
s.t.\ e_i^l &= b_{G,i}^l \text{ and } u_i = 0,
\end{aligned}
$$

where expected consumer surplus as of stage 1 is given by

$$
\begin{aligned}
CS^{SC} &= n \left[\int_0^{y^{SC}} v - p_i^{SC} - tx^2 dx + \int_{y^{SC}}^{1/n} v - p_j^{SC} - t\left(1/n - x\right)^2 dx \right] \\
&= n \left[\frac{\left(b^{SC} + v - c\right)}{n} - \frac{52t}{48n^3} - \frac{n\sigma^2}{16t} \right].
\end{aligned}
$$

Note again that G has private information about all n firms' marginal costs because it partially owns all firms in the market. Maximizing (2.16) leads to the following offer

$$
b_G^{SC} = \frac{1}{2n\left(1 + s^{SC}\right)\gamma}.
$$

The equilibrium incentive can now be calculated as

$$
b_i^{SC} = s^{SC} b_G^{SC} + \left(1 - s^{SC}\right) b_{I,i}^{SC}.
$$

Making use of symmetry where $E(c^{SC}) = c - b^{SC}$, with $e^{SC} = b^{SC}$, we get the equilibrium expression shown in Proposition 2.2. Setting $s^{SC} = 0$, it can be immediately checked that $b^{SC} = b^*$. Moreover, it can be checked that the first derivative of b^{SC} with respect to s^{SC},

$$
\frac{\partial b^{SC}}{\partial s^{SC}} = \frac{1}{2} \frac{\left[4\left(2s^{SC} + \frac{1}{2} + \left(s^{SC}\right)^2\right)\gamma t + \left(s^{SC}\right)^2 n\right]\left(n - 2t\gamma\right)}{\left(1 + s^{SC}\right)^2 \left(ns^{SC}n - 2t\gamma\right)^2 \gamma},
$$

is always negative by Assumption 2.1a.

This completes the proof of Proposition 2.2.

Proof of Proposition 2.3. The pricing decisions of all firms are made by the private principals whose objective function is

$$
\pi_i^{AC} = (p_i^{AC} - c_i^{AC})(\frac{1}{n} + \frac{n\left(E(p_j^{AC}) - p_i^{AC}\right)}{t}) - w_i^{AC} - F. \tag{2.17}
$$

Maximization of (2.17) yields the first order conditions given by

$$
p_i^{AC} = \frac{t}{2n^2} + \frac{c_i^{AC} + E(p_j^{AC})}{2}.
$$

Based on the procedure proposed by Basar and Ho (1974), we calculate the rivals' expected prices as

$$
E(p_j^{AC}) = \frac{t}{2n^2} + \frac{c_j^{AC} + E(p_i^{AC})}{2}, \tag{2.18}
$$

where firm i's expected price, $E(p_i^{AC})$, is

$$E(p_i^{AC}) = \frac{t}{2n^2} + \frac{E(c_i^{AC}) + E(p_j^{AC})}{2}.$$ (2.19)

Inserting successively (2.18) and (2.19) into the first order condition, we get each firm's equilibrium price and equilibrium demand, respectively, presented in (2.12).

According to Lemma 2.1, the agents' optimal effort choice satisfies $e_i^{AC} = b_i^{AC}$. At the initial stage of the game, all principals simultaneously choose the incentive schemes for their respective agents. While the partially private firm's managerial incentive is constructed based on both (2.16) and (2.15), firm j's managerial incentive is solely based on (2.15). Thereby, expected consumer surplus used for G's optimization problem presented in (2.16) is calculated as

$$
\begin{aligned}
CS^{AC} &= n \left[\int_0^{y^{AC}} v - p_i^{AC} - tx^2 dx + \int_{y^{AC}}^{1/n} v - p_j^{AC} - t\left(1/n - x\right)^2 dx \right] \\
&= \frac{1}{36} \frac{E(c_j^{AC}) \left[E(c_j^{AC}) - 2\left[\left(c - b_{G,i}^{AC}\right) + 9t\right] \right] + n^2 \left(c - b_{G,i}^{AC}\right)^2}{t} \\
&\quad - \frac{1}{2}\left(c - b_{G,i}^{AC} - 2v\right) - \frac{13t}{12n^2} + \frac{n^2\sigma^2}{16t}.
\end{aligned}
$$

It is important to note that $CS^{AC} \neq CS^{SC}$ which is explained by G 'only' knowing half of the firms' (expected) marginal costs, but not all firms' marginal costs as in the symmetric case.

However, the individual offers of G and I_i are given by

$$
\begin{aligned}
b_{G,i}^{AC} &= \frac{1}{4} \frac{t\left(9 + 12s^{AC}\right) - 4n^2\left(\frac{9}{4} + s^{AC}\right) b_j^{AC}}{n\left[\frac{9}{2}t\gamma\left(1 + s^{AC}\right) - n\left(\frac{9}{4} + s^{AC}\right)\right]} \quad \text{and} \\
b_{I,i}^{AC} &= \frac{6t - 2n^2 b_j^{AC}}{n\left(9t + 9tr\sigma^2 - 2n\right)}.
\end{aligned}
$$

Note that $E(c_j) = c - b_j^{AC}$ with $e_j^{AC} = b_j^{AC}$. Since the incentive scheme is calculated as the weighted average of each principal's individual offer where s^{AC} is used as the weight (see (2.8)), the managerial incentive of firm i is finally given by

$$b_i^{AC}\left(b_j^{AC}\right) = s^{AC} b_{G,i}^{AC}\left(b_j^{AC}\right) + (1 - s^{AC}) b_{I,i}^{AC}\left(b_j^{AC}\right).$$

The entirely private firm, j, is exclusively controlled by one private principal, I_j, who offers her manager a piece rate given by

$$b_j^{AC}\left(b_i^{AC}\right) = b_{I,j}^{AC}\left(b_i^{AC}\right) = \frac{6t - 2n^2 b_i^{AC}}{n\left(9t + 9tr\sigma^2 - 2n\right)}.$$

It is easily seen that managerial incentives are strategic substitutes, i.e., $\partial b_i^{AC}(b_j^{AC})/\partial b_j^{AC} < 0$ and $\partial b_j^{AC}\left(b_i^{AC}\right)/\partial b_i^{AC} < 0$ hold. Solving $b_i^{AC}\left(b_j^{AC}\right)$ and $b_j^{AC}\left(b_i^{AC}\right)$ simultaneously, we get the equilibrium values presented in Proposition 2.3. In addition, setting $s^{AC} = 0$, it is easily shown that both firms, i and j, give their agents identical incentives to reduce marginal costs, i.e., $b_i^{AC} = b_j^{AC} = 2/3n\gamma$.

In contrast to the previous cases, it is not guaranteed neither by definition or by Assumption 2.1b that managerial incentives are non-negative in equilibrium. Therefore, we need to invoke additional requirements which we explicitly take into consideration throughout the entire analysis. For the equilibrium incentive of the partially private firm i the transport cost parameter, t, must satisfy $t \leq t_L$ or $t \geq t_H$, where $t_H > t_L$. The threshold values are given by

$$t_L = \frac{1}{36}\frac{\left(17 + 12s^{AC} + \sqrt{1 + 72s^{AC} + 96(s^{AC})^2}\right)n}{(1 + s^{AC})\gamma} \quad \text{and} \tag{2.20}$$

$$t_H = \frac{1}{9}\frac{\left(17 + 10s^{AC} + \sqrt{1 + 92s^{AC} + 76(s^{AC})^2}\right)n}{(4 + 3s^{AC})\gamma}. \tag{2.21}$$

If the transport cost parameter is such that $t \leq t_L$ or $t \geq t_H$ holds, then b_i^{AC} is always non-negative in equilibrium. The conditions for the equilibrium incentive of the private firm to be non-negative are $t \leq t_D$ or $t \geq t_L$ with $t_L > t_D$, where t_D is given by

$$t_D = \frac{1}{36}\frac{\left(17 + 11s^{AC} + \sqrt{1 + 54s^{AC} + 89(s^{AC})^2}\right)n}{(1 + s^{AC})\gamma}. \tag{2.22}$$

Hence, the transport cost parameter, t, must satisfy $t < t_D$ or $t > t_H$ for both managerial incentives, b_i^{AC} and b_j^{AC}, to be non-negative in equilibrium, where $t_D < t_L < t_H$. For the remaining analysis, we solely consider situations in which both managerial incentives are non-negative in equilibrium.

In a next step, we compare b_i^{AC} and b_j^{AC} to determine which managerial incentive is larger in equilibrium. For this purpose, we define $\theta = b_j^{AC} - b_i^{AC}$ which can be calculated as

$$\theta = \frac{t s^{AC} \left(\frac{9}{2} t\gamma - n\right)}{\left[27\gamma^2 t^2 (1 + s^{AC}) - 18\gamma n t \left(\frac{17}{12} + s^{AC}\right) + n^2 (6 + s^{AC})\right] n}.$$

It can be immediately checked that, by Assumption 2.1b, the numerator is always positive. Turning to the denominator simple algebra shows that it has the following two zeros

$$
\begin{aligned}
t_L &= \frac{1}{36} \frac{\left[17 + 12 s^{AC} + \sqrt{1 + 72 s^{AC} + 96 (s^{AC})^2}\right] n}{(1 + s^{AC})\gamma} \quad \text{and} \\
t_L' &= \frac{1}{36} \frac{\left[17 + 12 s^{AC} - \sqrt{1 + 72 s^{AC} + 96 (s^{AC})^2}\right] n}{(1 + s^{AC})\gamma},
\end{aligned}
$$

where t_L' is irrelevant because it is always implied by concavity (Assumption 2.1b). It follows that the denominator is positive (negative) if $t > t_L$ ($t < t_L$). Non-negativity (ensuring that both b_i^{AC} and b_j^{AC} are non-negative) requires that $t \le t_D$ or $t \ge t_H$ so that we conclude that the denominator is always positive (negative) if $t > t_H$ ($t < t_D$). Our result in Proposition 2.3 follows immediately.

Finally, we demonstrate that the marginal effects of s^{AC} on b_i^{AC} and b_j^{AC} depend on both the level of t and the level of s^{AC}. We begin with the inspection of the marginal effect of s^{AC} on b_i^{AC} which is given by

$$\frac{\partial b_i^{AC}}{\partial s^{AC}} = -\frac{4}{3} \frac{\left(n - \frac{9}{4} t\gamma\right) \left(n - \frac{9}{2} t\gamma\right)^2 (n - 2 t\gamma)}{\left[27\gamma^2 t^2 (1 + s^{AC}) - 18\gamma n t \left(\frac{17}{12} + s^{AC}\right) + n^2 (6 + s^{AC})\right]^2 \gamma n}.$$

While the denominator is always positive, we focus on the numerator's sign. The following critical values can be calculated

$$\bar{t} = \frac{4n}{9\gamma} \quad \text{and} \quad \bar{\bar{t}} = \frac{n}{2\gamma},$$

for which $(n - 9/4 t\gamma) (n - 9/2 t\gamma)^2 (n - 2 t\gamma) = 0$. Checking with concavity (Assumption 2.1b) it is revealed that $t > \bar{t}$ is only implied if $s^{AC} \le 1/4$, while $t > \bar{\bar{t}}$ is never implied. Thus, $\bar{t}$ is only relevant for $s^{AC} > 1/4$. Furthermore, it can be shown that the following ordering holds: $\bar{t} < \bar{\bar{t}} < t_D < t_L < t_H$. In other words, both critical values are feasible in the sense that $b_i^{AC} \ge 0$ and $b_j^{AC} \ge 0$ always hold in equilibrium. For $s^{AC} > 1/4$, both

critical values are relevant and the numerator is negative resulting in $\partial b_i^{AC}/\partial s^{AC} > 0$ if $\bar{t} < t < \bar{\bar{t}}$. If, otherwise, $t < \bar{t}$ or $t > \bar{\bar{t}}$, then the numerator is always positive leading to $\partial b_i^{AC}/\partial s^{AC} < 0$. For $s^{AC} < 1/4$, the only relevant critical value is $\bar{\bar{t}}$ where the numerator is positive (negative) if $t > \bar{\bar{t}}$ ($t < \bar{\bar{t}}$). The results in Proposition 2.3 follow immediately.

Performing the same procedure for the marginal effect of s^{AC} on b_j^{AC}, which is given by

$$\frac{\partial b_j^{AC}}{\partial s^{AC}} = -\frac{4}{3} \frac{\left(n - \frac{9}{4}t\gamma\right)\left(n - \frac{9}{2}t\gamma\right)(n - 2t\gamma)}{\left[27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right)\right]^2 \gamma n},$$

we find a third critical value of $\underline{t} = 2n/9\gamma$ in addition to $\bar{t}$ and $\bar{\bar{t}}$ for which the numerator equals zero. However, $\underline{t}$ is irrelevant because $t > \underline{t}$ always holds by Assumption 2.1b. Note that $\bar{t} < \bar{\bar{t}} < t_D < t_L < t_H$. Thus, for $\partial b_j^{AC}/\partial s^{AC}$ the same results hold as for $\partial b_i^{AC}/\partial s^{AC}$.

This completes the proof of Proposition 2.3.

Proof of Proposition 2.4. It is easily checked that the equilibrium incentives in the symmetric case are equal to those in the benchmark case if G's minority share is equal to zero, i.e., $b^{SC}(s^{SC} = 0) = b^* = 1/n\gamma$ holds. Moreover, we know from Proposition 2.2 that the managerial incentive in the symmetric case is decreasing when the governmental minority share increases, i.e., $\partial b^{SC}/\partial s^{SC} < 0$ holds. This suffices to prove that $b^* > b^{SC}$ holds for every $s^{SC} \in (0, 1/2)$.

In a second step, we demonstrate that whether or not managerial incentives are higher in the benchmark case than in the asymmetric case depends on the level of competition in the product market, t, as claimed in Proposition 2.4. We start with the partially private firm, i. Let the relevant measure be $\phi_i^{AC} = b^* - b_i^{AC}$. If $\phi_i^{AC} > 0$, then managerial incentives in the benchmark case are higher than in the asymmetric case for partially private firms. The opposite holds for $\phi_i^{AC} < 0$. More precisely, ϕ_i^{AC} is given by

$$\phi_i^{AC} = \frac{1}{18} \frac{243\gamma^2 t^2 \left(\frac{2}{3} + s^{AC}\right) - 144\gamma nt \left(\frac{17}{16} + s^{AC}\right) + 10n^2 \left(\frac{18}{15} + s^{AC}\right)}{\left[27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right)\right]\gamma n}. \tag{2.23}$$

Inspection of the denominator shows that there is only one admissible critical value for which $27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right) = 0$: it is given by t_L (see (2.20)). Hence, the denominator is positive (negative) if $t > t_H$ ($t < t_D$). Note again that it must

be that $t < t_D$ or $t > t_H$ to guarantee positive equilibrium incentives in the asymmetric case, i.e., $b_i^{AC} \geq 0$ and $b_j^{AC} \geq 0$ always hold in equilibrium.

Turning to the numerator, we find the following two critical values

$$\widetilde{t} = \frac{1}{36} \frac{n\left(17 + 16s^{AC} + \sqrt{1 + 32s^{AC} + 136(s^{AC})^2}\right)}{\left(1 + \frac{3}{2}s^{AC}\right)\gamma} \quad \text{and}$$

$$\widetilde{\widetilde{t}} = \frac{1}{36} \frac{n\left(17 + 16s^{AC} - \sqrt{1 + 32s^{AC} + 136(s^{AC})^2}\right)}{\left(1 + \frac{3}{2}s^{AC}\right)\gamma},$$

where $\widetilde{\widetilde{t}}$ is irrelevant because $t > \widetilde{\widetilde{t}}$ is always implied by Assumption 2.1a. The second zero, $\widetilde{t}$, is relevant and feasible since the following ordering holds: $\widetilde{t} < t_D < t_L < t_H$, i.e., non-negative equilibrium incentives are ensured. The numerator is positive (negative) if $t > \widetilde{t}$ ($t < \widetilde{t}$). The results in Proposition 2.4 follow immediately.

Finally, we analyze whether or not b^* is larger than b_j^{AC}. We define the relevant measure $\phi_j^{AC} = b^* - b_j^{AC}$ which is given by

$$\phi_j^{AC} = \frac{1}{18} \frac{162\gamma^2 t^2 \left(1 + s^{AC}\right) - 126\gamma nt \left(\frac{17}{14} + s^{AC}\right) + 10n^2 \left(\frac{18}{15} + s^{AC}\right)}{\left[27\gamma^2 t^2 \left(1 + s^{AC}\right) - 18\gamma nt \left(\frac{17}{12} + s^{AC}\right) + n^2 \left(6 + s^{AC}\right)\right]\gamma n}.$$

If $\phi_j^{AC} > 0$, then managerial incentives in the benchmark case are higher than in the asymmetric case for private firms. The opposite holds for $\phi_j^{AC} < 0$. We begin by examining the denominator. It is immediately seen that the denominator is identical with (2.23). It follows that there also exists only one admissible zero which is given by t_L. The denominator is positive (negative) if $t > t_L$ ($t < t_L$). Inspection of the numerator's sign reveals that there are two zeros given by

$$\widehat{t} = \frac{1}{36} \frac{n\left(17 + 14s^{AC} + \sqrt{1 + 108s^{AC} + 116(s^{AC})^2}\right)}{\left(1 + s^{AC}\right)\gamma} \quad \text{and}$$

$$\widehat{\widehat{t}} = \frac{1}{36} \frac{n\left(17 + 14s^{AC} - \sqrt{1 + 108s^{AC} + 116(s^{AC})^2}\right)}{\left(1 + s^{AC}\right)\gamma},$$

where $\widehat{\widehat{t}}$ is irrelevant since $t > \widehat{\widehat{t}}$ is always implied by Assumption 2.1a. The second zero, $\widehat{t}$, is relevant, and it is easily calculated that the following ordering holds: $t_D < t_L < t_H < \widehat{t}$, i.e., $\widehat{t}$ is feasible. The numerator is positive (negative) if $t > \widehat{t}$ ($t < \widehat{t}$). Our results in Proposition 2.4 follow immediately.

This completes the proof of Proposition 2.4.

Equilibrium analysis with consumer protection. The equilibrium incentives in the benchmark case do not change as a consequence of consumer protection, since G does not own any firm, i.e., all firms are private. Hence, the equilibrium incentives remain the same and are given in Proposition 2.1. However, consumer protection does affect equilibrium incentives in both cases of partial public ownership. We start with the symmetric case. Recall that consumer surplus is given by

$$
\begin{aligned}
CS^{SC} &= n \left[\int_0^{y^{SC}} v - p_i^{SC} - tx^2 dx + \int_{y^{SC}}^{1/n} v - p_j^{SC} - t\left(1/n - x\right)^2 dx \right] \\
&= n \left[\frac{\left(b^{SC} + v - c\right)}{n} - \frac{52t}{48n^3} - \frac{n\sigma^2}{16t} \right].
\end{aligned}
$$

The private principal and the public principal individually offer the following incentives

$$
b_{I,i}^{SC} = \frac{2t + n^2 \left(E(c^{SC}) - c\right)}{n \left(2t\gamma - n\right)} \quad \text{and}
$$

$$
b_G^{SC} = \frac{1}{2ns^{SC}\gamma}.
$$

The equilibrium incentive is derived based on $b_i^{SC} = s^{SC}b_G^{SC} + \left(1 - s^{SC}\right) b_{I,i}^{SC}$, where $E(c^{SC}) = c - b^{SC}$ with $e^{SC} = b^{SC}$. Note that due to symmetry $b_i^{SC} = b^{SC} \forall i$. Solving for b^{SC} gives

$$
b^{SC} = \frac{4rt\sigma^2 \left(\frac{3}{2} - s^{SC}\right) + t(6 - 4s^{SC}) - n}{\gamma n \left(t\gamma - \frac{1}{2}s^{SC}n\right)}
$$

in equilibrium with $b^{SC}(s^{SC} = 0) = (6t\gamma - n)/4nt\gamma^2 > b^*$. It can be easily checked that, by Assumption 2.1a, both the numerator and the denominator are strictly positive, i.e., the equilibrium incentive is always positive. The marginal effect of s^{SC} is given by

$$
\frac{\partial b^{SC}}{\partial s^{SC}} = -\frac{1}{2} \frac{(n - 2t\gamma)(n - 4t\gamma)}{\gamma n(s^{SC}n - 2t\gamma)^2},
$$

where $\partial b^{SC}/\partial s^{SC} < 0$ always holds, i.e., managerial incentives are always decreasing in s^{SC} in the symmetric case.

In a next step, we turn to the asymmetric case where consumer surplus from G's perspective is calculated as

$$
\begin{aligned}
CS^{AC} &= n\left[\int_0^{y^{AC}} v - p_i^{AC} - tx^2 dx + \int_{y^{AC}}^{1/n} v - p_j^{AC} - t\left(1/n - x\right)^2 dx\right] \\
&= \frac{1}{36} \frac{E(c_j^{AC})\left[E(c_j^{AC}) - 2\left[\left(c - b_{G,i}^{AC}\right) + 9t\right]\right] + n^2\left(c - b_{G,i}^{AC}\right)^2}{t} \\
&\quad - \frac{1}{2}\left(c - b_{G,i}^{AC} - 2v\right) - \frac{13t}{12n^2} + \frac{n^2\sigma^2}{16t}.
\end{aligned}
$$

The partially public firm's equilibrium incentive is given by $b_i^{AC} = s^{AC}b_G^{AC} + \left(1 - s^{AC}\right)b_{I,i}^{AC}$, where

$$
b_G^{AC} = \frac{t(9 + 12s^{AC}) - b_j^{AC}n^2(1 + 4s^{AC})}{18s^{AC}t\gamma n - n^2(1 + 4s^{AC})} \quad \text{and}
$$

$$
b_{I,i}^{AC} = \frac{6t - 2b_j^{AC}n^2}{n(9t\gamma - 2n)}.
$$

Note that $E(c_j) = c - b_j^{AC}$ with $e_j^{AC} = b_j^{AC}$. The entirely private firm's managerial incentive is given by

$$
b_j^{AC} = \frac{6t - 2b_i^{AC}n^2}{n(9t\gamma - 2n)}.
$$

Solving simultaneously, we get the following equilibrium incentives

$$
b_i^{AC} = \frac{1}{42}\frac{n^2(40s^{AC} + 8) - 324tn\gamma\left(\frac{1}{18} + s^{AC}\right) + 567s^{AC}t^2\gamma^2}{n\gamma\left[n^2\left(\frac{2}{7} + s^{AC}\right) - \frac{54}{7}tn\gamma\left(\frac{1}{12} + s^{AC}\right) + \frac{81}{7}\left(s^{AC}t^2\gamma^2\right)\right]} \quad \text{and} \tag{2.24}
$$

$$
b_j^{AC} = \frac{1}{42}\frac{n^2(40s^{AC} + 8) - 270tn\gamma\left(\frac{1}{15} + s^{AC}\right) + 324s^{AC}t^2\gamma^2}{n\gamma\left[n^2\left(\frac{2}{7} + s^{AC}\right) - \frac{54}{7}tn\gamma\left(\frac{1}{12} + s^{AC}\right) + \frac{81}{7}\left(s^{AC}t^2\gamma^2\right)\right]}. \tag{2.25}
$$

First, we analyze the conditions for managerial incentives to be non-negative in equilibrium. We begin with the partially public firm's equilibrium incentive presented in (2.24). Examining the numerator first, we find the following two zeros

$$
\begin{aligned}
\bar{t}_D &= \frac{1}{63}\frac{n\left(1 + 18s^{AC} + \sqrt{1 - 20s^{AC} + 44(s^{AC})^2}\right)}{s^{AC}\gamma} \quad \text{and} \\
\bar{t}_D' &= \frac{1}{63}\frac{n\left(1 + 18s^{AC} - \sqrt{1 - 20s^{AC} + 44(s^{AC})^2}\right)}{s^{AC}\gamma},
\end{aligned}
$$

where $\bar{t}_D'$ is irrelevant because it is always implied by Assumption 2.1b. The second zero, $\bar{t}_D$, is relevant for $s^{AC} < 5/22 - (1/22)\sqrt{14} \equiv s_1$. Otherwise, it is implied by concavity as well.

Hence, the numerator is positive (negative) if $t > \bar{t}_D$ ($t < \bar{t}_D$), given $s^{AC} < s_1$. If $s^{AC} \geq 5/22 + (1/22)\sqrt{14} \equiv s_2$ holds, then the numerator is always positive. The denominator exhibits also two zeros given by

$$\bar{t}_L = \frac{1}{36} \frac{n\left(1 + 12s^{AC} + \sqrt{1 - 8s^{AC} + 32(s^{AC})^2}\right)}{s^{AC}\gamma} \text{ and}$$

$$\bar{t}'_L = \frac{1}{36} \frac{n\left(1 + 12s^{AC} - \sqrt{1 - 8s^{AC} + 32(s^{AC})^2}\right)}{s^{AC}\gamma},$$

where t' is irrelevant, i.e., $t > t'$ always holds by concavity. The denominator is positive (negative) if $t > \bar{t}_L$ ($t < \bar{t}_L$). It follows that the relevant condition for $b_i^{AC} \geq 0$ to hold encompasses two cases: 1.) Given $s^{AC} < \bar{s}_1$, the equilibrium incentive is non-negative whenever $t < \bar{t}_D$ or $t > \bar{t}_L$; 2.) Given $s^{AC} \geq \bar{s}_2$, the equilibrium incentive is non-negative if $t > \bar{t}_L$.

Now we turn to the private firm's managerial incentive presented in (2.25). Setting the numerator equal to zero, i.e., $n^2(40s^{AC}+8) - 270tn\gamma\left(\frac{1}{15} + s^{AC}\right) + 324s^{AC}t^2\gamma^2 = 0$, we find the following two threshold values

$$\bar{t}_H = \frac{1}{36} \frac{n\left(1 + 15s^{AC} + \sqrt{1 - 2s^{AC} + 65(s^{AC})^2}\right)}{s^{AC}\gamma} \text{ and}$$

$$\bar{t}'_H = \frac{1}{36} \frac{n\left(1 + 15s^{AC} - \sqrt{1 - 2s^{AC} + 65(s^{AC})^2}\right)}{s^{AC}\gamma}.$$

The second zero, $\bar{t}'_H$, can be neglected, i.e., $t > \bar{t}'_H$ always holds by concavity. It can be immediately seen that the numerator is positive (negative) if $t > \bar{t}_H$ ($t < \bar{t}_H$). Since the denominator is identical with (2.24), we can infer that it is positive (negative) if $t > \bar{t}_L$ ($t < \bar{t}_L$). Note that $\bar{t}_D < \bar{t}_L < \bar{t}_H$. Thus, for both managerial incentives, b_i^{AC} and b_j^{AC}, to be non-negative the following conditions, depending on s^{AC}, have to be met: 1.) given $s^{AC} < \bar{s}_1$, managerial incentives are non-negative whenever $t < \bar{t}_D$ or $t > \bar{t}_H$; 2.) given $s^{AC} \geq \bar{s}_2$, managerial incentives are non-negative if $t < \bar{t}_L$ or $t > \bar{t}_H$. It should be noted that for the remaining analysis we solely consider cases where both managerial incentives are non-negative in equilibrium.

In a second step, we examine the marginal effects of s^{AC} on b_i^{AC} and b_j^{AC}. The marginal

effect of s^{AC} on b_i^{AC} is given by

$$\frac{\partial b_i^{AC}}{\partial s^{AC}} = \frac{4}{49} \frac{\left(n - \frac{9}{4}t\gamma\right)\left(n - \frac{9}{2}t\gamma\right)^2}{\left[\frac{81}{7}\gamma^2 t^2 s^{AC} - \frac{54}{7}\gamma nt\left(\frac{1}{12} + s^{AC}\right) + n^2\left(\frac{2}{7} + s^{AC}\right)\right]^2 \gamma},$$

where the denominator is always positive. The numerator reveals one zero

$$\bar{t} = \frac{4n}{9\gamma}$$

which is only relevant if $s^{AC} > 1/4$ holds. In this case, the marginal effect is negative (positive) if $t > \bar{t}$ ($t < \bar{t}$). In contrast, if $s^{AC} \le 1/4$, then $t > \bar{t}$ is always implied by Assumption 2.1b, and the marginal effect is always negative. The first derivative of b_j^{AC} with respect to s^{AC} is given by

$$\frac{\partial b_j^{AC}}{\partial s^{AC}} = \frac{4}{49} \frac{\left(n - \frac{9}{4}t\gamma\right)\left(n - \frac{9}{2}t\gamma\right)n}{\left[\frac{81}{7}\gamma^2 t^2 s^{AC} - \frac{54}{7}\gamma nt\left(\frac{1}{12} + s^{AC}\right) + n^2\left(\frac{2}{7} + s^{AC}\right)\right]^2 \gamma}.$$

Again, the denominator is always positive so that we focus on the numerator's sign. Setting the numerator equal to zero yields the following two threshold values

$$\underline{t} = \frac{2n}{9\gamma} \text{ and } \bar{t} = \frac{4n}{9\gamma}.$$

The first zero is irrelevant, since $t > \underline{t}$ always holds by concavity. The second zero, $\bar{t}$, is only relevant for $s^{AC} > 1/4$. The same results hold as before when the marginal effects on b_i^{AC} were analyzed.

Proof of Proposition 2.5. It is straight forward to check that managerial incentives in the symmetric case are always larger than in the benchmark case. We already know that $b^{SC}(s^{SC} = 0) = (6t\gamma - n)/4nt\gamma^2 > b^*$. Moreover, we have demonstrated that $\partial b^{SC}/\partial s^{SC} < 0$ always holds, i.e., the marginal effect of s^{SC} on b^{SC} is strictly negative. Hence, there could possibly exist an $s^{SC} \in (0, 1/2)$ for which $b^* > b^{SC}$ holds. This claim can be easily rejected based on $b^{SC}(s^{SC} = 1/2) = 1/n\gamma = b^*$, i.e., equilibrium incentives in the symmetric case are never lower than $b^* \ \forall s^{SC} \in (0, 1/2)$.

Now, it is demonstrated that whether or not partially public firms offer stronger incentives than firms in the benchmark case depends on the level of competition, t. We define

$\phi_i^{AC} = b^* - b_i^{AC}$ to be our relevant measure which can be presented by

$$\phi_i^{AC} = \frac{1}{42} \frac{2n^2 \left(2 + s^{AC}\right) - 81 s^{AC} t^2 \gamma^2 - 9nt\gamma}{\left[\frac{81}{7} \gamma^2 t^2 s^{AC} - \frac{54}{7} \gamma nt \left(\frac{1}{12} + s^{AC}\right) + n^2 \left(\frac{2}{7} + s^{AC}\right)\right] \gamma n}. \tag{2.26}$$

If $\phi_i^{AC} > 0$ ($\phi_i^{AC} < 0$), then managerial incentives are higher (lower) in the benchmark case. The numerator has two zeros

$$\widetilde{t'} = \frac{1}{18} \frac{n\left(\sqrt{1 + 16s^{AC} + 8(s^{AC})^2} - 1\right)}{s^{AC}\gamma} \quad \text{and}$$

$$\widetilde{\widetilde{t}} = \frac{1}{18} \frac{n\left(-\sqrt{1 + 16s^{AC} + 8(s^{AC})^2} - 1\right)}{s^{AC}\gamma},$$

where $\widetilde{\widetilde{t}}$ can be ignored because it is not feasible. The second zero $\widetilde{t'}$ is irrelevant, since $t > \widetilde{t'}$ always holds by concavity. It follows that the numerator is strictly negative. Turning to the denominator we find the following two zeros

$$\bar{t}_L = \frac{1}{36} \frac{n\left(1 + 12s^{AC} + \sqrt{1 - 8s^{AC} + 32(s^{AC})^2}\right)}{s^{AC}\gamma} \quad \text{and}$$

$$\bar{t}'_L = \frac{1}{36} \frac{n\left(1 + 12s^{AC} - \sqrt{1 - 8s^{AC} + 32(s^{AC})^2}\right)}{s^{AC}\gamma},$$

where $\bar{t}'_L$ can neglected because $t > \bar{t}'_L$ is always implied by Assumption 2.1b. The denominator is positive (negative) if $t > \bar{t}_L$ ($t < \bar{t}_L$). Accounting for non-negativity our results in Proposition 2.5 follow immediately.

Finally, we analyze whether or not private firms offer stronger incentives in the asymmetric case than private firms in the benchmark case. We use $\phi_j^{AC} = b^* - b_j^{AC}$ as our relevant measure where

$$\phi_j^{AC} = \frac{1}{42} \frac{2n^2 \left(2 + s^{AC}\right) + 162 s^{AC} t^2 \gamma^2 - 54n\gamma \left(\frac{1}{6} + s^{AC}\right)}{\left[\frac{81}{7} \gamma^2 t^2 s^{AC} - \frac{54}{7} \gamma nt \left(\frac{1}{12} + s^{AC}\right) + n^2 \left(\frac{2}{7} + s^{AC}\right)\right] \gamma n}.$$

Since the denominator is identical with the denominator in (2.26), the relevant threshold value is given by $\bar{t}_L$. The numerator has two zeros

$$\widehat{t'} = \frac{1}{36} \frac{n\left(1 + 6s^{AC} + \sqrt{1 - 20s^{AC} + 20(s^{AC})^2}\right)}{s^{AC}\gamma} \quad \text{and}$$

$$\widehat{\widehat{t}} = \frac{1}{36} \frac{n\left(1 + 6s^{AC} - \sqrt{1 - 20s^{AC} + 20(s^{AC})^2}\right)}{s^{AC}\gamma},$$

where $\overset{\rightharpoonup}{\widehat{t}}$ is irrelevant, i.e., $t > \overset{\rightharpoonup}{\widehat{t}}$ always holds by concavity. The second zero is only relevant for $s^{AC} < 1/2 - (1/5)\sqrt{5} \equiv \bar{s}_1$. Otherwise, i.e., $s^{AC} > \bar{s}_1$, $t > \widehat{t'}$ always holds. Note that $\bar{s}_1 < s_1$. Moreover, given $s^{AC} < \bar{s}_1$, the following ordering holds: $\bar{t}_D < \widehat{t'} < \bar{t}_L < \bar{t}_H$. Hence, $\widehat{t'}$ is not feasible, since it falls in the interval which leads to negative equilibrium incentives. Our results in Proposition 2.5 follow immediately.

This completes the proof of Proposition 2.5.

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Chapter 3

Managerial Incentives and Competition in Two-Sided Markets

3.1 Introduction

Issues emerging from separation of ownership and control are traditionally an important concern in economics. Whereas the literature on agency problems in 'one-sided' markets is vast, two-sided markets have been neglected so far. In this chapter, we attempt to fill this gap by focussing on managerial incentives to provide effort in a setting of two-sided platforms competing for buyers and sellers. The main question we address is to what extent platform competition and indirect network externalities affect managerial incentives.

One implication is the newspaper market where editors care about the quality of the content they publish. They rely on the work of their journalists which cannot be perfectly monitored. Journalists, who produce content for the editors, have to deliver a certain required level of quality in order to get published. Although they are mainly paid on a per line basis, journalists must take the quality of their articles into account because meeting a required quality level is necessary for getting published and paid at all. This example encompasses the two main features of our model: two-sided platforms and an agency relationship within a platform characterized by ex post asymmetric information. Other examples include the market for game consoles, smartphones, and search engines, where the platforms' managing directors can be regarded as principals and the developers as agents.[1] Again, the principals' payoffs depend on their agents' effort which cannot be perfectly monitored.

In this chapter, we combine a principal-agent model with a market game where competition between two-sided platforms is explicitly modelled using Armstrong's (2006) setup. Therefore, we consider a game which consists of two phases. In the first phase (contracting phase), principals simultaneously offer a contract to their agents. Agents then choose effort levels which aim at increasing quality on the buyer side. After uncertainty is resolved, the second phase, i.e., the market phase, starts. Now, principals simultaneously set prices

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[1] The reader should not confuse developers working within a platform with those using a platform to sell applications, games, etc. We strictly focus on the former constituting the agency relationship in our framework.

competing for buyers and sellers. Finally, buyers and sellers decide which platform(s) to join. We distinguish three cases concerning the buyers' and sellers' platform adoption possibilities: 1.) single-homing buyers and sellers (full single-homing, FSH), 2.) single-homing buyers and multi-homing sellers (partial single-homing, PSH), and 3.) multi-homing buyers and sellers (full multi-homing, FMH). In doing so, we cover different platform markets which are characterized by different adoption possibilities.[2] The closest works in the spirit of ours are Baggs and de Bettignies (2007) and Raith (2003). They analyze how managerial incentives to reduce marginal costs and enhance quality, respectively, are affected by product market competition. Thereby, product market competition is explicitly modelled by using a Hotelling setup and Vickrey-Salop setup, respectively. However, the main difference between these papers and our analysis is that we introduce indirect network externalities in the market phase by examining two-sided platforms.

We first study the effects of competition on managerial incentives to provide higher quality on the buyer side. For this purpose, we focus on the marginal increase of competition, measured by the transport cost parameters buyers and sellers, respectively, face when deciding which platform to adopt. Hence, we take higher product substitutability as indicative of intensified competition between the platforms. Thereby, a decrease of the transport cost parameters can be a result of higher platform compatibility realized by strategic corporate decisions or forced by some regulatory authority. Moreover, it could be due to decisions concerning product design. For instance von Ungern-Sternberg (1988) provides an analysis of firms' incentives to offer general purpose products by reducing transport costs in an oligopolistic environment.[3] In this context, a decrease of the transport cost parameters is

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[2]One example for PSH constitutes operating systems where users typically purchase only one operating system, whereas most developers design applications for several operating systems. The same is true for the newspaper market and smartphones. Examples reflecting FMH are credit cards and possibly super markets.

[3]More specifically, the transport cost parameter, t, is endogenous in von Ungern-Sternberg's (1988) setting. It reflects the degree to which the product offered by a firm is a general purpose product: the lower t, the more general purpose the product.

interpreted as an increase of a product's general purpose.

In a second step, we shift our focus to changes of indirect network externalities. Since the existence of indirect network externalities represents a distinguishing feature of our setting, it is natural to ask how it affects managerial incentives. According to Belleflamme and Peitz (2010) increases of the marginal network benefits buyers and sellers enjoy when adopting the same platform are due to sellers' investments in e.g., quality or cost reduction. Based on this interpretation, we ask whether or not such investments trigger principals to give their agents stronger incentives to provide higher platform quality. Put another way, it is analyzed if sellers' investments and platform quality are substitutes or complements.

We demonstrate that in all three cases the effects of competition on managerial incentives cannot be unambiguously characterized by the *rent reduction effect* and *business stealing effect* as in e.g., Raith (2003) and Baggs and de Bettignies (2007). We identify two factors instead which jointly determine how managerial incentives are affected by fiercer competition. First, each platform's relative profitability, i.e., the gross profit on the buyer side compared to the gross profit on the seller side. We find that the profits must be relatively balanced for competition to have a positive effect on managerial incentives. Second, the buyers' and sellers' adoption possibilities, i.e., whether they are able to choose only one platform (single-homing) or to adopt both platforms at the same time (multi-homing). Hence, the degree to which buyers and sellers perceive platforms to be heterogeneous shapes our results. We show that multi-homing on either side makes the effects on managerial incentives independent of each platform's relative profitability. Whereas, with single-homing buyers and sellers, managerial incentives are only increased if the gross profits on either side are balanced, competition always positively affects managerial incentives in the PSH case and the FMH case. A similar reasoning holds with regards to the effects of indirect network externalities on managerial incentives.

The chapter is structured as follows. Section 3.2 provides a literature overview. In Sections 3.3 and 3.4, we present our model and derive the equilibria for each of the three cases. Section 3.5 covers the core part of the chapter. Here, we study the effects of competition and

indirect network externalities on managerial incentives to provide higher platform quality. In Section 3.6, we discuss our results. Section 3.7 concludes.

3.2 Related Literature

So far, the burgeoning literature on two-sided markets has ignored agency problems. While existing papers starting with the seminal works of Armstrong (2006) and Rochet and Tirole (2003, 2006) mainly focus on the effects of indirect network externalities on pricing structures, demand elasticities and platform competition, their inherent assumption is that platforms are entrepreneurial firms.[4] One slight exception which is worthwhile to mention for our purposes are Belleflamme and Peitz (2010). While maintaining the assumption that platforms are entrepreneurial, they analyze sellers' investment incentives with open platforms and for-profit platforms. More specifically, they presume that sellers' investments in e.g., quality or cost reduction, increase both buyers' and sellers' marginal network benefits of joining a platform. Based on this view, we also analyze the interplay of sellers' investments and managerial incentives by asking whether or not managerial incentives are boosted by sellers' investments. However, we extend these papers by considering platforms which consist of a principal-agent pair. By this means, we introduce an agency relationship where the agent can exert unobservable effort after accepting the offered contract by the principal. Moreover, we allow for asymmetric information between competing platforms by specifying that platform quality, which directly affects the buyer side, is each platform's private information.

It is worthwhile to note that there are other analyses allowing for asymmetric information in a two-sided market context. Elison, Fudenberg and Möbius (2004) and Halaburda and Yehezkel (2011) consider asymmetric information between two-sided platforms on the one hand and buyers and sellers on the other hand. Thereby, platforms are the principals

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[4]Other important works include e.g., Gabszewicz et al. (2001), Caillaud and Jullien (2003), Anderson and Coate (2005), and Hagui (2006). For more recent papers see e.g., Armstrong and Wright (2007), Nocke, Peitz and Stahl (2007), Hagui (2009), Weyl (2010) and Belleflamme and Peitz (2010).

and buyers and sellers are the agents. More precisely, buyers and sellers do not know their benefit of joining a platform and learn it privately after adoption. A mechanism is applied in both papers which leads to truthful revelation by buyers and sellers. While Ellison, Fudenberg and Möbius (2004) assume that platforms charge uniform access prices, Halaburda and Yehezkel (2011) extend this analysis by introducing transaction fees which allow for divide-and-conquer strategies. Another paper, which also considers asymmetric information in two-sided markets, is by Peitz, Rady and Trepper (2011). They consider a monopoly platform which initially does not know the marginal network benefits each side enjoys and can perform learning by experimentation. However, these papers suppose that platforms are entrepreneurial. We rather focus on issues of asymmetric information within and between two-sided platforms. Therefore, we consider platforms which are characterized by a principal-agent relationship, and which have private information about their own quality level.

Our analysis also relates to the old debate whether or not competition induces managers to work harder which was originated by Leibenstein's (1966) seminal work on "x-inefficiencies". Since then, several papers have analyzed this topic and suggest different effects of competition on productive efficiency. Existing empirical works generally find that competition has a positive (overall) impact. Two representatives providing evidence on this issue are Nickell (1996) and Baggs and de Bettignies (2007).[5] Among the first theoretical papers to formalize the relationship between competition and managerial effort are Hart (1983) and Schmidt (1997).[6] However, their models rely on different grounds. In Hart's

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[5] More specifically, Nickell (1996) demonstrates that competition increases firms' factor productivity growth. Baggs and de Bettignies (2007) find that stronger competition increases firms' incentives to improve quality and to reduce costs. Moreover, Baggs and de Bettignies (2007) identify the agency effect, and they show that it also positively affects quality provision and cost reduction.

[6] Other, not less important, papers are e.g., Holmström (1982), Scharfstein (1988), and Hermalin (1992, 1994).

hidden information model[7] managerial slack is reduced by the existence of entrepreneurial firms in conjunction with perfectly correlated input prices. He finds that the relationship between competition and managerial slack is unambiguous in the sense that increased competitive pressure always decreases managerial slack.[8],[9] In contrast, Schmidt (1997) uses a hidden action model and considers managers who account for bankruptcy with a certain probability when they exert effort.[10] He shows that, on one side, competition increases the probability of bankruptcy, and thus makes managers work harder. On the other side, competition may reduce profits and possibly decreases the agents' marginal gain of exerting effort. Since the second effect can be either positive or negative, the overall effect of competition is ambiguous.

More recent theoretical papers extend the previous works by explicitly modelling competition between firms.[11] The first example is Raith (2003) who analyzes a principal-agent model with ex post asymmetric information where principals give their agents incentives

[7]In fact, Hart (1983) allows for both hidden action and hidden information, since the principals of managerial firms neither observe their managers effort levels nor the realized input prices.

[8]Note that Hart (1983) only allows for the extreme cases of perfect competition and monopoly, i.e., he neglects oligopolistic and monopolistic market structures. Moreover, Scharfstein (1988) demonstrates that Hart's results do not hold if the assumptions on the manager's utility function with respect to the degree of risk aversion are relaxed.

[9]Martin (1993) also finds an unambiguous relationship between competition and managerial slack. In contrast to Hart (1983), he rather argues that competition has a negative effect on firms' efficiency, i.e., the higher the number of firms in the market, the higher the average costs in equilibrium.

[10]Note that in Schmidt's (1997) setting the probability of bankruptcy is conditional on the cost level, i.e., it is only positive if the manager was unsuccessful in reducing costs. Moreover, it is weakly increasing in the degree of competition. This implies that an increase in competition increases the probability of bankruptcy, and thus the manager's disutility when the firm is "liquidated".

[11]The reader should note that the "value-of-a-cost-reduction" effect, found by Schmidt (1997) to be ambiguous, is further subdivided into the business stealing effect and scale effect (rent reduction effect) by that literature. It follows that explicitly taking competition into account allows a more detailed analysis of the effects of competitive pressure on managerial incentives.

to reduce marginal costs. After the principals have designed contracts, they compete in prices à la Vickrey-Salop. The main focus of the chapter, beside the effects of competition and risk on managerial incentives, is the comparison between exogenous and endogenous market structures with regards to their implications for managerial equilibrium incentives. It is shown that, while the effects of competition can be either positive or negative for a fixed number of firms, the effects become unambiguously positive for an endogenous market structure. Thereby, stronger competition is measured by higher product substitutability. The second paper is by Baggs and de Bettignies (2007) who consider a Hotelling duopoly model. They rather presume that agents' effort aims at increasing firms' quality. They demonstrate that equilibrium incentives are lower when quality is non-verifiable compared with verifiable quality levels which can be contracted upon. The resulting inefficiency is attributed to higher agency costs and termed agency effect. In contrast to these papers, we consider competition in markets where indirect network externalities are prevalent. Moreover, we focus on the impact of sellers' investments on managerial incentives which are approximated by increased indirect network externalities.

3.3   The Model

There are two platforms $i = 1, 2$ which compete for two distinct groups of agents: buyers (B) and sellers (S). The two groups of agents have to join the platforms in order to derive cross-benefits from membership, i.e., each agent exerts an indirect network externality on the other group's agents when joining the same platform.[12] The distinction between existing works on two-sided markets and ours is that we consider platforms to be partially managerial rather than entirely entrepreneurial. In the following, this feature will be discussed in more detail. We start by introducing the players of our game.

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[12] More precisely, indirect network externalities constitute "pure membership externalities" in our setup according to the definition provided by Rochet and Tirole (2006). However, we maintain the more general notion of indirect network externalities throughout the entire analysis.

Platforms. Platforms are located at the ends of the Hotelling line of unit length. Each platform consists of a risk-neutral principal and a risk-averse agent. While each platform's principal decides on the (access) prices B and S have to pay when joining platform i, her agent can exert effort e_i to increase buyers's stand alone utility of adoption.[13] Thus, the agents' effort aims at increasing the platforms' quality from the buyers' perspective. Principals cannot monitor their agents post-contractual behavior, i.e., effort is unobservable. Realized quality is expressed by $x_i = x + e_i + \theta_i$, where $x > 0$ is a constant, and θ_i denotes a normally distributed random variable with zero mean and variance σ^2, i.e., $\theta_i \sim N(0, \sigma^2)$ i.i.d. Each principal offers her agent a contract (d_i, b_i) such that an agent's wage is given by $w_i = d_i + b_i (x_i - x)$, where d_i is a (fixed) salary, and $b_i (x_i - x)$ an effort-related bonus, with b_i denoting the piece rate and managerial incentive to provide quality, respectively. Throughout the analysis, we assume that quality is verifiable so that it can be contracted upon.

The agent can accept or reject the contract which is a take-it-or-leave-it offer. If the agent does not accept the offer, then she gets her reservation utility which is normalized to zero, i.e., $\overline{u} = 0$ holds. Agent i's effort costs are given by $ke_i^2/2$. For each agent's utility we suppose a CARA utility function

$$u_i = -\exp\left(-r\left[w_i - ke_i^2/2\right]\right), \tag{3.1}$$

where r denotes the agent's (constant absolute) degree of risk aversion. Firm i's realized quality level, x_i, is private information, i.e., the platforms can only form expectations about their rival's quality level when setting prices for B and S. For simplicity, we assume that platforms incur neither variable costs nor fixed costs of serving B and S. Their only cost is given by the wage, w_i.

Buyers. Buyers are uniformly distributed along the Hotelling line of unit length. We

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[13] For the sake of simplicity, we restrict our focus on (fixed) membership fees. Hence, the price buyers and sellers pay, when joining a platform, is a (fixed) membership fee. For an analysis of (variable) usage fees see e.g., Armstrong (2006) and Rochet and Tirole (2006).

analyze two cases: single-homing buyers and multi-homing buyers. If buyers single-home, they can join either platform A or B, but not both platforms. In the multi-homing case, we additionally consider users who can choose to adopt both platforms 1 and 2.[14] However, a buyer's utility always depends on the number of sellers served by the same platform(s). More precisely, if platform i attracts n_i^S sellers, then buyers' gross utility in the single-homing case is given by

$$U_i^B = \alpha n_i^S - p_i^B + x_i, \tag{3.2}$$

where α denotes the marginal network benefit, i.e., the indirect network externality an additional seller exerts on one buyer, and p_i^B is the access price charged by platform i. Buyers also benefit from platform i's realized quality, x_i, which, among other things, depends on the agents' effort. In addition, buyers incur transport costs which are linear in distance and increase at rate $t_i > 0$. For simplicity, we presume symmetric transport cost parameters, i.e., $t_i = t_j = t$ with $i \neq j$.

In the multi-homing case, a buyer's gross utility is

$$U_{i+j}^B = \alpha(n_i^S + n_j^S) - p_i^B - p_j^B + x_i + x_j, \tag{3.3}$$

if she adopts both platforms with $i \neq j$. Hence, a multi-homing buyer benefits from all sellers active in the market, $(n_i^S + n_j^S)$, and both platforms' quality levels, $(x_i + x_j)$, but she pays access prices to both platforms and incurs higher transport costs. If, on the contrary, a buyer adopts only one platform in the multi-homing case, i.e., either 1 or 2, then her utility is identical with (3.2).

Sellers. We analyze two cases concerning the sellers' platform adoption: single-homing and multi-homing. While the first case is equivalent to the single-homing case for buyers, the multi-homing case reflects Armstrong's (2006) "competitive bottleneck" model where the sellers' decision to adopt platform i is independent of adopting the rival platform, j. In

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[14] The case of multi-homing buyers is based on Choi's (2010) framework. It differs from Armstrong's (2006) "competitive bottleneck" model, since buyers still regard both platforms as heterogeneous (differentiated) so that their decision to join one platform is not completely independent of joining the other.

the single-homing case, the sellers' gross utility of joining platform i is given by

$$U_i^S = \beta n_i^B - p_i^S, \tag{3.4}$$

where β and p_i^S denote the sellers' marginal network benefit and the sellers' access price, respectively. The amount of buyers on platform i is given by n_i^B. Sellers also incur linear and symmetric transport costs where the transport cost parameter is denoted by $\tau > 0$.

If, however, we shift our focus to multi-homing sellers, then their utility function is given by

$$U_i^S = \beta n_i^B - p_i^S - f, \tag{3.5}$$

where f denotes the sellers' fixed cost of platform adoption. Note that in this case sellers do not incur any transport costs, since they regard both platforms as homogeneous. Sellers are heterogenous with respect to their fixed costs of platform adoption which we denote by $f > 0$. Thereby, we specify f to be uniformly distributed along a unit interval, i.e., $f \in [0, \infty]$.

Timing. The game consists of two phases. In the first phase (contracting phase), each platform i's principal offers her agent a contract, (d_i, b_i), to maximize her expected profit. Given that the agents accept the offer, they simultaneously choose effort levels maximizing (3.1). Note again that each agent's effort level is unobservable. Subsequently, uncertainty is resolved and each principal i learns its realized quality level which is private information. In the second phase (market phase), principals simultaneously and non-cooperatively set prices, p_i^B and p_i^S, to both sides of the market in order to maximize profits. Finally, buyers and sellers make their adoption decisions knowing each platform's realized quality level.

We separately analyze three cases concerning the buyers' and sellers' adoption decision: 1.) both buyers and sellers single-home (full single-homing, FSH), 2.) buyers single-home and sellers mutli-home (partial single-homing, PSH), and 3.) both buyers and sellers multi-home (full multi-homing, FMH). For each case, we first present the equilibrium, and then, we examine how intensified competition and increased indirect network externalities affect managerial incentives.

We concentrate on market-sharing equilibria whose existence is assured by the following assumptions:

Assumption 3.1. *When both buyers and sellers single-home, then $4t\tau - (\alpha + \beta)^2 > 0$ is the necessary and sufficient condition for the market-sharing equilibrium to exist.*

Assumption 3.2. *When sellers multi-home and buyers single-home, then $8t - 6\alpha\beta - \alpha^2 - \beta^2 > 0$ is the necessary and sufficient condition for the market-sharing equilibrium to exist.*

Assumption 3.3. *When both buyers and sellers multi-home, then $4t - (\alpha + \beta)^2 > 0$ is the necessary and sufficient condition for the market-sharing equilibrium to exist.*

We show in the Appendix that the assumptions guarantee strict concavity of the principals' profits with respect to both prices and managerial incentives.

The game is solved for a symmetric subgame perfect Bayesian-Nash equilibrium. Restricting our analysis to symmetric equilibria implies that platforms offer the same price pair (p^B, p^S) and identical managerial incentives in equilibrium. This appears to be common practice in the related literature to keep the model tractable.[15]

3.4 Equilibrium Analysis

In this section, we derive the equilibria for all three cases. We start with the case where both buyers and sellers single-home.

1. Single-homing buyers and sellers (FSH). Assuming full market coverage, i.e., $n_i^B = 1 - n_j^B$ and $n_i^S = 1 - n_j^S$, respectively, and solving simultaneously, platform i's market shares among buyers and sellers can be expressed by

$$
\begin{aligned}
n_i^B &= \frac{1}{2} + \frac{1}{2} \frac{\tau\left(p_j^B - p_i^B\right) + \alpha\left(p_j^S - p_i^S\right) + \tau\Delta_i}{t\tau - \alpha\beta} \text{ and} \\
n_i^S &= \frac{1}{2} + \frac{1}{2} \frac{\beta\left(p_j^B - p_i^B\right) + t\left(p_j^S - p_i^S\right) + \beta\Delta_i}{t\tau - \alpha\beta},
\end{aligned}
\tag{3.6}
$$

---

[15] See e.g., Raith (2003) and Baggs and de Bettignies (2007).

where $\Delta_i = x_i - x_j$ measures the difference between platform i's and platform j's realized quality levels. If $\Delta_i \neq 0$, then the platforms are vertically differentiated from the buyers perspective. Thereby, either platform i or platform j offers a higher quality level if $\Delta_i > 0$ and $\Delta_i < 0$, respectively.

Given (3.6), principals simultaneously set p_i^B and p_i^S to maximize profits given by $\pi_i = p_i^B n_i^B + p_i^S n_i^S - w_i$. Note that at this stage of the game the wage principal i pays her agent and her realized quality level are given. In addition, principal i does not know her rival's realized quality due to private information. Thus, her profit depends on the rival's expected prices which must equal

$$E(p^B) = \frac{t\tau - \alpha\beta}{\tau} - \frac{\beta}{\tau}E(p^S) \text{ and } E(p^S) = \frac{t\tau - \alpha\beta}{\tau} - \frac{\alpha}{t}E(p^B) \tag{3.7}$$

in a symmetric equilibrium. Solving simultaneously, we get $E(p^B) = t - \beta$ and $E(p^S) = \tau - \alpha$, i.e., expected prices equal the standard equilibrium prices derived in a setting of competing platforms with FSH by Armstrong (2006). Calculating the first order conditions and using (3.7) yields the following equilibrium prices

$$
\begin{aligned}
p_i^B &= t - \frac{(\alpha + \beta)}{2\tau}(p_i^S + \alpha) + \frac{1}{2}(E(\Delta_i) + \alpha - \beta) \text{ and} \\
p_i^S &= \tau - \frac{(\alpha + \beta)}{2t}p_i^B - \frac{1}{2}(\alpha - \beta) + \frac{\beta}{2t}(E(\Delta_i) - \alpha - \beta),
\end{aligned}
\tag{3.8}
$$

where $E(\Delta_i)$ is the difference between platform i's realized quality level and her rival's expected quality level, i.e., $E(\Delta_i) = x_i - E(x_j)$. The first two (three) terms on the right-hand side of the expressions in (3.8) correspond to the standard equilibrium prices where t (τ) is the market power parameter and $((\alpha + \beta)/2\tau)(p_i^S + \alpha)$ $(((\alpha + \beta)/2t)(p_i^B) - (1/2)(\alpha - \beta))$ is platform i's external benefit from an additional seller (buyer). Although, given $\Delta_i \neq 0$, platforms are only vertically differentiated from the buyers' view, the prices to both groups of agents, B and S, depend on $E(\Delta_i)$. This is due to the presence of indirect network externalities. For instance, consider an expected quality advantage of platform i, i.e., $E(\Delta_i) > 0$ holds. In this case, platform i attracts more buyers which in turn makes adoption of platform i more attractive for the sellers. Thereby, buyers are additionally charged half of the quality difference $E(\Delta_i)$. The sellers' access price is adjusted by $(\beta/2t)E(\Delta_i)$ because

they do not directly benefit from platform i's quality advantage, but indirectly through the buyers.

Given unobservability of e_i, principals explicitly take the incentive compatibility constraint into account when offering a wage contract to their agents. By doing so, they trigger their agents to choose their individually optimal effort levels in the contracting phase. The following lemma illustrates agent i's optimal effort choice.

Lemma 3.1. *When both buyers and sellers single-home, then the optimal effort level is given by $e_i = b_i/k$.*

Proof. See the Appendix.

Lemma 3.1 states a standard result in moral hazard models: agent i's optimal effort level is positively related to the piece rate, b_i. It can be immediately checked that e_i does not directly depend on the product differentiation parameters, t and τ, nor on the indirect network externalities measured by α and β. The reason is that agent i maximizes (3.1) which does not directly depend on these market parameters.

Finally, we consider the initial stage of the game. Principals maximize their expected profits by offering a linear wage contract to their respective agents. Each principal's profit is uncertain due to the dependence of each platform's quality level on θ_i. The optimization problem can be expressed by

$$
\begin{aligned}
\underset{b_i}{Max} E\left(\pi_i\right) &= p_i^B(e_i, E(x_j))n_i^B(e_i, E(x_j)) + p_i^S(e_i, E(x_j))n_i^S(e_i, E(x_j)) - w_i(e_i) \quad (3.9) \\
s.t.\ e_i &= \frac{b_i}{k} \text{ and } u_i \geq 0,
\end{aligned}
$$

where the participation constraint becomes binding, i.e., $u_i = 0$ holds.

Solving (3.9) and imposing symmetry leads to the following proposition.

Proposition 3.1. *When both buyers and sellers single-home, there exists a unique symmetric equilibrium for the entire game. The equilibrium incentive is given by*

$$
b = \frac{1}{2} \frac{\tau(2t - \beta) + \alpha(\tau - \beta) - \alpha^2}{m\left(4t\tau - (\alpha + \beta)^2\right)}, \quad (3.10)
$$

and each principal's expected equilibrium profit is

$$E(\pi) = \frac{1}{2}\left[(t + \tau - \alpha - \beta) - \frac{mb^2}{k}\right],$$

where $m = (1 + kr\sigma^2)$ is a parameter reflecting the agents' risk aversion.

Proof. See the Appendix.

The equilibrium incentive depends on both product differentiation parameters as well as on both marginal indirect network externalities. Compared with the standard equilibrium profit, where platforms are entrepreneurial, $E(\pi)$ is lower due to separation of ownership and control.[16] The term $mb^2/2k$, i.e., the agency cost due to hidden action, which increases with higher b, is subtracted. Thus, expected profits are reduced in equilibrium if b increases.

2. Single-homing buyers and multi-homing sellers (PSH). A seller adopts platform i if her cost of adoption is such that $f \leq \overline{\beta}\overline{n}_i^B - \overline{p}_i^S$, where a bar indicates the PSH case. Note that the assumption of full market coverage on the buyer side, i.e., $n_i^B = 1 - n_j^B$, is maintained. Given the utility functions in (3.2) and (3.5), we first derive the marginal consumers, and then solve simultaneously to get the following equilibrium amount of buyers and sellers adopting platform i:

$$\overline{n}_i^B = \frac{1}{2} + \frac{1}{2}\frac{\alpha\left(\overline{p}_j^S - \overline{p}_i^S\right) + \left(\overline{p}_j^B - \overline{p}_i^B\right) + \overline{\Delta}_i}{t - \alpha\beta} \quad \text{and} \tag{3.11}$$

$$\overline{n}_i^S = \frac{\beta}{2} + \frac{1}{2}\frac{\beta\left(\overline{p}_j^B - \overline{p}_i^B + \overline{\Delta}_i + \alpha\overline{p}_j^S\right) - \overline{p}_i^S(2t - \alpha\beta)}{t - \alpha\beta}.$$

In the fourth stage, principals set profit maximizing prices, $\overline{p}_i^B$ and $\overline{p}_i^S$, using the equilibrium demand functions in (3.11). Making use of the fact that expected prices under symmetry are $E(\overline{p}^B) = t - (1/4)\beta - (3/4)\alpha\beta$ and $E(\overline{p}^S) = (1/4)(\beta - \alpha)$, the relevant first-order conditions of $\overline{\pi}_i = \overline{p}_i^B\overline{n}_i^B + \overline{p}_i^S\overline{n}_i^S - \overline{w}_i$ can be presented by

$$\overline{p}_i^B = t - \frac{(\alpha + \beta)}{2}\overline{p}_i^S - \frac{6\alpha\beta + \alpha^2 + \beta^2}{8} + \frac{1}{2}E(\overline{\Delta}_i) \quad \text{and} \tag{3.12}$$

$$\overline{p}_i^S = \frac{1}{8}\frac{\beta\left(4E(\overline{\Delta}_i) + 8t - \alpha^2 - \beta^2 - 6\alpha\beta\right) - 4\overline{p}_i^B(\alpha + \beta)}{2t - \alpha\beta}.$$

---

[16]Note that due to symmetry we get $\Delta_i = 0$, where $i = 1, 2$.

Again, it can be checked that the expected quality difference, $E(\overline{\Delta}_i)$, positively affects both equilibrium quantities and equilibrium prices if platform i has a quality advantage over its competitor. As in the FSH case, buyers are directly charged half of $E(\overline{\Delta}_i)$, whereas the sellers' access price is adjusted by $\beta/(4t - 2\alpha\beta)$ reflecting that they indirectly benefit from quality differences through the buyers.

According to Lemma 3.1, we can calculate agent i's optimal effort level as $\overline{e}_i = \overline{b}_i/k$. The structure of the optimal effort level is the same as in the FSH case. In other words, it always equals the ratio of the managerial incentive, $\overline{b}_i$, and the agent's effort cost parameter, k.

At stage 1, principals maximize their expected profits via $\overline{b}_i$ facing the same optimization problem presented in (3.9). Making use of symmetry, the equilibrium can be presented as follows.

Proposition 3.2. *When buyers single-home and sellers multi-home, there exists a unique symmetric equilibrium for the entire game which yields the following equilibrium incentive and expected profit, respectively,*

$$\overline{b} = \frac{t - \alpha\beta}{m(4t - 3\alpha\beta - \frac{1}{2}(\alpha^2 + \beta^2))} \tag{3.13}$$

and

$$E(\overline{\pi}) = \frac{1}{2}\left[\left(t - \frac{3}{4}\alpha\beta - \frac{1}{8}(\alpha^2 + \beta^2)\right) - \frac{m\overline{b}^{*2}}{k}\right],$$

where $m = (1 + kr\sigma^2)$ is a parameter reflecting the agents' risk aversion.

Proof. See the Appendix.

The difference of expected profits compared with the FSH case is exclusively due to the platforms' competitive bottleneck characteristic. The same is true with respect to the agency cost, $m\overline{b}^2/2k$. It differs from the agency cost in the FSH case only because $\overline{b} \neq b$.

3. Multi-homing buyers and sellers (FMH). Maintaining the assumption of multi-homing sellers, we derive now the equilibrium additionally considering multi-homing buyers.

In contrast to the sellers, buyers still regard platforms 1 and 2 as differentiated, i.e., they incur positive transport costs given by $t > 0$. Hence, there are buyers who single-home and adopt only one platform, and buyers choosing to access both platforms at the same time realizing a (gross) utility given by (3.3). The equilibrium amount of buyers single-homing and multi-homing on platform i is

$$
\begin{aligned}
\widetilde{a}_i^B &= 1 - \frac{\widetilde{x}_j - \alpha \widetilde{p}_j^S - \widetilde{p}_j^B}{t - \alpha\beta} \text{ and} \\
\widetilde{a}_i^M &= \frac{\widetilde{x}_i + \widetilde{x}_j - \alpha(\widetilde{p}_i^S + \widetilde{p}_j^S) - (\widetilde{p}_i^B + \widetilde{p}_j^B)}{t - \alpha\beta} - 1,
\end{aligned}
\tag{3.14}
$$

where a tilde indicates FMH and the 'M' in the superscript stands for multi-homing buyers. Unlike FSH and PSH, the quantities in (3.14) do not represent platform i's demand on the buyer side. Buyers' demand is rather calculated as

$$
\widetilde{n}_i^B = \widetilde{a}_i^B + \widetilde{a}_i^M = \frac{\widetilde{x}_i - \alpha \widetilde{p}_i^S - \widetilde{p}_i^B}{t - \alpha\beta}.
\tag{3.15}
$$

The equilibrium amount of sellers per platform is presented by

$$
\widetilde{n}_i^S = \frac{\beta(\widetilde{x}_i - \widetilde{p}_i^B) - t\widetilde{p}_i^S}{t - \alpha\beta}.
\tag{3.16}
$$

In the FMH case, each platform i's equilibrium demand does not depend anymore on the rival's expected quality level, $E(\widetilde{x}_j)$. One implication is that principals set prices and managerial incentives independent of the rival platform's quality choice. Hence, private information does not play any role. Based on (3.15) and (3.16) the first-order conditions yield the following profit maximizing prices

$$
\begin{aligned}
\widetilde{p}_i^B &= \frac{\widetilde{x}_i - (\alpha + \beta)\widetilde{p}_i^S}{2} \text{ and} \\
\widetilde{p}_i^S &= \frac{\beta\widetilde{x}_i - (\alpha + \beta)\widetilde{p}_i^B}{2t}.
\end{aligned}
\tag{3.17}
$$

Using Lemma 3.1 and maximizing expected profits over the contract parameters $\widetilde{b}_i$ according to (3.9), we get the following proposition.

Proposition 3.3. *When both buyers and sellers multi-home, there exists a unique equilibrium for the entire game. The equilibrium incentive is given by*

$$
\widetilde{b} = \frac{1}{2} \frac{2x}{m(4t - (\alpha + \beta)^2) - 2/k}
\tag{3.18}
$$

and each principal's expected equilibrium profit is

$$E(\widetilde{\pi}) = \frac{(x + \widetilde{b}/k)^2 + \sigma^2}{4t - (\alpha + \beta)^2} - \frac{m\widetilde{b}^2}{2k},$$

where $m = (1 + kr\sigma^2)$ is a parameter reflecting the agents' risk aversion.

Proof. See the Appendix.

In contrast to FSH and PSH, both equilibrium incentives and profits depend on the constant quality level, x. The higher x, the higher $\widetilde{b}$ and $E(\widetilde{\pi})$. Moreover, $\widetilde{b}$ does not only enter equilibrium profits via the agency cost. It also positively affects the platforms' expected gross profit. Both properties are due to the fact that each platform's profit function is independent of the rival's quality choice which is explained with the existence of multi-homing buyers. It follows that it is unnecessary to impose symmetry, i.e., $\widetilde{b}_i = \widetilde{b}_j$, at the first stage of the game when solving for equilibrium incentives.

3.5 The Effects of Competition and Indirect Network Externalities

We are now in the position to analyze the effects of competition and indirect network externalities on managerial incentives. For this purpose, we focus on the equilibrium piece rates, b, $\overline{b}$, and $\widetilde{b}$, which represent the share of quality enhancement a principal grants her agent as a variable payment. Put another way, the piece rates reflect the incentive platform i's principal gives her agent to exert effort, and thereby to increase quality for the buyers. Note that our findings can be directly transferred to platform i's quality level which enables us to characterize the effect of competition and indirect network externalities on platform quality.

We use the product differentiation parameters as measures for the level of competition, either on both sides of the market (FSH) or only on the buyers' side of the market (PSH and FSH). If t and τ, respectively, increases, then competition is reduced due to lower platform substitutability. The inverse is true if the parameters decrease. As a result, competition

becomes fiercer. Based on this reasoning, we ask how a marginal increase in competition for buyers and sellers, respectively, affects managerial incentives in equilibrium. Moreover, for the FSH case, we provide an analysis of the joint effect of t and τ on b, where we ask how a joint increase in competition for both buyers and sellers affects managerial incentives.

In recent papers, as Raith (2003) and Baggs and de Bettignies (2007), which deal with the effects of competition on managerial incentives, two opposing effects were used to characterize the findings: the *rent reduction effect* (RRE) and the *business stealing effect* (BSE).[17] The former is associated with lower incentives for managers to exert effort caused by a decrease in equilibrium prices. Hence, the RRE displays a negative sign when competition marginally increases. The latter unambiguously induces principals to give their agents stronger incentives. Due to higher demand elasticity, it becomes easier to increase market shares by exerting more effort, and to 'steal' some of the rival's demand. Thus, the BSE exhibits a positive sign when competition gets stronger.

In contrast to these papers, our setup comprises indirect network externalities. It follows that we have to derive the RRE and BSE for every side of the two platforms, i.e., the buyer side and the seller side. We find that the RRE can never be unambiguously identified, irrespective of the case and the side of the market, because it exhibits a negative sign in some cases. Given FSH or PSH, the BSE is clearly identified on the buyer side. Otherwise, it can take on both negative and positive signs. This observation leads us to the following lemma.

Lemma 3.2. *Due to indirect network externalities, the effects of competition on managerial incentives cannot be unambiguously characterized by the rent reduction effect and the business stealing effect.*

Proof. See the Appendix.

To illustrate our finding, we focus on competition for buyers measured by t and neglect

---

[17]Note that Raith (2003) uses the term 'scale effect' instead of *rent reduction effect*. Baggs and de Bettignies (2007) use the term 'increased business stealing effect' to describe the effect of increased competition on the marginal gain of higher quality on demand. However, we maintain the notion of *business stealing effect*.

competition on the seller side which is only relevant with FSH. Nevertheless, it can be easily demonstrated that the same results hold when competition for sellers gets tougher. For a more detailed discussion see the Appendix.

Using equilibrium profits as of stage 3, where quality levels are realized, we can calculate the first derivative with respect to x_i for each of the three cases to get the marginal effect of an increase in platform quality. Furthermore, we need to differentiate the profit functions with respect to t in order to examine the impact of increased competition for buyers on the marginal gain of quality provision:

$$
\frac{\partial^2 \pi_i}{\partial x_i \partial t} \quad | \quad x_i = x_j = \left[\frac{\partial^2 p_i^B}{\partial x_i \partial t} n_i^B + \frac{\partial p_i^B}{\partial t} \frac{\partial n_i^B}{\partial x_i} + \frac{\partial p_i^B}{\partial x_i} \frac{\partial n_i^B}{\partial t} + p_i^B \frac{\partial^2 n_i^B}{\partial x_i \partial t} \right] + \tag{3.19}
$$
$$
\left[\frac{\partial^2 p_i^S}{\partial x_i \partial t} n_i^S + \frac{\partial p_i^S}{\partial t} \frac{\partial n_i^S}{\partial x_i} + \frac{\partial p_i^S}{\partial x_i} \frac{\partial n_i^S}{\partial t} + p_i^S \frac{\partial^2 n_i^S}{\partial x_i \partial t} \right].
$$

Note that w_i does not appear in (3.19). We separate (3.19) into effects on the buyer side and effects on the seller side, presented in the first bracket and second bracket on the right-hand side of the equation, respectively. In each bracket, the first two terms represent the RRE, whereas the third and the fourth term constitute the BSE. Table 3.1 shows which sign the effects display in each case, where a '+' ('−') denotes a positive (negative) marginal effect of intensified competition for buyers, and a '0' stands for no effect.

Table 3.1: Effect of Competition on the Marginal Gain to Provide Quality

	Buyer Side				Seller Side			
	RRE		BSE		RRE		BSE	
	$\frac{\partial^2 p_i^B}{\partial x_i \partial t}$	$\frac{\partial p_i^B}{\partial t} \frac{\partial n_i^B}{\partial x_i}$	$\frac{\partial p_i^B}{\partial x_i} \frac{\partial n_i^B}{\partial t}$	$\frac{\partial^2 n_i^B}{\partial x_i \partial t}$	$\frac{\partial^2 p_i^S}{\partial x_i \partial t}$	$\frac{\partial p_i^S}{\partial t} \frac{\partial n_i^S}{\partial x_i}$	$\frac{\partial p_i^S}{\partial x_i} \frac{\partial n_i^S}{\partial t}$	$\frac{\partial^2 n_i^S}{\partial x_i \partial t}$
FSH	+/−	−	0	+	+/−	0	0	+/−
PSH	+/−	−	0	+	+/−	0	0	+/−
FMH	+/−	+/−	+/−	+	+/−	+/−	+/−	+

It can be immediately seen that, in almost any case, the two effects cannot be clearly identified. An exception builds the BSE on the buyer side given FSH and PSH, whereas the RRE is never strictly negative.

In a last step, we focus on the buyers' and sellers' marginal network benefits, and ask how a marginal increase in α and β individually affects managerial incentives in equilibrium. The reason for an increase in α and β can be investments in quality or in cost-reduction by the sellers which are studied by Belleflamme and Peitz (2010).[18] Referring to our framework, the relevant question is whether or not such investments induce agents to work harder, and thus to provide higher platform quality.

However, the ratio of the marginal network parameters also reflects the relative competitive situation between the two sides of the market from the platforms' view. Put another way, the ratio of α and β determines which side of the market is more 'important' for the platforms. For instance, if $\alpha < \beta$, then, all other things being equal, platform competition for buyers is fiercer in terms of price levels. It follows that buyers are more 'important' because they exert a stronger external effect on sellers than the other way around. Platforms seek for buyers in order to generate the relatively higher profits on the seller side. Hence, the ratio of the marginal network benefits plays a crucial role in determining relative platform competition.

We proceed as follows. For each case, we first analyze the marginal effects of intensified competition for buyers and sellers, respectively. Then, we concentrate on the effects of an increase in marginal network benefits, and study whether or not they push agents to exert more effort in equilibrium. We assume that buyers and sellers never exhibit identical marginal network benefits, i.e., $\alpha \neq \beta$, throughout the entire analysis. This assumption does not change our results, but it eliminates some uninteresting cases, when the effects of competition are analyzed. More precisely, we get rid of situations in which a marginal increase in competition has no effect on managerial incentives. This is true for all three

---

[18]Belleflamme & Peitz (2010) deal with sellers' incentives to invest in a two-sided markets setting. Their main focus is the impact of open platforms and profit-maximizing platforms on sellers' investment incentives based on a quiet general investment game. They suppose that sellers' investments in quality or cost-reduction increase both marginal network benefits, i.e., α and β. Furthermore, they present several examples serving as microfoundations for the link between sellers' investments and indirect network externalities.

cases.

3.5.1 Single-homing Buyers and Sellers (FSH)

When buyers and sellers single-home, then platforms 1 and 2 are differentiated from both groups' perspective. Thus, we separately analyze the impact of increased competition for both buyers and sellers on managerial incentives using marginal changes in t and τ as our relevant measures. Our findings on the individual effects of t and τ are presented in Proposition 3.4.

Proposition 3.4. *The marginal effects of t and τ on b are characterized by the following cases:*

i) Given that $\alpha < \beta$, stronger competition for buyers increases (decreases) managerial incentives if $\tau < \tau^*$ ($\tau > \tau^*$). The opposite holds for $\alpha > \beta$.

ii) Given that $\alpha < \beta$, stronger competition for sellers increases (decreases) managerial incentives if $t > t^*$ ($t < t^*$). The opposite holds for $\alpha > \beta$.

Proof. See the Appendix.

We demonstrate that whether or not managerial incentives are increased when competition for buyers and sellers, respectively, gets stronger, depends on the initial levels of competition t and τ as well on the relative magnitude of α and β. If sellers marginally benefit more from membership than buyers, i.e., $\alpha < \beta$ holds, then the initial level of competition for sellers must be sufficiently high so that agents are induced to exert more effort in equilibrium. Otherwise, equilibrium incentives are decreased. The converse is true in the case where buyers marginally benefit more than sellers, i.e., $\alpha > \beta$ holds. A corresponding reasoning holds for the marginal effect of τ on b.

Intuitively, the gross profit a platform realizes on the buyer side, given by $(1/2)(t - \beta)$, must not be to small compared to the gross profit realized on the seller side, $(1/2)(\tau - \alpha)$, for managerial incentives to increase. Hence, initial per group profits have to be balanced for competition to have a positive effect on equilibrium incentives. If they are not, in the

sense that e.g., gross profits on the seller side are sufficiently higher compared to the buyer side, then competition on either side negatively affects managerial incentives.

In a next step, we examine the joint effect of t and τ on b. Put another way, we ask how managerial incentives are affected when competition for both groups B and S gets stronger, i.e., both t and τ decrease. For that reason, we use the following measure

$$\phi_{t\tau} = \frac{\partial b}{\partial t} + \frac{\partial b}{\partial \tau}, \tag{3.20}$$

defined as the sum of the individual effects of t and τ on equilibrium incentives. If $\phi_{t\tau}$ is negative, then the joint effect is positive, and agents are induced to exert more effort in equilibrium. Otherwise, the joint effect is negative, i.e., $\phi_{t\tau} > 0$ holds.

We already know from Proposition 3.4 how t and τ individually affect b. It is shown that the effects of intensified competition for buyers and sellers, respectively, are not strictly positive. One can ask now whether the situation changes if competition on both sides of the market increases. Our results are established as follows.

Corollary 3.1. *Given $\alpha < \beta$, the joint effect of t and τ on managerial incentives is always positive if $\tau < \tau^*$. For $\tau > \tau^*$, the joint effect is positive (negative) if $t > t^{**}$ ($t < t^{**}$). The opposite holds for $\alpha > \beta$.*

Proof. See the Appendix.

The joint effect of increased competition crucially depends on the parameters α, β, t, and τ. Given $\alpha < \beta$, a positive individual effect of t dominates, so that managerial incentives are always increased, irrespective of the individual effect of τ. Whenever the individual effect of t is negative, i.e., $\partial b / \partial t > 0$ holds, it is only exceeded by a positive individual effect of τ if the initial level of competition for buyers is sufficiently low, i.e., $t > t^{**}$. The joint effect otherwise reduces managerial incentives. However, the same reasoning applies when individual effects were concerned. The relative profitability must be such that the (gross) profit on the buyer side is not too low for managerial incentives to increase.

Finally, we examine how a marginal increase of marginal network benefits affects managerial incentives. Proposition 3.5 presents our results.

Proposition 3.5. *The marginal effects of α on managerial incentives are characterized by the following cases:*

i) Given $\tau > \alpha$, an increase in α always increases managerial incentives if $(\alpha - \beta)$ and $[\tau - 1/2 (\alpha + \beta)]$ have the same sign. Otherwise, managerial incentives are increased (decreased) if $t > t^+$ $(t < t^+)$.

ii) Given $\tau < \alpha$, an increase in α always decreases managerial incentives if $(\alpha - \beta)$ and $[\tau - 1/2 (\alpha + \beta)]$ exhibit opposite signs. Otherwise, managerial incentives are increased (decreased) if $t < t^+$ $(t > t^+)$.

The corresponding results hold for the individual effects of β, except that α and β have to be interchanged, and a different critical value t^{++} applies.

Proof. See the Appendix.

Given that the level of competition on the seller side is relatively low, i.e., $\tau > \alpha$ holds, an increase in α induces managers to exert more effort if buyers initially enjoy a higher (lower) marginal network benefit than sellers, and competition for sellers is sufficiently low (high). In this case, it is ensured that the initial level of competition for buyers is sufficiently low, i.e., $t > t^+$ always holds. Otherwise, it can be also be that $t < t^+$ resulting in decreased managerial incentives. For relatively strong competition on the seller side, i.e., $\tau < \alpha$ holds,[19] the marginal effect of α is always negative if buyers initially enjoy higher (lower) marginal benefits from membership than sellers, and competition for sellers is sufficiently high (low). The reason is that, by concavity, $t > t^+$ always holds. Otherwise, i.e., $(\alpha - \beta)$ and $[\tau - 1/2 (\alpha + \beta)]$ display the same sign, the marginal effect can be positive given that the level of competition for buyers is sufficiently high, i.e., $t < t^+$.

Again, the platforms' relative profitability is crucial for making managers exert more effort in equilibrium. In the first case, $\tau > \alpha$, it must be that the gross profit on the buyer side is not too low compared with the seller side. In the second case, $\tau < \alpha$, the gross profit on the buyer side must not be too high compared to the seller side in order to get a

---

[19] Note that in such a scenario platforms make a loss on the seller side, since $\tau - \alpha$ is the price sellers' are charged in equilibrium.

positive marginal effect on b. Hence, the relative profitability must be such that platforms' per group profits are relatively balanced. Otherwise, managers are induced to work less hard in equilibrium.

Referring to our example of investments by sellers in quality or cost reduction as the origin for increases in α and β, we draw the conclusion that sellers' investments and platform quality can be either substitutes or complements. Thereby, the platforms' relative profitability determines whether or not sellers' investments marginally boost managerial incentives to increase quality.

3.5.2 Single-homing Buyers and Multi-homing Sellers (PSH)

When sellers multi-home, then their decision whether or not to join a platform is independent of joining the rival platform. Hence, platforms do not compete for sellers anymore, i.e., platforms are so called "competitive bottlenecks" from the sellers' perspective. The consequence is that multi-homing reduces our analysis to competition for buyers. The only measure of competition is now the transport cost buyers incur, t, when deciding which platform to join. We start with the analysis of the marginal effects of a decrease in t on managerial incentives. The following proposition summarizes our result.

Proposition 3.6. *A marginal increase in competition for buyers always increases managerial incentives.*

Proof. The first derivative of $\bar{b}$ with respect to t is given by

$$\frac{\partial \bar{b}}{\partial t} = -\frac{2\left(\alpha - \beta\right)^2}{m\left(8t - \alpha^2 - 6\alpha\beta - \beta^2\right)^2}. \tag{3.21}$$

We can immediately verify that (3.21) is always negative. The result follows immediately. $\blacksquare$

In contrast to FSH, managers are always induced to exert more effort when competition for buyers gets tougher. This result heavily relies on the platforms' bottleneck characteristic. Stronger competition on the buyer side always triggers principals to give their respective managers stronger incentives to exert effort, and thus to increase platform quality in equilibrium. Relative profitability, i.e., the relationship between each platform's per group gross

profits, does not play any role when sellers regard platforms as homogeneous.

In a next step, we examine the marginal effects of α and β on the managerial equilibrium incentive, $\bar{b}$. Our findings are presented by the following proposition.

Proposition 3.7. *The marginal effects of α and β on managerial incentives are characterized by the following cases:*

i) Given $\alpha > \beta$, an increase in α always increases managerial incentives. Given $\alpha < \beta$, managerial incentives increase (decreases) if $t < \bar{t}^*$ ($t > \bar{t}^*$).

ii) Given $\alpha < \beta$, an increase in β always increases managerial incentives. Given $\alpha > \beta$, managerial incentives increase (decrease) if $t < \bar{t}^{**}$ ($t > \bar{t}^{**}$).

Proof. See the Appendix.

When platforms initially subsidize sellers, i.e., they incur a loss on the seller side ($\alpha > \beta$), then a marginal increase in α always has a positive effect on $\bar{b}$. This result is regardless of the platforms' relative profitability. If, on the other hand, platforms realize profits on the seller side, i.e., $\alpha < \beta$, a marginal increase in α has only a positive effect if competition for buyers is sufficiently strong, i.e., $t < \bar{t}^*$. It follows that the profit on the buyer side has to be sufficiently low for managerial incentives to increase. Otherwise, principals have no incentive to push their managers to exert more effort. A corresponding reasoning holds for the marginal effect of β. However, relative profitability still matters, but only partially depending on whether or not platforms subsidize sellers. Interpreting an increase of α and β, respectively, as a result of investments by sellers, one implication is that sellers' investments and platform quality can be again either substitutes or complements. Hence, sellers' investments can have a negative or positive effect on managerial incentives.

3.5.3 Multi-homing Buyers and Sellers (FMH)

In contrast to the sellers, buyers still perceive the platforms as differentiated which is reflected by the positive transport cost parameter t. Apart from joining only one platform, buyers are now enabled to adopt both platforms at the same time realizing a gross utility given by (3.3). We start by asking how stronger competition affects equilibrium incentives,

$\widetilde{b}$. As in the PSH case, our analysis is reduced to competition on the buyer side measured by t. We obtain the following result.

Proposition 3.8. *A marginal increase in competition for buyers always increases $\widetilde{b}$.*

Proof. The marginal effect of t on $\widetilde{b}$ is calculated as

$$\frac{\partial \widetilde{b}}{\partial t} = -\frac{8xk^2m}{\left[mk\left(4t - (\alpha + \beta)^2\right) - 2\right]^2}. \tag{3.22}$$

It follows immediately that (3.22) is always negative, predicting a strictly positive effect of intensified competition on managerial incentives.

As before, with PSH, the relative profitability of the platforms is not decisive. Principals always induce their agents to exert more effort in response to stronger competition on the buyer side.

Finally, we examine the marginal effects of α and β on managerial incentives. The following proposition illustrates how increased indirect network externalities affect the incentives principals give their respective agents to provide higher quality.

Proposition 3.9. *A marginal increase of α and β, respectively, always induces managers to exert more effort.*

Proof. The marginal effects of α and β on $\widetilde{b}$ are identical. They are presented by

$$\frac{\partial \widetilde{b}}{\partial \alpha} = \frac{\partial \widetilde{b}}{\partial \beta} = \frac{4xk^2m(\alpha + \beta)}{\left[mk\left(4t - (\alpha + \beta)^2\right) - 2\right]^2},$$

where it is straightforward to check that, by definition, the numerator is always positive. Our result follows immediately.

Unlike in the previous cases, relative platform profitability is irrelevant for the effect of increased indirect network externalities on managerial incentives. If α and β, respectively, increases, then platform quality increases, too. In this case, investments by sellers in e.g., quality always trigger principals to give their managers stronger incentives to exert effort, and thus to increase platform quality from the buyers' view. It follows that sellers' investments and platform quality are complements when both buyers and sellers multi-home.

3.6   Discussion and Extensions

In this chapter, we exclusively focus on platform quality by introducing vertical product differentiation (given $\Delta_i \neq 0$) on the buyer side. In this sense, higher platform quality directly benefits the buyers, whereas the sellers indirectly benefit from platform quality through indirect network effects. One could also ask how are the platforms' incentives to provide quality on the seller side. Our model fits well to analyze this question if the focus is exclusively on the seller side rather than on the buyer side. We would only have to introduce vertical product differentiation on the seller side and derive the equilibria and marginal effects.

If one is interested in the interplay of platform quality provision on the buyer side and the seller side, we would have to extend our model by presuming that managerial effort also directly affects the sellers' (stand alone) utility from platform adoption. We could possibly use a framework in which each platform consists of one principal and two agents. One agent exerts effort to increase quality on the buyer side, while the other agent is responsible for platform quality on the seller side. Alternatively, we could assume that there is only one agent per platform who performs two tasks. Our model is not well suited to incorporate such extensions because the equilibrium values and marginal effects would be very complex and too difficult to interpret. A more general or reduced approach would be more appropriate.

A simplifying assumption, used in our model, is that the platforms' agents are symmetric with respect to their degree of risk aversion measured by r, and their efficiency when exerting effort denoted by k. We could extend our analysis by assuming asymmetric agents. While the calculations would become tedious, the corresponding results seem straightforward: the more efficient agent (or, alternatively, the less risk avert agent) would exert more effort. We would end up in an equilibrium where one platform offers higher quality and exhibits either higher market shares on both sides of the market or charges higher equilibrium prices or

both.[20]

In addition, we could examine the consequences of platforms facing different distribution functions of the random variable θ_i. Such an asymmetry would essentially lead to the same consequences as asymmetries concerning r and k. The derivation of the perfect Bayesian-Nash equilibria would, again, become more complex. To get unique equilibria one would have to apply the proposed methodology by Basar and Ho (1974) who allow for asymmetric oligopolies with private information.[21]

The wage function, w_i, is continuous in the expected quality level. This seems to be hardly met in reality where the agents' wage rather appears to be a discrete function of quality: agents do not receive a variable payment at all if they do not meet some quality requirements. Nevertheless, the basic principle is met; principals, e.g., editors, have to ensure that their agents, e.g., journalists, provide a certain quality level without being able to observe their agents' effort. If we reformulate the variable payment as a (partially) discrete decision, it is natural to modify the agents effort choice to be discrete as well. In this case, the entire analysis would get more tedious. At the same time, we would not generate new insights because our results would qualitatively remain the same.

Another extension, which could be performed, is to consider the choice of platform differentiation (or platform compatibility) as endogenous. Our framework can be used to derive hypotheses under which circumstances the platforms would have an incentive to become more compatible and more substitutable, respectively. For this purpose, we could use the expected equilibrium profits as of stage 1, i.e., given optimal managerial incentives, and differentiate them with respect to t and τ, respectively. For FSH and PSH, we can demonstrate that platforms never have an incentive to become more compatible.

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[20] Whether equilibrium market shares are higher or equilibrium prices or both depends on the groups' quality sensitivity.

[21] See also Sakai (1985) who examines the value of information in a Cournot duopoly based on the procedure proposed by Basar and Ho (1974). Thereby, the case of private information with asymmetric oligopolies is also analyzed.

In the FMH case, we were not able to find an analytical solution without imposing strong numerical restrictions on some parameters.[22]

Finally, one could claim that realized quality levels are not verifiable, so that it cannot be contracted upon. In that case, we would have to make use of output related measures such as profits or sales.[23] It seems natural to invoke profits or sales on the buyer side as the relevant performance measure, since managerial effort aims at increasing platform quality form the buyers' perspective. Moreover, we could compare to what extent different contractual designs affect managerial incentives. However, we leave his task for further research.

3.7 Conclusion

The present chapter deals with managerial incentives in two-sided markets where platforms compete for buyers and sellers. It has been shown that the effects of competition cannot be unambiguously characterized by the *rent reduction effect* and *business sealing effect.* It is rather the combination of each platform's relative profitability and the groups', B and S, adoption possibilities which shapes managerial incentives in equilibrium. The same holds for the effects of the marginal network benefit parameters, α and β. Thereby, we derive conditions under which sellers' investments in e.g., quality enhancement or cost reduction, and platform quality constitute substitutes or complements. We conclude that the existence of indirect network externalities leads to effects of competition on managerial incentives which cannot be explained by existing works such as e.g., Raith (2003) and Baggs and de Battignies (2007) focussing on 'one-sided' markets. Insofar, our analysis contributes to explain the 'mechanics' of competition in markets which are characterized by two-sided platforms such as e.g., newspapers, game consoles, search engines, or smartphones.

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[22] Detailed calculations can be requested from the author.

[23] See Raith (2008) for a recent paper which compares the effects of "input" measures and "output" measures when agents have specific knowledge of the output levels.

Moreover, we also extend the existing literature on two-sided markets by introducing an agency relationship within the platforms.

Appendix

Derivation of Assumption 3.1 and Assumption 3.2. We start with FSH. Principal i's profit in stage 4 is given by $\pi_i = p_i^B n_i^B \left(p_i^B, p_i^S, \Delta_i \right) + p_i^S n_i^S \left(p_i^S, p_i^B, \Delta_i \right) - w_i$. Using (3.6) we can calculate the Hessian with respect to p_i^B and p_i^S and its determinant which is given by

$$\det H_i = \frac{1}{4} \frac{4t\tau - (\alpha + \beta)^2}{(t\tau - \alpha\beta)^2}.$$

It can be immediately checked that $\det H_i$ is positive if $4t\tau - (\alpha + \beta)^2 > 0$. A positive $\det H_i$ in conjunction with the first entry of the Hessian given by $(-\tau)/(t\tau - \alpha\beta)$ establishes strict concavity of π_i in p_i^B and p_i^S, respectively, if $(-\tau)/(t\tau - \alpha\beta) < 0$ holds. The latter inequality is met because $4t\tau - (\alpha + \beta)^2 > 0$ implies $t\tau - \alpha\beta > 0$. Thus, the sufficient condition for π_i to be strictly concave is presented by Assumption 3.1.

In addition, we have to ensure that $E(\pi_i)$, i.e., principal i's expected profit which she maximizes in the first stage, is strictly concave in b_i. It can be easily checked that $\partial^2 E(\pi_i)/\partial b_i^2 < 0$ is always met for $k > 0$. Hence, $4t\tau - (\alpha + \beta)^2 > 0$ suffices to guarantee the existence of a unique market-sharing equilibrium for the entire game in the FSH case.

Next, we discuss the sufficient condition for the existence of a market-sharing equilibrium for the PSH case. In this case, concavity of stage 4 profits $\overline{\pi}_i$ is fulfilled if $8t - 6\alpha\beta - \alpha^2 - \beta^2 > 0$. This inequality ensures both a positive determinant of the Hessian, i.e. $\det H_i^{mh} > 0$, and negativity of the Hessian's first entry. The Hessian is calculated by using (3.11) and is given by

$$\det \overline{H}_i = \frac{1}{4} \frac{8t - 6\alpha\beta - \alpha^2 - \beta^2}{(t - \alpha\beta)^2}.$$

Moreover, it can be easily checked that concavity of $E(\overline{\pi}_i)$ is always implied since $k > 0$ holds by definition. Hence, the relevant condition is given by $8t - 6\alpha\beta - \alpha^2 - \beta^2 > 0$ which guarantees the existence of a unique market-sharing equilibrium for the entire game.

Finally, we demonstrate that $4t - (\alpha + \beta)^2 > 0$ is the sufficient condition for a unique market sharing equilibrium to exist in the FMH case. The determinant of the Hessian of

stage 4 profits with respect to $\widetilde{p}_i^B$ and $\widetilde{p}_i^S$ is

$$\det \widetilde{H}_i = \frac{1}{4} \frac{4t - (\alpha + \beta)^2}{(t - \alpha\beta)^2}.$$

The first entry of the Hessian is $(-2)/(t - \alpha\beta)$. Both criteria, a positive determinant and a negative first entry, are met if inequality $4t - (\alpha + \beta)^2 > 0$ holds which constitutes the sufficient condition formulated in Assumption 3.3.

Proof of Lemma 3.1. We apply the μ-σ-principle for the CARA utility function with a normally distributed random variable θ_i. Therefore, agent i's expected utility, $E(u_i)$, can be calculated as $E(u_i) = u_i(\mu_i - (1/2)r\sigma_i^2)$, where μ_i and σ_i^2 denote the expected value of w_i and the variance of w_i, respectively. This approach significantly simplifies the derivation of the certainty equivalent.

The agents simultaneously choose effort levels to maximize their expected utility which is identical with maximizing their certainty equivalent. The certainty equivalent in the single-homing case is given by

$$C_i = d_i + b_i e_i - \frac{k}{2} e_i^2 - \frac{1}{2} r b_i^2 \sigma^2, \tag{3.23}$$

where the term $(1/2)r b_i^2 \sigma^2$ represents agent i's risk premium. Maximizing (3.23) over e_i gives the optimal effort level presented in Lemma 3.1, i.e., $e_i = b_i/k$. Applying the same procedure for the two remaining cases, PSH and FMH, yields an optimal effort level of $\overline{e}_i = \overline{b}_i/k$ and $\widetilde{e}_i = \widetilde{b}_i/k$, respectively. It can be immediately verified that the structure of the optimal effort levels is identical in all three cases. However, one should keep in mind that the optimal piece rate, and thus the effort exerted differ dependent on the case we analyze, i.e., the adoption possibilities of B and S.

This completes the proof of Lemma 3.1.

Proof of Proposition 3.1. Given the market shares in (3.6) the principals choose prices

to maximize the following profit function in the fourth stage of the game

$$
\begin{aligned}
\pi_i \;=\;& p_i^B \Big(\frac{1}{2} + \frac{1}{2} \frac{\tau \left(E p_j^B \right) - p_i^B \right) + \alpha \left(E(p_j^S) - p_i^S \right) + \tau E(\Delta_i)}{t\tau - \alpha\beta} \Big) \\
& + p_i^S \Big(\frac{1}{2} + \frac{1}{2} \frac{\beta \left(E(p_j^B) - p_i^B \right) + t \left(E(p_j^S) - p_i^S \right) + \beta E(\Delta_i)}{t\tau - \alpha\beta} \Big) \\
& - w_i
\end{aligned}
$$

which yields the first order conditions presented by (3.8). Solving simultaneously, we get the equilibrium prices which are used to calculate equilibrium market shares. Platform i's expected profit as of stage 3, where quality levels are given, is presented by

$$
\begin{aligned}
E(\pi_i) \;=\;& \frac{1}{2(4t\tau - (\alpha+\beta)^2)} [\alpha^3 - \alpha^2(E(\Delta_i) + t + \tau - 3\beta) + \alpha(\tau(E(\Delta_i) - 4t - 2\beta) \quad (3.24) \\
& - \beta(E(\Delta_i) + 2t - 3\beta)) + 4t\tau^2 + \tau(2t(2t + E(\Delta_i)) - \beta(E(\Delta_i) + 4t) - \beta^2) \\
& - \beta^2(t - \beta)] - w_i,
\end{aligned}
$$

where $E(\Delta_i) = x_i - E(x_j)$ with $x_i = x + e_i + \theta_i$ and $E(x_j) = x + e_j$. Using Lemma 3.1, i.e., agent i's optimal effort choice, $e_i = b_i/k$, (3.24) can be rewritten, contingent on the managerial incentive, $E(\pi_i(b_i, E(x_j)))$. In the first stage, principals simultaneously maximize their expected profits over b_i. Since $b_i = \arg\max E(\pi_i(b_i, E(x_j)))$ is independent of $E(x_j)$, we do not need to impose symmetry, i.e. $b_i = b_j = b$, at this stage of the game to get the symmetric equilibrium incentives presented in Proposition 3.1. In addition, by invoking Assumption 3.1 we ensure that the symmetric equilibrium is the unique market-sharing equilibrium.

This completes the proof of Proposition 3.1.

Proof of Proposition 3.2. The procedure corresponds to the Proof of Proposition 3.1. The only differences are that platforms constitute competitive bottlenecks from the sellers perspective and that we need to make use of the symmetry assumption when deriving equilibrium incentives in the first stage of the game, i.e. $\bar{b}_i = \bar{b}_j = \bar{b}$. Moreover, Assumption 3.2 is invoked in order to guarantee existence and uniqueness of the symmetric market-sharing equilibrium.

This completes the proof of Proposition 3.2.

Proof of Proposition 3.3. The procedure corresponds to the Proof of Proposition 3.1. The only differences are that now both buyers and sellers multi-home and that each platform i's expected profits as of stage 3 of the game, $E(\widetilde{\pi}_i)$, are entirely independent of the rival's expected quality, $E(\widetilde{x}_j)$. The latter argument leads to the fact that symmetry does not have to be imposed at the initial stage of the game (as in the PSH case before). Moreover, Assumption 3.3 is invoked in order to guarantee existence and uniqueness of the symmetric market-sharing equilibrium.

This completes the proof of Proposition 3.3.

Proof of Lemma 3.2. We will only present the proof for the FSH case when competition for buyers becomes stronger, i.e., t marginally decreases. It is straightforward to calculate the BSE and RRE for the remaining cases. Note again that we need to make use of (3.19) which is presented by

$$
\frac{\partial^2 \pi_i}{\partial x_i \partial t} = \left[\frac{\partial^2 p_i^B}{\partial x_i \partial t} n_i^B + \frac{\partial p_i^B}{\partial t} \frac{\partial n_i^B}{\partial x_i} + \frac{\partial p_i^B}{\partial x_i} \frac{\partial n_i^B}{\partial t} + p_i^B \frac{\partial^2 n_i^B}{\partial x_i \partial t} \right] +
$$
$$
\left[\frac{\partial^2 p_i^S}{\partial x_i \partial t} n_i^S + \frac{\partial p_i^S}{\partial t} \frac{\partial n_i^S}{\partial x_i} + \frac{\partial p_i^S}{\partial x_i} \frac{\partial n_i^S}{\partial t} + p_i^S \frac{\partial^2 n_i^S}{\partial x_i \partial t} \right].
$$

Let us first focus on the RRE which is represented by the first and second term in each bracket. On the buyer side, the RRE can be calculated as

$$
\frac{\partial^2 p_i^B}{\partial x_i \partial t} = -\frac{2\tau \left(\alpha^2 - \beta^2 \right)}{\left(4t\tau - (\alpha+\beta)^2 \right)^2} , \frac{\partial p_i^B}{\partial t} \Big|_{x_i = x_j} = 1 ,
$$
$$
\frac{\partial n_i^B}{\partial x_i} = \frac{1}{2} \frac{(\alpha-\beta)^2}{(t\tau - \alpha\beta) \left(4t\tau - (\alpha+\beta)^2 \right)}.
$$

The first expression, $\partial^2 p_i^B / \partial x_i \partial t$, can be either positive or negative. If $\alpha > \beta$, then it is negative indicating a positive effect of competition on the marginal incentive to provide higher quality. If, in contrast, $\alpha < \beta$, then the opposite holds. The second component of the RRE, $\left(\partial p_i^B / \partial t \right) \left(\partial n_i^B / \partial x_i \right)$, always exhibits a positive sign resulting in a negative effect of increased competition. Hence, the overall RRE on the buyer side can be either negative or positive depending on the relative magnitude of α and β. The RRE on the seller side

can be calculated as

$$
\frac{\partial^2 p_i^S}{\partial x_i \partial t} = \frac{4\tau^2 (\alpha - \beta)}{\left(4t\tau - (\alpha + \beta)^2\right)^2} , \frac{\partial p_i^S}{\partial t}\Big|_{x_i = x_j} = 0 ,
$$

$$
\frac{\partial n_i^S}{\partial x_i} = \frac{1}{2} \frac{2t\tau\alpha - (\alpha + 2t\tau) + \beta^3}{(t\tau - \alpha\beta)\left(4t\tau - (\alpha + \beta)^2\right)} .
$$

The first expression, $\partial^2 p_i^S / \partial x_i \partial t$, is positive (negative) if $\alpha > \beta$ ($\alpha < \beta$). The second term is always equal to zero implying that stronger competition for buyers has no effect on the equilibrium price for sellers. The RRE on the seller side critically depends on the relative magnitude of α and β, and thus cannot be unambiguously characterized.

We now turn to the BSE. Simple algebra shows that the BSE on the buyer side can be presented by

$$
\frac{\partial^2 n_i^B}{\partial x_i \partial t} = -\frac{1}{2} \frac{\tau^2 (\alpha - \beta)^2 \left(8t\tau - \alpha^2 - \beta^2 - 6\alpha\beta\right)}{(t\tau - \alpha\beta)^2 \left(4t\tau - (\alpha + \beta)^2\right)^2} ,
$$

$$
\frac{\partial p_i^B}{\partial x_i} = \frac{2t\tau - \alpha\beta - \beta^2}{4t\tau - (\alpha + \beta)^2} , \frac{\partial n_i^B}{\partial t}\Big|_{x_i = x_j} = 0.
$$

The first expression, $\partial^2 n_i^B / \partial x_i \partial t$, always exhibits a negative sign which means that stronger competition for buyers always has a positive effect. However, the BSE's second component, $\left(\partial p_i^B / \partial x_i\right)\left(\partial n_i^B / \partial t\right)$, always equals zero so that no effect of increased competition on firm i's equilibrium market share can be identified. On the seller side, the BSE is calculated as

$$
\frac{\partial^2 n_i^S}{\partial x_i \partial t} = -\frac{1}{2} \frac{(\alpha - \beta)\tau \left(\beta^4 + 5\alpha\beta^3 - 8t\tau\beta^2 + 3\alpha^2\beta^2 - \alpha^3\beta - 8t\tau\alpha\beta + 8t^2\tau^2\right)}{(t\tau - \alpha\beta)^2 \left(4t\tau - (\alpha + \beta)^2\right)^2} ,
$$

$$
\frac{\partial p_i^S}{\partial x_i} = \frac{\tau (\beta - \alpha)}{4t\tau - (\alpha + \beta)^2} , \frac{\partial n_i^S}{\partial t}\Big|_{x_i = x_j} = 0.
$$

The second term of the BSE on the seller side, $\left(\partial p_i^S / \partial x_i\right)\left(\partial n_i^S / \partial t\right)$, is always equal to zero, i.e., stronger competition for buyers has no effect. However, the second component of the BSE, $\partial^2 n_i^S / \partial x_i \partial t$, is more complicated to analyze. It can be immediately seen that the denominator is always positive so that we have to concentrate on the numerator's sign. We

get two critical values (zeros) when examining the numerator:

$$t_1 = \frac{1}{2}\frac{\beta^2 + \alpha\beta - \frac{1}{2}\sqrt{2\beta\left(\beta^3 + 2\alpha\beta^2 - 2\alpha^2\beta + 2\alpha^3\right)}}{\tau} \quad \text{and}$$

$$t_2 = \frac{1}{2}\frac{\beta^2 + \alpha\beta + \frac{1}{2}\sqrt{2\beta\left(\beta^3 + 2\alpha\beta^2 - 2\alpha^2\beta + 2\alpha^3\right)}}{\tau}.$$

One can check that $t > t_1$ always holds by concavity (see Assumption 3.1). It follows that

the second zero is relevant. Checking with concavity again, it can be demonstrated that

$t > t_2$ is always implied by $\alpha > \beta$. Hence, the effect of competition is always positive,

i.e., $\partial^2 n_i^S / \partial x_i \partial t < 0$ holds, whenever $\alpha > \beta$. If, on the contrary $\alpha < \beta$, then increased

competition has a positive (negative) effect whenever $t < t_2$ ($t > t_2$) holds. Hence, the BSE

on the seller side can be either positive or negative depending on the relative magnitude of

α and β as well as on the initial level of competition for buyers, t.

This completes the proof of Lemma 3.2.

Proof of Proposition 3.4. The equilibrium managerial incentive (3.10) in Proposition

3.1 is given by

$$b = \frac{1}{2}\frac{\tau(2t - \beta) + \alpha(\tau - \beta) - \alpha^2}{m(4t\tau - (\alpha + \beta)^2)},$$

where $m = 1 + kr\sigma^2$ is a constant parameter indicating the agents' degree of risk aversion.

Taking the first derivative of (3.10) with respect to t, we get the following marginal effect

$$\frac{\partial b^*}{\partial t} = \frac{\tau\left(\alpha - \beta\right)\left(\alpha + \beta - 2\tau\right)}{m\left(4t\tau - (\alpha + \beta)^2\right)^2}. \tag{3.25}$$

If (3.25) is negative, then increased competition has a positive impact on managerial incen-

tives. If it is positive, then stronger competition exhibits a negative effect. It is straight-

forward to calculate the critical value $\tau^* = (1/2)(\alpha + \beta)$ for which the numerator in (3.25)

equals zero. In addition, we must distinguish two cases concerning α and β, namely $\alpha > \beta$

and $\alpha < \beta$, in order to fully characterize the sign of (3.25).

In a second step, we study the effect of increased competition for sellers, i.e., τ decreases,

on (3.10). The marginal effect of τ is presented by

$$\frac{\partial b^*}{\partial \tau} = \frac{1}{2}\frac{(\alpha + \beta)\left(\alpha - \beta\right)\left(t - \frac{1}{2}(\alpha + \beta)\right)}{m\left(4t\tau - (\alpha + \beta)^2\right)^2}. \tag{3.26}$$

As before, we must account for the two cases: $\alpha > \beta$ and $\alpha < \beta$. Calculating the zero of (??) yields a critical value given by $t^* = (1/2)(\alpha + \beta)$. Our results in Proposition 3.4 are established.

This completes the proof of Proposition 3.4.

Proof of Corollary 3.1. The joint competition effect defined by (3.20) is calculated as

$$\phi_{t\tau} = \frac{(\alpha - \beta)\left(2\beta(t + \tau) + 2\alpha(t + \tau - \beta) - 4\tau^2 - \alpha^2 - \beta^2\right)}{m\left(4t\tau - (\alpha + \beta)^2\right)^2}. \tag{3.27}$$

Inspection of (3.27) reveals that we have to consider two cases: $\alpha > \beta$ and $\alpha < \beta$. Furthermore, the critical value

$$t^{**} = \frac{\alpha^2 + 2\alpha(\beta - \tau) - 2\beta\tau + 4\tau^2 + \beta^2}{2(\alpha + \beta)}$$

is obtained for which $\phi_{t\tau}(t = t^{**}) = 0$ holds. As a preliminary result, it can be stated that the joint competition effect is positive (negative) if $t < t^{**}$ ($t < t^{**}$), given $\alpha > \beta$. The opposite holds for $\alpha < \beta$. Explicit consideration of Assumption 3.1, which postulates that $t > (1/4\tau)(\alpha + \beta)^2$ holds, specifies that t^{**} is only relevant if $\tau > (1/2)(\alpha + \beta)$. In this case, t can be larger or smaller than t^{**}. Hence, it is implied by concavity that the transport cost parameter, t, is always larger than t^{**} if $\tau < (1/2)(\alpha + \beta)$.

This proves our results in Corollary 3.1.

Proof of Proposition 3.5. We use the first derivatives of b with respect to α and β which are given by

$$\frac{\partial b}{\partial \alpha} = -\frac{1}{2}\frac{\alpha(2\beta^2 - 4t\tau + 2\beta\tau) + \alpha^2(\beta + \tau) + \beta^3 + 4t\tau^2 - 3\beta^2\tau}{m\left(4t\tau - (\alpha + \beta)^2\right)^2} \tag{3.28}$$

and

$$\frac{\partial b}{\partial \beta} = -\frac{1}{2}\frac{\alpha^2(3\tau - 2\beta) - \alpha\beta(\beta - 2\tau) - \beta^2\tau - 4t\tau^2 + 4\beta t\tau - \alpha^3}{m\left(4t\tau - (\alpha + \beta)^2\right)^2}, \tag{3.29}$$

to evaluate the marginal effects on managerial incentives. Since the denominators of (3.28) and (3.29) are always positive, we have to determine the sign of the numerators. We begin with the marginal effect of α presented in (3.28). The numerator must be less than zero so

that α has a positive marginal effect on b. Otherwise, managerial incentives are negatively affected. A critical value in terms of the initial level of competition for buyers, t, can be calculated which is given by

$$t^+ = \frac{2\alpha\beta\tau + 3\beta^2\tau - \alpha^2(\beta + \tau) - 2\alpha\beta^2 - \beta^3}{4\tau(\tau - \alpha)}.$$

Depending on whether τ is larger or smaller than α, we find that t must be larger and smaller, respectively, for the marginal effect of α to be positive. Checking with concavity postulated by Assumption 3.1, it can be demonstrated that t^+ is irrelevant only if $(\alpha - \beta)$ and $(\alpha + \beta - 2\tau)$ have the same sign, i.e. $t > t^+$ always holds by concavity. If, in contrast, $(\alpha - \beta)$ and $(\alpha + \beta - 2\tau)$ exhibit opposite signs, then the consequences of $t > t^+$ and $t < t^+$ have to be analyzed.

The same procedure is performed with regards to the marginal effect of β on b. In this case, we find the following critical value

$$t^{++} = \frac{2\alpha\beta\tau + 3\alpha^2\tau - \beta^2(\alpha + \tau) - 2\alpha^2\beta - \alpha^3}{4\tau(\tau - \beta)},$$

which differs from t^+ only in the way that α and β are interchanged. Depending on whether τ is larger or smaller than β, it is found that t must be smaller and larger, respectively, for (3.29) to be positive. Accounting for concavity, it can be easily checked that t^{++} is irrelevant if $(\beta - \alpha)$ and $(\alpha + \beta - 2\tau)$ display the same sign. Hence, $t > t^{++}$ always holds in that case. Otherwise, i.e., $(\beta - \alpha)$ and $(\alpha + \beta - 2\tau)$ exhibit opposite signs, the consequences of $t > t^{++}$ and $t < t^{++}$ have to be considered.

This proves Proposition 3.5.

Proof of Proposition 3.7. The equilibrium incentive in (3.13) is given by

$$\bar{b} = \frac{t - \alpha\beta}{m(4t - 3\alpha\beta - \frac{1}{2}(\alpha^2 + \beta^2))}.$$

Calculating the first derivative of $\bar{b}$ with respect to α

$$\frac{\partial \bar{b}}{\partial \alpha} = \frac{2\beta^3 - \beta(4t + 2\alpha^2) + 4\alpha t}{m\left(8t - \alpha^2 - 6\alpha\beta - \beta^2\right)^2}$$

gives us the marginal effect of α on managerial incentives in the PSH case. Since the denominator is always positive, we need to check whether the numerator's sign. If it is positive (negative), then the marginal effect is positive (negative). Simple algebra gives the following critical value

$$\bar{t}^* = \frac{1}{2}\beta(\alpha + \beta),$$

for which $\partial \bar{b}/\partial \alpha = 0$ holds if $t = \bar{t}^*$. Moreover, we have to consider two cases: $\alpha > \beta$ and $\alpha < \beta$. For $\alpha > \beta$, we find that managerial incentives are positively (negatively) affected if $t > \bar{t}^*$ ($t < \bar{t}^*$). The opposite is true for $\alpha < \beta$. Accounting for concavity postulated by Assumption 3.2, we find that $t > \bar{t}^*$ is always implied if $\alpha > \beta$. It follows that the critical value, $\bar{t}^*$, is irrelevant in this case. However, if $\alpha < \beta$, we have to account for $\bar{t}^*$.

The same procedure is performed with regards to the marginal effect of β which is

$$\frac{\partial \bar{b}}{\partial \beta} = \frac{2\alpha^3 - \alpha(4t + 2\beta^2) + 4\beta t}{m\left(8t - \alpha^2 - 6\alpha\beta - \beta^2\right)^2}.$$

The critical value is given by

$$\bar{t}^{**} = \frac{1}{2}\alpha(\alpha + \beta).$$

Note that both the marginal effect and the critical value of β are entirely identical with those of α, if the marginal network benefits α and β are interchanged.

The results in Proposition 3.7 follow immediately.

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Part II

Antitrust and Regulation

Chapter 4

An Equilibrium Analysis of Efficiency Gains from Mergers

4.1   Introduction

Ever since Williamson's (1968) seminal paper on the "welfare trade-offs" the efficiency defence has been heralded by economists as an essential element of a competition policy which seriously takes into account economic thinking (see e.g., Neven and Röller, 2002 for the EU).[1] In the US, the horizontal merger guidelines of the FTC and the DOJ, as amended in April 1997, state that "the primary benefits of mergers to the economy is their potential to generate efficiencies." Yet, there is not much evidence that the efficiency defense has been a success story.[2] Röller (2011) provides a survey of the recent EU merger decisions and concludes that "efficiencies have not played a major role in phase II EU merger evaluations since 2004." More precisely, Röller (2011) surveys all phase II merger cases since May 2004, when the new EU merger guidelines came into force which explicitly allow for an efficiency defence. He reports that only in 5 out of 37 cases efficiencies were claimed. Quite remarkably, the Commission accepted efficiencies only in two cases, while they were never decisive for the final decision. Both practical and economic reasons have been delivered for that observation (see Motta and Vasconcelos, 2005). Specifically, Röller (2011) argues that the merging parties' may run into danger of signalling a "weak" case, i.e., a merger which is mostly anticompetitive, when claiming efficiencies.

A correct assessment of efficiencies should be based on a comparison of what would happen with and without a merger.[3] In the former scenario, two questions become important: first, whether claimed efficiencies are verifiable, and second, whether efficiencies are sub-

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[1] Efficiencies were introduced explicitly into the US Merger Guidelines in 1997 (Section 4), and into the European Merger Guidelines in 2004 (EC Horizontal Merger Guidelines, 2004/03, Article 77). See Ilzkovitz and Meiklejohn (2003) for an assessment from the Commission's perspective.

[2] See Röller, Stennek, and Verboven (2001), and Camesasca (1999) who report that the US authorities have been very reluctant to take efficiencies into account. Yet, federal courts did so, though most times the defence was either not critical or was rejected.

[3] See Farrell and Shapiro (2001) who emphasize that the comparison of the "with merger" and "without merger" cases is critical for the assessment of efficiencies which are not synergies.

stantial, and thereby, making an otherwise anticompetitive merger procompetitive. We will assume that the answer to the first question is positive. The answer to the second question critically depends on the size of the efficiencies and the competitive situation before and after the merger.

The analysis of the "without merger" scenario becomes critical when claimed efficiencies do not qualify as synergies.[4] This is typically the case when the merging parties' gain from scale economies or benefit from rationalization; e.g., in the form of joint distribution and logistic centers. No-synergy efficiencies are in principle also realizable without a merger through so-called internal growth. Quite intuitively, one would expect a merger to be not desirable (both from a social or consumer welfare perspective) if claimed efficiencies are likely to be realized without the merger taking place. That kind of reasoning is mirrored in competition law and practice in the form of the additional requirement that claimed efficiencies must be *merger specific*. The merger specificity requirement, therefore, adds a new counterfactual to merger analysis which asks whether or not efficiencies are likely to be implemented *without* the merger.[5] In the following, the term efficiencies is used to denote efficiencies which are *not* synergies.

In conjunction with the requirement that efficiencies have to be merger specific, a claimed efficiency must also be classified as verifiable and beneficial to consumers. If these three criteria are cumulatively met, then a claimed efficiency will be accepted by antitrust authorities according to both the EU and the US merger guidelines. Since we do not focus

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[4] According to Farell and Shapiro (1990) synergies are the result of the joint use of merging firms' specific assets (see also Farrell and Shapiro, 2001). When claimed efficiencies are synergies, then a merger is necessary for their realization. As a consequence, synergies by definition cannot be realized without the merger.

[5] We agree with Farrell and Shapiro's (2001) view that changing market environments and technological progress make a forward looking "without merger" analysis necessary to take all relevant information into account. By doing so, we also reject Hausman and Leonard's (1999) position which declares the counterfactual as unnecessary because no-synergy efficiencies should have been implemented *before* the merger. Thus, if they have not been implemented before the merger, they are always classified as merger specific according to Hausman and Leonard (1999).

on issues concerning verifiability, we assume for simplicity that this criterion is always met. In addition, claimed efficiencies must benefit consumers. One can also say that claimed efficiencies must be substantial in the sense that consumers are not worse off after the merger.

In this chapter, the main focus will be on merger specificity.[6] Based on a without merger and with merger comparison, which explicitly takes the counterfactual into account, we provide two formalizations of merger specificity. Thereby, we assume that efficiencies result from the implementation of a more efficient technology which can be adopted *with* and *without* the merger. It follows that efficiencies in our context are never classified as synergies, although they possibly violate the definition of *mergers with no synergies* offered by Farrell and Shapiro (1990, p.112).[7] However, we endogenize the decision to realize efficiencies where the adoption problem is specified to be discrete. This is especially relevant when the no-merger case, i.e., the counterfactual, is analyzed. Then, firms simultaneously and non-cooperatively decide whether or not to implement the more efficient technology. The outcome of this adoption game is crucial for deciding whether or not efficiencies can be classified as merger specific. Using a technology adoption approach as the source of efficiencies has not been analyzed so far. On top of that, we specify the merger decision itself to be endogenous and followed by the adoption decision.

We use a standard Cournot oligopoly model for analyzing the social welfare effects of

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[6] For example, the US merger guidelines define merger specific efficiencies as follows: "The Agencies credit only those efficiencies likely to be accomplished with the proposed merger and unlikely to be accomplished in the absence of either the proposed merger or another means having comparable anticompetitive effects. These are termed merger-specific efficiencies."

[7] This is true if the more efficient technology is adopted in the merger case, but would not be adopted without the merger, although adoption is possible. In that case, the production technology changes with the merger so that, according to Farrell and Shapiro (1990), efficiencies would be classified as synergies. The reason for that discrepancy lies in the technology adoption decision which will be discussed in more detail later.

a merger which creates efficiencies in the form of variable cost reductions.[8] Moreover, we focus on the unilateral effects of a merger between firms which face more competitive (and with that, larger) firms.[9] This allows us to distinguish between a catch-up merger and a merger to dominance. In the former case, the merging parties' joint post-merger market share is always smaller than the market share of the largest non-merging firms. In the latter case, in contrast, the merging parties obtain the largest market share in the industry.

We proceed in three steps. First, we treat efficiencies as exogenous; that is, we assume that a certain efficiency arises as a result of the merger.[10] Second, we suppose that efficiencies are endogenous so that the merging firms can decide to implement the efficiency jointly (merger case) or independently (no-merger case). This enables us to examine whether or not a claimed efficiency is merger specific. Third, we analyze the entire three-stage game (full game) where firms can decide to merge at the initial stage, while the remaining stages consist of the implementation of the efficiency, and finally, product market competition. The analysis of the full game puts us in a position to study whether proposed mergers are accompanied by merger specific efficiencies and an approval by a welfare maximizing antitrust authority. In addition, we take a closer look at the current practice. We ask whether or not the efficiency defence improves antitrust authorities' decisions on proposed mergers compared with a social welfare standard which always considers efficiencies when realized.

Our main result under exogenous efficiencies is that there is a non-monotone relationship between efficiencies and social welfare. This result critically depends on considering a catch-up merger. More precisely, a merger among relatively small firms can reduce social welfare whenever efficiencies are moderate, i.e., neither too small nor too large. The reason is that

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[8] That is, we focus on static efficiencies which do not require R&D and innovations. See Röller (2011) for the distinction between static and dynamic efficiency considerations in EU competition policy.

[9] We call two firms being non-dominant if their combined pre-merger market shares are smaller than 50 percent. This mirrors roughly the practice adopted by the EU Commission.

[10] Actually, this is what much of the literature beginning with the seminal paper by Farrell and Shapiro (1990) has been doing. Clearly, this approach implicitly assumes that efficiency gains are merger specific.

for moderate efficiencies a catch-up merger reduces overall productive efficiency by reducing the more efficient, i.e., dominant firms' market shares. We note that this result casts doubt on works which propose a monotone relationship between social welfare and efficiencies (as, for instance, Williamson, 1968, Farrell and Shapiro, 1990, and Besanko and Spulber, 1993). In addition, it contrasts with the supposition that efficiencies are more likely to be taken into account by competition authorities when the concentration effect of the merger is not too large, i.e., when the merging parties' market share is relatively small.[11]

In the second part, we analyze endogenous efficiencies. We compare the incentives to implement an efficiency in case of a merger with the incentives in the no-merger case. In the latter case, we consider an adoption game in which the merger candidates decide simultaneously and non-cooperatively about the implementation of a particular efficiency. We define efficiencies to be merger specific if the merged firm's incentive does not fall short of the independent firm's incentive in the no-merger case.

We characterize cases where incentives are larger when no merger occurs. This is more likely to be the case, the stronger the competition among non-dominant firms for the adoption of the efficiencies becomes. Intuitively, when competition for the implementation of an efficiency enhancing technology is strong, then each of the merger candidates aims for it, while the size of the market allows only one firm to profitably implement the efficiency.

Next, we investigate the entire game where the non-dominant firms decide about the merger at an initial stage. This allows us to study the selection process behind the merger proposals which finally reach the competition authority. Our analysis reveals that firms are most likely to find a merger profitable when the efficiencies are not merger specific, i.e., whenever firms' incentives are larger to implement the efficiencies without a merger. Accordingly, in those instances, where firms can claim merger specific efficiencies, they do

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[11] For instance, the US Horizontal Merger Guidelines (2010, Section 10) state: "In the Agencies' experience, efficiencies are most likely to make a difference in merger analysis when the likely adverse competitive effects, absent the efficiencies, are not great. Efficiencies almost never justify a merger to monopoly or near-monopoly."

not find it profitable to merge in the first place. Finally, we show that a decision rule, requiring that claimed efficiencies have to be substantial and merger specific (substantial plus specific test (SST)), leads to both type I and type II errors compared with a social welfare standard not containing an efficiency defence. We take those results as indicative that the high expectations in an efficiency defence in merger control have been frustrated. In short, the efficiency defence appears to be largely superfluous, when all elements of merger control are taken in to account: first, the profitability of the merger proposal, second, a proper analysis of the specificity of claimed efficiencies, and finally, the decision rule of the authority.

Our model contributes to both the analysis of unilateral effects and efficiencies in merger control (see, for a survey, Röller, Stennek, and Verboven, 2001). That literature did not analyze the conditions under which claimed efficiencies are merger specific. Rather, it has been focusing on characterizing critical levels claimed efficiencies should pass to make a merger beneficial for consumers and (or) welfare.[12] A common assumption has been that the efficiencies under consideration were assumed to be merger specific, or, in the parlance of Farrell and Shapiro (1990), are of the synergy type. This approach was also taken by Cheung (1992) who provided an example highlighting the idea that a merger of relatively inefficient firms may reduce social welfare.[13] Banal-Estanol, Macho-Stadler, and Seldeslachts (2008) analyze endogenous synergies. However, they examine complementary resources which allow the merged entity to realize larger efficiencies, and they focus on the interplay between the implementation of efficiencies and stable market structures. Lagerlöf and Heidhues (2005) study how costly information acquisition by the merging parties affects the costs

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[12] See Farrell and Shapiro (1990) and McAfee and Williams (1992). That literature also derived the so-called 50 percent rule which says that (under reasonable assumptions) a merger is welfare increasing if the merging parties' combined pre-merger market share is not larger than 50 percent. For a more recent contribution see Goppelsroeder, Schinkel, and Tuinstra (2008) and Nocke and Whinston (2010).

[13] Relatedly, Zhao (2001) has shown that a marginal reduction of a firm's marginal cost reduces social welfare in an asymmetric Cournot oligopoly whenever the firm's market share is sufficiently small.

and benefits associated with an efficiency defense. Amir, Diamantoudi, and Xue (2009) analyze how uncertainty about efficiencies on the competitors' side affects the profitability and social desirability of a merger.

The remainder is organized as follows. In Section 4.2, we present our basic model. In Section 4.3, we analyze the welfare effects of a horizontal merger with exogenous efficiencies. In Section 4.4, we introduce endogenous efficiencies and analyze the full game. In Section 4.5, we examine the substantial plus specific test from a welfare perspective. Finally, extensions to our model are presented in Section 4.6. Section 4.7 concludes the chapter.

4.2 The Model

We use a (linear) Cournot oligopoly model with homogeneous products which is characterized by the following elements: *i)* A fixed number of firms indexed by $i = 1, ..., N$, *ii)* a linear (inverse) demand schedule $p(Q) = A - Q$, and *iii)* constant marginal costs $MC_i \geq 0$. Firms compete in Cournot style; i.e., they set their output levels $q_i \geq 0$ with $Q := \sum_i q_i$ non-cooperatively and simultaneously.

Given that all firms are active, equilibrium quantities are given by

$$q_i^* = \frac{A - N \cdot MC_i + \sum_{j \neq i} MC_j}{N + 1}. \tag{4.1}$$

In the following, we specify $N = 4$ and consider a market structure with two largest ("dominant") firms and two smallest ("non-dominant") firms indexed by $d = 1, 2$ and $n = 3, 4$, respectively.[14] Total quantity Q is the sum of firms' individual outputs q_i. Let $Q := \sum q_d + \sum q_n$.

We focus on a merger between firms which are initially not dominant. This allows us to distinguish two cases: *first*, a catch-up merger, and *second*, a merger to dominance.

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[14]Our main point is to focus on the merger effect in the presence of dominant (i.e., large) firms. We examine the effects of a merger among firms which are sufficiently large (so that oligopolistic interaction is an appropriate approximation of real world firm interaction). We call these firms initially non-dominant, though competition law is likely to screen them as anticompetitive. More specifically, under EU legislation, those firms may be seen as dominant, or their merger may give rise to the creation of a dominant position.

It is convenient to assume $MC_d = a$ and $MC_n = a + c$, with $0 < a < A$, and to set $A - a = 1$.[15] Then, we obtain the normalized marginal costs $c_1 = c_2 = 0$ and $c_3 = c_4 =: c$ for the dominant and the non-dominant firms, respectively. For that purpose, we invoke the following assumption which we maintain throughout the entire analysis.

Assumption 4.1. *The dominant firms have marginal costs $c_1 = c_2 = 0$ and the non-dominant firms have positive marginal costs $c_3 = c_4 = c$, with $c \in [0, 1/3)$.*

Using formula (4.1), the dominant firms' joint equilibrium market share is strictly larger than 50 percent for any $0 < c < 1/3$.[16] For the interpretation of our analysis, it is instructive to note that the joint market share of firms 3 and 4 is strictly decreasing in c.[17] That is, we can interpret c as an indicator of firms' market shares in the no-merger case.[18]

A merger may lead to efficiencies. We focus on efficiencies which directly impact on competition among firms. Efficiencies come as marginal cost reductions, parameterized by $s > 0$, so that post-merger marginal costs are $c - s$. We assume that efficiencies are not too large, so that the initially dominant firms always remain active in the market.

Assumption 4.2. *Efficiencies, s, fulfill $0 < s \leq 1/2$, so that the initially dominant firms remain always active in equilibrium.*

A necessary prerequisite for realizing s is the implementation of a more efficient technology which comes at some fixed cost $F > 0$. We focus on the question whether efficiencies are merger specific or not. Therefore, we propose to analyze this issue by comparing firms' incentives to implement the efficiency with and without a merger. We consider an efficiency

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[15] In an extension to our basic model, we drop the last assumption, i.e., $A - a = 1$, to analyze how market expansion (decline) and technical progress (decline) affect equilibria.

[16] The parameter constraint $c < 1/3$ implies that the non-dominant firms produce strictly positive outputs.

[17] Precisely, using (4.1) the joint market share of firms 3 and 4 is given by the expression $(1 - 3c)/(2 - c)$ which is strictly decreasing in c.

[18] This view is consistent with the competition authorities' practice, since pre-merger market shares are typically used as a first screening devise for market power and for the likely adverse merger effects.

claim only as merger specific if the merger increases the incentives to carry out the efficiency. More precisely, we distinguish two definitions of merger specificity.

Definition 4.1. (weak merger specificity). *A claimed efficiency is weakly merger specific if the merged firm has a strictly larger incentive to implement s than any individual non-dominant firm without the merger.*

The assessment of whether or not claimed efficiencies are weakly merger specific is based on a comparison of adoption incentives with a merger with firms' individual incentives without a merger. One can argue that it might be very challenging in practice to calculate adoption incentives due to information asymmetries, unavailability of data, etc. We, therefore, provide an alternative, less informational demanding, definition.

Definition 4.2. (strong merger specificity). *A claimed efficiency is strongly merger specific if the efficiency is only adopted with the merger. That is, each non-dominant firm does not find it profitable to implement s individually.*

With Definitions 4.1 and 4.2 at hand, we can analyze whether claimed efficiencies are indeed merger specific. For that purpose, we consider a three-stage game which consists of a merger stage, a technology adoption stage, and finally, a competition stage. More precisely, in the first stage, the non-dominant firms 3 and 4 decide whether or not to merge. In the second stage, either the merged entity (if firms 3 and 4 merged in the previous stage) or firms 3 and 4 independently (if they did not merge in stage 1) decide whether or not to adopt an efficiency enhancing technology which reduces marginal costs by s. In the third stage, all firms observe the decisions in the previous periods and compete à la Cournot. Given our assumptions, subgame perfect strategies in the last stage follow from applying formula (4.1).

We proceed in two steps. In a first step, we analyze the effect of a merger when efficiencies are exogenous. In a second step, we shift our focus on endogenous efficiencies which allows us to analyze merger specific efficiencies. By letting firms 3 and 4 decide about the merger at the initial stage, we examine the subgame perfect equilibrium of the entire game, and the

effects on social welfare. Furthermore, in Section 4.5, we compare a decision rule requiring efficiencies to be both substantial and merger specific (substantial plus specific test (SST)) with a social welfare standard allowing for all realized efficiencies.

4.3 Merger Analysis with Exogenous Efficiencies

Assuming that a merger between the non-dominant firms leads to efficiency gains s, we compare the pre-merger equilibrium with the post-merger equilibrium.[19] Before the merger, the dominant and the non-dominant firms maximize their profits $\pi_d = p(Q)q_d$ and $\pi_n = (p(Q) - c)q_n$, respectively. Using (4.1), we obtain the firms' pre-merger equilibrium quantities $q_d^* = (1 + 2c)/5$ and $q_n^* = (1 - 3c)/5$, where a single asterisk indicates equilibrium values in the no-merger case. Assumption 4.1 implies that, before the merger, the non-dominant firms' joint market share is always smaller than the dominant firms' joint market share.

When firms 3 and 4 merge, they realize efficiency gains denoted by s. We use the subscript "m" to refer to the merged entity. The merged firm's profit function is then given by $\pi_m = p(Q)q_m - (c - s)q_m$. Proceeding as before, we obtain the equilibrium quantities $q_d^{**} = (1 + c - s)/4$ and $q_m^{**} = [1 - 3(c - s)]/4$, where two asterisks indicate the equilibrium values after merger. It immediately follows that efficiencies reduce the dominant firms' quantities, whereas they increase the merged firm's output.

Given firms' quantities, we obtain the equilibrium values of firms' profits, consumer surplus, CS, and social welfare, SW, both before and after the merger (social welfare is defined as the sum of firms' profits and consumer surplus). We define the change of the merging firms' profits, the dominant firms' profits, consumer surplus, and social welfare due to the merger by $\Delta\pi_m := \pi_m^{**} - 2\pi_n^*$, $\Delta\pi_d := \pi_d^{**} - \pi_d^*$, $\Delta CS := CS^{**} - CS^*$, and $\Delta SW := SW^{**} - SW^*$, respectively.

The following proposition shows how the profitability of the merger, its external effect on

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[19] In this section, we abstract from any costs of implementing the efficiencies. This will be an issue below, where we compare the incentives to adopt the efficiency in case of merger and in case of no merger.

the competitors, and its impact on consumer surplus depend on the realized efficiencies.[20]

Proposition 4.1. *Depending on the efficiency level, s, of the merger, there exist unique critical values $0 < \widehat{s}(c) < \widetilde{s}(c) < 1/2$ such that the following orderings hold:*

i) If $s < \widehat{s}(c)$, then $\Delta \pi_m < 0$, $\Delta \pi_d > 0$, and $\Delta CS < 0$.

ii) If $\widehat{s}(c) < s < \widetilde{s}(c)$, then $\Delta \pi_m > 0$, $\Delta \pi_d > 0$, and $\Delta CS < 0$.

iii) If $\widetilde{s}(c) < s$, then $\Delta \pi_m > 0$, $\Delta \pi_d < 0$, and $\Delta CS > 0$.

Equality, $\Delta \pi_m = 0$ and $\Delta \pi_d = \Delta CS = 0$, holds for $s = \widehat{s}(c)$ and $s = \widetilde{s}(c)$, respectively. The critical values, $\widehat{s}(c)$ and $\widetilde{s}(c)$, are both monotonically decreasing.

Proposition 4.1 states that consumers and the merged entity are better off if efficiencies are substantial which corresponds to the case where $s > \widetilde{s}(c)$. Only in those instances the dominant firms' profits decrease. For intermediate efficiencies, $\widehat{s}(c) < s < \widetilde{s}(c)$, both the dominant firms and the merged firm benefit, but consumer surplus is reduced. Finally, the dominant firms realize higher profits, while consumers and the merged entity are harmed due to the merger if the efficiency level is sufficiently small, i.e., $s < \widehat{s}(c)$.

Proposition 4.1 mirrors the observation that a merger is generally more likely to be approved the smaller the merging parties' market shares and the larger the efficiency gains.[21] For instance, the relationship between efficiencies and the likelihood of approval is stated explicitly in US Horizontal Merger Guidelines: "The greater the potential adverse competitive effect of a merger, the greater must be the cognizable efficiencies, and the more they must be passed through to customers, for the Agencies to conclude that the merger will not have an anticompetitive effect in the relevant market."

We next address the question how social welfare changes when the two non-dominant firms merge.

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[20] All proofs are provided in the Appendix.

[21] A common observation in empirical studies is that "the probability of a phase-2 investigation and of a prohibition of the merger increases with the parties' market shares" (see, for instance, Bergman, Jakobsson, and Razo, 2005).

Proposition 4.2. *A merger, which gives rise to exogenous efficiencies, affects social welfare in the following way:*

i) If $c < 9/107$, then there exists a unique critical value $\widetilde{\widetilde{s}}(c)$ such that social welfare strictly increases (decreases) for $s > \widetilde{\widetilde{s}}(c)$ ($s < \widetilde{\widetilde{s}}(c)$). Equality holds at $s = \widetilde{\widetilde{s}}(c)$.

ii) If $9/107 < c < (5\sqrt{23} - 1)/322$, a merger always increases social welfare.

iii) If $c > (5\sqrt{23}-1)/322$, then there exist two critical values $\underline{s}(c)$ and $\overline{s}(c)$, with $\underline{s}(c) < \overline{s}(c)$, such that $\Delta SW < 0$ for $s \in (\underline{s}(c), \overline{s}(c))$, while the opposite is true for $s < \underline{s}(c)$ or $s > \overline{s}(c)$. Equality holds at $s = \underline{s}(c)$ and $s = \overline{s}(c)$. Moreover, $\underline{s}(c)$ is monotonically decreasing, and $\overline{s}(c)$ is monotonically increasing.

Proposition 4.2 shows that the pre-merger market shares of the non-dominant firms are important for assessing the welfare effects. Case *i)* mirrors the more standard result that relatively large pre-merger market shares, which is implied by c being relatively small, raise the bar for the efficiency level. In that case, social welfare can only increase if the efficiencies are large enough. Otherwise, the negative impact on consumer surplus and the merged entity's profit outweighs the positive external effect on the rival dominant firms' profits. The relevant threshold value, $\widetilde{\widetilde{s}}(c)$, is identified for both catch-up mergers and mergers to dominance.

However, this reasoning is not valid anymore when we consider mergers of smaller firms, i.e., $c > 9/107$ starts to hold. Case *ii)* shows that there is a region of intermediate pre-merger market shares in which any merger among non-dominant firms, i.e., catch-up merger and merger to dominance, is desirable. In that area, the efficiency gain is either sufficiently small, so that the dominant firms' gain outweighs the loss in consumer surplus, or the efficiency gain is large enough, so that the consumers benefit outbalances the dominant firms' losses. Yet, case *iii)* highlights the surprising insight that mergers among rather small firms are much more complex. It reveals that a non-monotone relationship is also possible when catch-up mergers are considered, i.e., $s \leq c$ holds. If pre-merger market shares are small, then efficiency gains must be sufficiently low or high, so that a catch-up merger becomes welfare improving. In that parameter region, moderate efficiency levels are indicative of a

welfare reducing merger. Intuitively, if realized efficiencies are small, a catch-up merger has only little influence on the dominant firms' profit levels and consumer surplus. Hence, for small efficiencies the merger is likely to be welfare improving as it increases the merging firms' efficiency. If the efficiency is sufficiently large, i.e., $s > \bar{s}(c)$ holds, then the increase in consumer surplus and in the merging firm's profit outweigh the loss incurred by the dominant competitors. For the case of moderate efficiencies, $\underline{s} < s < \bar{s}$, both consumer surplus and the merging firms' joint profit increase. Yet, both effects together do not suffice to compensate for the dominant firm's relatively large profit reduction. Hence, social welfare decreases if efficiency gains are in that area because of the merger's negative effect on overall productive efficiency. Note again, that such an outcome depends crucially on considering catch-up mergers, i.e., mergers among firms which still face more efficient (and hence, larger) rivals after the merger.

Finally, comparing Propositions 4.1 and 4.2 shows that an increase of consumer surplus does not necessarily imply an increase in social welfare, whenever catch-up mergers between small firms are prevalent. We, therefore, undermine the presumption that the monotonicity of ΔCS with regards to s also holds for social welfare, ΔSW, as promoted in e.g., Besanko and Spulber (1993). Our results indicate that the introduction of an efficiency defence does not necessarily tend to improve social welfare.

4.4 Merger Analysis with Endogenous Efficiencies

We now solve the entire three-stage game. Given the optimal strategies in the last stage of the game, which are given by (4.1), we first have to consider two subgames in the second stage of the game: the no-merger subgame and the merger subgame. In the following subsection, we start by analyzing the non-dominant firms' incentives to adopt a new technology to realize efficiencies given the initial merger decision. In the merger subgame, the merged entity decides whether or not to adopt the new technology, while in the no-merger subgame each non-dominant firm individually decides about adoption. Subsequently, we analyze the merger decision at the initial stage of the game. This allows us to examine the

subgame-perfect equilibrium of the entire game. Moreover, we are able to check whether or not proposed catch-up mergers are accompanied by merger specific efficiencies and an approval when a social welfare maximizing antitrust authority is considered.

4.4.1 Endogenous Efficiencies and Merger Specificity

Depending on the non-dominant firms' decision whether or not to merge in the first stage of the game, we have to consider two subgames: the merger subgame and the no-merger subgame. In each subgame, the non-dominant firms decide about the implementation of a new technology which reduces marginal cost by s and comes at a cost of F. We denote the strategies "adopt" and "not adopt" by A and NA, respectively.

Adoption incentives in the merger subgame. The merged entity implements the new technology if the profit increase does not fall short of the adoption costs, F. In case of adoption, the merged firm's equilibrium output is $q_m^{**}(A) = [1 - 3(c - s)]/4$, where the argument A indicates the adoption of the efficiency enhancing technology. If the merged firm abstains from implementing the efficiencies, then its equilibrium output is $q_m^{**}(NA) = [1 - 3c)]/4$. Clearly, the merged firm implements the efficiency if

$$\phi_m := \pi_m^{**}(A) - \pi_m^{**}(NA) \geq F, \qquad (4.2)$$

where ϕ_m measures the adoption incentive of the merged firm. Straightforward calculations show that (4.2) implies an upper bound for F.

Lemma 4.1. *A merger of the non-dominant firms leads to adoption of the efficiency by the merged entity if and only if $F \leq \phi_m$ holds, with $\phi_m = 3s\left[2 + 3(s - 2c)\right]/16$. Moreover, $\phi_m > 0$, $\partial\phi_m/\partial s > 0$, and $\partial\phi_m/\partial c < 0$.*

Lemma 4.1 shows that the merged firm's incentive to implement the efficiency is increasing in the efficiency level, but decreasing in its initial efficiency level represented by c. The latter property follows from noticing that the implementation of the efficiency is generally more profitable when the competitive disadvantage vis-à-vis the dominant firms decreases.

In the following, we assume that the merged firm always has a strong incentive to adopt the efficiency, i.e., we restrict ourself to values of F such that $F < \phi_m$ holds.[22]

Adoption incentives in the no-merger subgame. In the no-merger subgame, firms 3 and 4 independently decide about the adoption of the efficiency, s. Again, each firm has two pure strategies "adopt" and "not adopt." If a firm decides to adopt, its marginal cost is reduced by s at a cost of F. If a firm does not adopt, its marginal cost remains at the level of c.

A firm's equilibrium output depends on both its own adoption decision, k, as well on the other non-dominant firm's adoption decision, k', with $k, k' = A, NA, r$. We write firm n's output, $q_n(k, k')$, and profit, $\pi_n(k, k')$, as a function of its own adoption decision, k, and the rival non-dominant firm's adoption decision, k'.[23] We consider both pure strategies and mixed strategies. In the latter case, a firm selects a probability distribution $(A, NA; r, 1-r)$, where r is the probability of adoption, and $1 - r$ is the counter probability. To proceed in a parsimonious way, we use r to indicate both the probability of adoption and the entire probability distribution. Below, we also use the pair (r, r) as representing the mixed strategy equilibrium.

Table 4.1 illustrates the technology adoption subgame where π_n^* and $\pi_{n'}^*$ are the subgame perfect equilibrium profits of the non-dominant firms depending on their adoption decisions.[24]

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[22] This assumption simplifies our analysis because it allows us to abstract from parameter constellations (s, c, F) under which the efficiency is not adopted by the merged entity, but by (at least) one of the non-dominant firms.

[23] For instance, $\pi_3(NA, A)$ denotes the profit of firm 3 if firm 3 does not adopt, while firm 4 adopts.

[24] The equilibrium profits stated in Table 4.1 are presented in the Appendix (Proof to Lemma 4.2).

Table 4.1: Technology Adoption Subgame (No-merger Case)

Firm n \ Firm n'	A	NA
A	$\pi_n^*(A, A) - F,\ \pi_{n'}^*(A, A) - F$	$\pi_n^*(A, NA) - F,\ \pi_{n'}^*(NA, A)$
NA	$\pi_n^*(NA, A),\ \pi_{n'}^*(A, NA) - F$	$\pi_n^*(NA, NA),\ \pi_{n'}^*(NA, NA)$

The following lemma states the subgame perfect equilibria of the adoption game depicted in Table 4.1.

Lemma 4.2. *In the no-merger case, the adoption game gives rise to the following (subgame perfect) equilibria:*

i) If $F < \pi_n^*(A, A) - \pi_n^*(NA, A)$, then (A, A) is the unique equilibrium.

ii) If $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$, then there are two pure equilibria, (A, NA) and (NA, A).

iii) If $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$, then there exists a unique mixed strategy equilibrium (r, r). The equilibrium mixed strategy, r, is monotonically decreasing in F, approaches one at the lower bound, and goes to zero at the upper bound.

iv) If $\pi_n^*(A, NA) - \pi_n^*(NA, NA) < F$, then the unique Nash equilibrium is (NA, NA).

For $F = \pi_n^*(A, A) - \pi_n^*(NA, A)$ all equilibria of cases i) and ii) exist, and for $F = \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ all equilibria of cases ii) and vi) exist. Moreover, $\pi_n^*(A, A) - \pi_n^*(NA, A) < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ holds always.

The equilibria stated in Lemma 4.2 are intuitive. The implementation of the efficiency enhancing technology is most attractive for the "first" firm adopting the technology. It is still attractive to implement the efficiency as a "second" firm (given that F is small enough), though the profit differential is smaller than in the former case, i.e., the orderings $0 < \pi_n^*(A, A) - \pi_n^*(NA, A) < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ hold. Hence, cases *i)* and *iv)* are straightforward. In case *i)*, both firms adopt as long as the fixed costs are small enough. In case *iv)*, the fixed costs are prohibitive so that none of the firms adopts. In the intermediate range of cases *ii)* and *iii)*, F is such that only a single firm can profitably adopt the efficiency enhancing technology with probability one. This gives rise to two pure strategy equilibria

and a unique mixed strategy equilibrium. In the mixed strategy equilibrium, the probability of adoption decreases monotonically when F increases.

We are now a position to analyze the incentives to adopt the efficiency in the no-merger case. We do so by focusing on *equilibrium incentives*. In other words, we examine a firm's *unilateral* incentive given that the other firm sticks to its equilibrium strategy. Our incentive measure is the difference between the equilibrium profit level and the hypothetical profit level in case of committing not to adopt the efficiency.

We obtain the following adoption incentives, $\phi_n^{k,k'}$, depending on the cases *i)-iv)* stated in Lemma 4.2. In case *i)*, the adoption equilibrium is (A, A). Hence, in equilibrium the adopting firm obtains the profit $\pi_n^*(A, A)$. If a firm commits not to adopt, it obtains $\pi_n^*(NA, A)$, while the other firm still adopts the efficiency in equilibrium. We, therefore, obtain $\phi_n^{A,A} := \pi_n^*(A, A) - \pi_n^*(NA, A)$.

In case *ii)*, only one firm adopts in equilibrium.[25] The equilibrium profit of the adopting firm is $\pi_n^*(A, NA)$. If that firm commits not to adopt, then its profit becomes $\pi_n^*(NA, A)$ because the other firm's best response is to adopt. Hence, our incentive measure becomes $\phi_n^{A,NA} := \pi_n^*(A, NA) - \pi_n^*(NA, A)$.

In case *iii)*, both firms adopt with some probability $r > 0$. Hence, a firm realizes the expected (equilibrium) profit $\pi_n^*(r, r)$ which must be equal to $\pi_n^*(A, r)$.[26] Note that $\pi_n^*(A, r)$ includes the fixed adoption costs, so that gross equilibrium profits are $\pi_n^*(A, r) + F$. If a firm commits not to adopt, then the other firm plays a best response which is to adopt for sure; that is, the hypothetical profit in case of choosing not to adopt is $\pi_n^*(NA, A)$.[27] Taking that

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[25] The equilibrium outcome in case *ii)* of Lemma 4.2 is either (A, NA) or (NA, A). In the following, we use the former, (A, NA), to denote that case.

[26] The mixed strategy equilibrium requires that a player is indifferent between his pure strategies. Hence, $\pi_n^*(A, r) = \pi_n^*(NA, r) = \pi_n^*(r', r)$ always holds given the other firm plays the equilibrium mixed strategy.

[27] Recall that the parameter regions of case *ii)* and case *iii)* in Lemma 4.2 are identical. That is, if the mixed strategy equilibrium exists, then the pure strategy equilibria, (A, NA) and (NA, A), also exist (and vice versa).

together, incentives in the mixed strategy equilibrium are $\phi_n^{r,r} := \pi_n^*(A, r) + F - \pi_n^*(NA, A)$.[28]

If case *iv)* applies, then the fixed cost of technology adoption, F, is such that in equilibrium each of the non-dominant firms does not have an incentive to implement the efficiency. Thus, case *iv)* represents the only candidate for strong merger specificity to emerge (according to Definition 4.2). Existence depends on whether or not values of F are feasible such that only in the merger scenario technology adoption is profitable, i.e., $\pi_n^*(A, NA) - \pi_n^*(NA, NA) < F \leq \phi_m$ must hold. The following result shows that such a constellation is possible.

Proposition 4.3. *There exists a critical value $\widehat{s}(c)$, with $\widehat{s}(c) := 22(1 - 3c)/31$, such that $\pi_n^*(A, NA) - \pi_n^*(NA, NA) < \phi_m$ holds for all $s < \widehat{s}(c)$. Hence, efficiencies are strongly merger specific if $s < \widehat{s}(c)$ and $F \in (\pi_n^*(A, NA) - \pi_n^*(NA, NA), \phi_m)$. In all other cases, efficiencies are never strongly merger specific. Moreover, $\widehat{s}(c)$ is monotonically decreasing in c and goes to zero as c approaches $1/3$.*

Proposition 4.3 shows that strong merger specificity can only occur if efficiencies are not too large, i.e., $s < \widehat{s}(c)$. Only if that condition is met, then there are values of F such that the efficiency is adopted in the merger case, but not in the no-merger case. If, otherwise, efficiencies exceed $\widehat{s}(c)$, then they are adopted anyway; that is , they will be implemented without the merger which makes those efficiencies not strongly merger specific.

This relationship highlights a logical flaw in the current formulation of the efficiency claim in competition law. It is logically flawed to require that efficiencies have to be both sufficiently large *and* merger specific. If the first requirement holds, then the second requirement is hard to meet as well. If the merging parties try to make a case for large efficiencies to be realized in case of a merger, then it is doubtful that claimed efficiencies are indeed merger specific, since there are large incentives to implement those "highly promising" efficiencies anyway.

We now analyze weak merger specificity by comparing the incentives to adopt the ef-

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[28] In case *iv)*, none of the two firms has a positive incentive to adopt the efficiency, i.e., $\phi_n^{iv)} := \pi_n^*(A, NA) - \pi_n^*(NA, NA) < 0$ holds.

ficiency in the case of a merger (Lemma 4.1) with the incentives which follow from the adoption game in case of no merger (Table 4.1). In the latter case, we have to distinguish the cases *i)-iv)* according to Lemma 4.2. We say that efficiencies are weakly merger specific if adoption incentives are larger in the merger case, ϕ_m, than in the no-merger case, $\phi_n^{k,k'}$, i.e., inequality

$$\Psi^{k,k'} := \phi_m - \phi_n^{k,k'} > 0 \qquad (4.3)$$

holds, where $\Psi^{k,k'}$ stands for the difference of both incentive measures depending on the adoption game outcome. Our results are presented in the following proposition.[29]

Proposition 4.4. *Suppose $F < \phi_m$. Whether or not efficiencies are weakly merger specific depends on the adoption equilibria in the case of no merger:*

i) If (A, A), then $\Psi^{A,A} > 0$ always holds.

ii) If (A, NA), then $\Psi^{A,NA} < 0$ always holds.

iii) If (r, r), then there exists a critical value $\widetilde{F}(c, s)$ such that $\Psi^{r,r} > 0$ ($\Psi^{r,r} < 0$) holds for $F < \widetilde{F}(c, s)$ ($F > \widetilde{F}(c, s)$). Equality holds at $F = \widetilde{F}(c, s)$. Moreover, $\partial \widetilde{F}(c, s)/\partial s > 0$.

iv) If (NA, NA), then $\Psi^{NA,NA} > 0$ always holds.

Finally, equality, $\Psi^{k,k'} = 0$, holds at $F = \pi_n^*(A, A) - \pi_n^*(NA, A)$ and at $F = \pi_n^*(A, NA) - \pi_n^*(NA, NA)$.

Case *iv)* of Proposition 4.4 mirrors the result of Proposition 4.3. Focusing on the remaining three cases of Proposition 4.4, we find that efficiencies are less likely to be (weakly) merger specific the larger the fixed adoption cost become. For low levels of F, case *i)* shows that efficiencies are always weakly merger specific, while for larger values of F case *ii)* reveals that the opposite becomes true. Finally, this ordering is also reflected in case *iii)* where the mixed strategy equilibrium holds in the adoption game. Again, for relatively small values of F, efficiencies are weakly merger specific, whereas the opposite holds for larger values of

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[29]To understand the ordering in the following proposition, it is instructive to note that $\phi_m > \phi^{A,A}$ is always true. The sign of $\phi_m - \phi^{NA,NA}$ follows from Proposition 4.3 which can be both positive or negative. By assuming that $F < \phi_m$, we do not consider cases where $\phi_m < F < \phi^{NA,NA}$. As mentioned above, in those instances the efficiency is only adopted in the absence of a merger.

F. That case also shows that merger specific efficiencies are more likely to occur when the level of the efficiency increases.

4.4.2 Merger Incentives and Endogenous Efficiencies

We are now in a position to analyze the full game. We focus on cases where $F < \phi_m$, so that it is always profitable for the merged entity to adopt the efficiency. In the first stage of the game, the two non-dominant firms decide whether or not to merge. To derive the subgame perfect equilibrium, we have to calculate the net profits in the merger case, $\Pi_m(A) := \pi_m^{**}(A) - F$, and in the no-merger case, $\Pi_n^{k,k'}$. The latter profit level depends on the equilibria of the adoption game (cases *i)-iv)* of Lemma 4.2). We say that firms have strict merger incentives if

$$\theta^{k,k'} := \Pi_m(A) - \left[\Pi_n^{k,k'} + \Pi_{n'}^{k',k}\right] > 0, \ n \neq n', \ k \neq k'$$

holds, i.e., the merged entity's net profit is larger than the sum of the non-dominant firms' profits, contingent on the outcome of the adoption game. The following proposition gives the subgame perfect equilibria of the entire game.

Proposition 4.5. *Suppose $F < \phi_m$. The non-dominant firms' merger decision depends on the equilibrium outcome in the no-merger subgame as follows:*

i) If (A, A), then there exists a critical value F' such that $\theta^{A,A} > 0$ ($\theta^{A,A} < 0$) for all $F > F'$ ($F < F'$), whenever $s > s_I(c)$, with $F' := -[\pi_m^*(A) - 2\pi_n^*(A, A)]$. If, otherwise, $s < s_I(c)$, then $\theta^{A,A} < 0$ holds for all feasible F.

ii) If (A, NA), then there exist critical values $s_K(c)$ and $s_L(c)$, with $s_K(c) < s_L(c)$, such that $\theta^{A,NA} < 0$ for $s < s_K$ or for $s > s_L$, while $\theta^{A,NA} > 0$ holds for $s_K < s < s_L$. Moreover, $s_K(c)$ and $s_L(c)$ are monotonically decreasing.

iii) If (r, r), then there exists a critical value $\widetilde{\widetilde{F}}(c, s)$ such that $\theta^{r,r} > 0$ ($\theta^{r,r} < 0$) holds for $F < \widetilde{\widetilde{F}}(c, s)$ ($F > \widetilde{\widetilde{F}}(c, s)$), whenever $s > s_I(c)$. If, otherwise, $s < s_I(c)$, then $\theta^{r,r} < 0$ holds for all feasible F.

iv) If (NA, NA), then $\theta^{NA,NA} < 0$ always holds.

Proposition 4.5 shows that merger incentives critically depend on the efficiency level and the adoption costs. In case $i)$, sufficiently large efficiencies are a necessary requirement for a merger to occur. If efficiencies are large enough, then large fixed costs are sufficient to induce a merger. In that region, it is the possibility to save fixed adoption costs which makes the merger attractive. Put another way, there are no gains from a purely monopolizing merger, i.e., $\pi_m^*(A) - 2\pi_n^*(A, A) < 0$ is always true.[30] Hence, the gain from saving fixed costs must offset that loss. For that to occur in the parameter range of case $i)$, the level of efficiency gains must be sufficiently large, as otherwise, a large value of F would change the adoption equilibrium.

The desire to save adoption costs through a merger also explains case $iv)$ of Proposition 4.5. In that region, firms do not adopt the efficiency in the no-merger case, while the efficiency is possibly implemented in case of a merger. Hence, incentives to save adoption costs by merging businesses are completely absent. It follows that firms decide to stay independent. From Proposition 4.3 we know that only this area gives rise to strongly merger specific efficiencies. However, by Proposition 4.5, we infer that this area should not play any role in merger control, since there will be no merger proposals.

Turning to case $ii)$, it is instructive to examine the decision rule for a merger which becomes

$$\theta^{A,NA} = \pi_m^{**}(A) - [\pi_n^*(A, NA) + \pi_n^*(NA, A)]. \tag{4.4}$$

Equation (4.4) does not include fixed adoption costs which cancel out because only one firm incurs them in the no-merger case. Case $ii)$ of Proposition 4.5 shows that the sign of $\theta^{A,NA}$ is negative for small and for large efficiencies, while it is positive for intermediate values of s. If efficiencies are quite small, then the merger is not profitable because of the dominant firms' response to increase their output. This is basically mirroring the so-called 80 percent rule according to Salant, Switzer, Reynolds (1983) which says that a merger in a linear Cournot oligopoly is not profitable if the merging parties' joint pre-merger market share falls short of that threshold. When the level of efficiencies increases, then the profit

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[30]This result relies on the well known merger paradox analyzed by Salant, Switzer, and Reynolds (1983).

of the merged firm tends to increase faster than the sum of profits in case of no merger. However, this relationship is reversed when efficiencies become very large.

Case *iii)* can be seen as a combination of the results presented in cases *i)* and *iv)*. If fixed adoption costs are large, then adoption is less likely in the mixed strategy equilibrium of the adoption game, so that possible gains from fixed cost savings disappear. Hence, for large enough F, merger incentives are absent. If, however, F becomes smaller, the probability of adoption increases in the no merger case equilibrium. Hence, fixed cost savings become important, so that a merger is attractive. Proposition 4.5 also states that the parameter range for a profitable merger increases when the level of the efficiency increases. In that sense, a merger becomes more likely in that area for increasing efficiencies.

Finally, we analyze the impact of a merger on social welfare. This allows us to examine the socially efficient merger decision an antitrust authority should apply for a proposed merger.[31] Given a social surplus rule, a merger is only approved if social welfare is larger after the merger when compared with the equilibrium emerging in case of no merger. For such an analysis it is critical to foresee the outcome of the adoption game as stated in Lemma 4.2. The comparison, therefore, depends on the cases *i)-iv)* of Lemma 4.2. Accordingly, we define $\Delta SW^{k,k'} := SW^{**} - F - SW^{k,k'}$, where SW^{**} stands for social welfare in the merger case (as defined in Section 4.3), and $SW^{k,k'}$ denotes social welfare (net of fixed adoption costs) in no-merger case depending on the equilibria of the adoption game. The antitrust authority approves a proposed merger whenever $\Delta SW^{k,k'} \geq 0$. It should be noted that the comparison of social welfare for the no adoption equilibrium (case *iv)* of Lemma 4.2) differs from Proposition 4.2 due to the existence of adoption costs, F. In the following proposition,

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[31]It might be questioned whether competition authorities follow a social welfare standard because many countries apply something close to a consumer standard (see Whinston, 2007). Yet, Neven and Röller (2005) show that if firms can lobby efficiently, then an authority with a consumer standard will end up maximizing social welfare (i.e., the sum of firms' profits and consumer surplus). Finally, we note that the debate is not fully settled yet. For instance, Farrell and Katz (2006) and Rosch (2006) discuss the pros and cons of a "total welfare" standard. Relatedly, Renckens (2007) argues that a total welfare standard is better suited than the consumer surplus standard for an effective merger control.

we present our results.

Proposition 4.6. *Suppose $F < \phi_m$. The welfare effects of a merger depend on the outcome of the adoption game, and hence, F as follows:*

i) If $F < \pi_n^*(A, A) - \pi_n^*(NA, A)$, then there exists a critical value $s_N(c, F)$ such that $\Delta SW^{A,A} > 0$ ($\Delta SW^{A,A} < 0$) for $s < s_N(c, F)$ ($s > s_N(c, F)$). Moreover, $s_N(c, F)$ is monotonically increasing in F.

ii) If $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ and considering the pure strategy equilibria in the adoption game in case of no merger, then there exist critical values $s_P(c)$ and $s_L(c)$, with $s_P(c) < s_L(c)$, such that $\Delta SW^{A,NA} > 0$ holds for $s_P(c) < s < s_L(c)$, while $\Delta SW^{A,NA} < 0$ holds for $s < s_P(c)$ and $s > s_L(c)$.

iii) If $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ and considering the mixed strategy equilibrium in the adoption game in case of no merger, there exists a critical value $s_R(c)$ at the lower bound of F such that $\Delta SW^{r,r} > 0$ for $s > s_R(c)$, while $\Delta SW^{r,r} < 0$ holds for $s < s_R(c)$. Moreover, $\Delta SW^{r,r}$ is monotonically decreasing in F.

iv) If $F > \pi_n^*(A, NA) - \pi_n^*(NA, NA)$, then the welfare effects of a merger correspond to our findings in Proposition 4.2 under the constraint that $s < \widehat{\widehat{s}}(c)$. Note that the non-monotonicity is preserved. For $s > \widehat{\widehat{s}}(c)$ the condition $F < \phi_m$ no longer holds.

Proposition 4.6 shows how a merger has to be evaluated from a social welfare perspective. For an appropriate assessment it is critical to examine the adoption game in the no-merger case, and thus to explicitly account for the counterfactual. Then, the merger's impact on social welfare depends not only on parameters c and s, but also on the adoption game outcome, and hence, F.

Given that (A, A) is the adoption game outcome, then a merger only increases social welfare if the efficiency level is sufficiently small, i.e., $s < s_N(c, F)$ holds. Moreover, this constraint becomes less binding when F increases due to fixed cost duplication. When only one non-dominant firm adopts the technology in equilibrium, (A, NA), then social welfare is only increased for intermediate efficiency levels, i.e., $s_P(c) < s < s_L(c)$. Otherwise, the merger should not be approved. Given that firms 3 and 4 play mixed strategies, (r, r), we

find that efficiencies must be larger than $s_R(c)$ for welfare to increase in equilibrium. Furthermore, we state that the area of feasible combinations of c and s is decreasing if the cost of adoption raises within the relevant interval. The last case where both non-dominant firms choose not to adopt in equilibrium is identical with our findings in Proposition 4.2, except that we have to account for the restriction $s < \widehat{s}(c)$ due to the existence of adoption costs. Qualitatively, our findings from Proposition 4.2 are maintained. The non-monotonicity of social welfare in c and s again appears to be specific for catch-up mergers.

4.4.3 Comparison of Results

We now compare our findings on the welfare effects with those on merger specificity given that firms 3 and 4 decide to merge. The presumption that the non-dominant firms choose to merge in equilibrium is important, since it reduces our analysis to merger proposals which constitute the necessary prerequisite for antitrust authorities to become active by performing a competitive appraisal. The comparison enables us to check whether or not welfare enhancing mergers are accompanied by merger specific efficiencies. It should be noted that we implicitly suppose that the merging firms always claim efficiency gains if they propose a merger, i.e., strategic efficiency claims are neglected for the moment. Moreover, it is assumed that the antitrust authority follows a social welfare standard without accounting for merger specificity. It rather accepts every efficiency gain realized by the merging firms. Table 4.2 summarizes our results from Propositions 4.4 to 4.6.

Table 4.2: Merger Decision, Merger Specificity, and Social Welfare

Adoption Outcome (no-merger case)	Merger? (Prop. 5)	Merger Specificity? (Prop. 3 & 4)	$\Delta SW > 0$? (Prop. 6)
(A, A)	possible, if s large	always	yes, if s small
(A, NA)	yes, for intermediate s	never	yes, for intermediate s
(r, r)	possible, if s large	yes, if F small	yes, if s large
(NA, NA)	never	always	see case iv)

Given (A, A) and a merger proposal, efficiencies are always merger specific, but the merger is only approved for sufficiently low s. In this case, a welfare improving merger is always accompanied by merger specific efficiencies. Note that not every proposed merger leads to welfare improvements. Turning to case *ii)*, claimed efficiencies are never merger specific, but a proposed merger is almost always socially desirable. Given (r, r), proposed mergers are not always accompanied by merger specific efficiencies. It follows that not every approved merger exhibits efficiencies which meet the criterion of merger specificity. The main insights are summarized in Remark 4.1.

Remark 4.1. (A, NA) *and* (r, r) *reflect cases in which welfare enhancing merger proposals are not accompanied by merger specific efficiencies. More precisely, if* (A, NA)*, then merger proposals are never accompanied by merger specific efficiencies, while in* (r, r) *proposals do not necessarily imply merger specific efficiencies.*

The reader should note that the only case for strong merger specificity efficiencies is (NA, NA), i.e., both non-dominant firms refuse to adopt in equilibrium, whereas the merged firm always adopts given $F < \phi_m$ holds. Surprisingly, in this case, firms 3 and 4 never propose a merger in equilibrium.

However, Remark 4.1 highlights that postulating merger specific efficiencies is not always consistent with the social welfare standard, i.e., the optimal decision rule. Based on this finding, we agree with Röller's (2011) argumentation that claiming efficiencies could signal a weak case under the assumption that an antitrust authority follows a social welfare standard. Not all cases reveal that a socially desirable merger proposal is accompanied by merger specific efficiencies which could explain why merging firms abstain from claiming efficiencies in most cases.

4.5 Substantial Plus Specific Test

One test, which may be particularly close to practice, is to require substantial and merger specific efficiencies.[32] We call that approach the substantial plus specific test (SST). Suppose substantial means that prices do not increase relative to the pre-merger equilibrium. That is, we can use Proposition 4.1 which states the change in consumer surplus due to exogenous efficiencies. This seems to be in line with both US and EC merger guidelines where it is postulated that consumers are (at least) not worse off as a result of the efficiency.

There is a fundamental difference between the requirements that efficiencies have to be substantial and merger specific. The latter explicitly accounts for the counterfactual situation by asking what would happen without a merger, whereas the former is based on a before-after comparison. In the parlance of our model, efficiencies are said to be substantial whenever consumer surplus is larger *after* the merger, $CS^{**}(A)$, when compared with the consumer surplus *before* the merger, $CS^*(NA, NA)$. This implies that only one condition is required, irrespective of the adoption game equilibrium in the no-merger case.

Given a merger proposal, we maintain our assumption that the antitrust authority evaluates a merger based on social welfare. But, in addition, it performs the SST to decide whether or not to accept claimed efficiencies. If efficiencies are not both substantial and merger specific, then the antitrust authority decides on the approval presuming that there are no efficiencies, i.e., $s = 0$ holds. In this case, the relevant measure is given by $\Delta SW^0 = \Delta SW(s = 0)$, where ΔSW is the change in social welfare with exogenous efficiencies from Proposition 4.2. Note that the welfare effect is positive (negative) whenever $c > 9/107$ ($c < 9/107$). Otherwise, as before, $\Delta SW^{k,k'}$ is applied.

The following table illustrates the conditions under which efficiencies are substantial and merger specific for all possible adoption equilibria in the no-merger case. In addition, it presents our findings on the welfare effects of a merger from Proposition 4.6.

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[32] In addition, efficiencies have to be verifiable. We suppose for simplicity that this requirement is met.

Table 4.3: Substantial plus Specific Test and Social Welfare

Adoption Outcome (no-merger case)	Substantial ($\Delta CS > 0$) (Prop. 1)	Merger Specificity? (Prop. 3 & 4)	$\Delta SW > 0$? (Prop. 6)
(A, A)	yes, if s large	always	yes, if s small
(A, NA)	yes, if s large	never	yes, for intermediate s
(r, r)	yes, if s large	yes, if F small	yes, if s large
(NA, NA)	yes, if s large	always	see case iv)

We can immediately verify that requiring efficiencies to be substantial does not always imply an increase in social welfare. We know from Remark 4.1 that the same is true for merger specificity. Comparing the decision an antitrust authority would take applying the SST with the optimal decision rule solely based on $\Delta SW^{k,k'}$, we draw the following conclusion.

Remark 4.2. *If the authority applies a substantial plus specific test (SST), then the following results follow from a social welfare perspective:*

Case i) Not every welfare enhancing efficiency is accepted leading to both type I and type II errors.

Case ii) Efficiencies are never accepted leading to both type I and type II errors.

Case iii) In some cases welfare enhancing efficiencies are not accepted resulting in type I and type II errors.

Case iv) Mergers are never proposed.

When antitrust authorities apply a SST based on a social welfare standard, then they run into danger to block socially desirable mergers (type I error) or to allow too many mergers (type II error). The reason is that mergers are evaluated based on ΔSW^0 if claimed efficiencies are not substantial and merger specific. Hence, antitrust authorities simply ignore the fact that merging firms do not care about efficiencies being substantial and merger specific when they decide to realize efficiency gains. Instead, merging firms care about profits. If their profits increase due to the adoption of the more efficient technology,

then efficiencies are realized. It follows that ΔSW^0 is the wrong measure inevitably leading to distorted decisions when compared with the optimal decision rule, $\Delta SW^{k,k'}$.

We conclude that an efficiency defence requiring efficiencies to be both substantial and merger specific is at least very questionable, since it results in serious distortions from a welfare perspective.

4.6   Extensions

In this section, we offer two extensions which are complementary to our previous analysis. The first extension deals with growing (declining) markets. First, we ask how market growth (decline) changes the merger specificity of claimed efficiencies. Second, we examine whether market growth (decline) affects the non-dominant firms' incentives to merge. Our second extension concerns the non-dominant firms' efficiency claims given a merger proposal. Until now, we implicitly made the assumption that merging firms always claim efficiency gains when they are realized. Introducing strategic efficiency claims enables the merging firms to choose whether or not to claim efficiencies when proposing a merger.

Growing and Declining Markets. We drop the assumption that $A - a = 1$ and instead set $A - a = \lambda$, with $\lambda \geq 1$. In the following, we take an increase (decrease) of λ as indicative of market growth (decline). In practice, efficiencies tend to be less convincing when the market is growing. Simply because then the efficiency is adopted anyway (by internal growth). In this case, the hypothesis should be supported that in growing markets efficiencies are less merger specific, whereas in declining markets the opposite holds.[33] Moreover, it can be checked whether or not the incentives to merge are reduced in growing markets and enhanced in declining markets.

We start our analysis with the effects of an marginal change in λ on merger specificity.[34]

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[33]For a discussion see Farrell and Shapiro (2001).

[34]More detailed calculations can be requested from the authors.

Our relevant measure is thus given by

$$\frac{\partial \Psi^{k,k'}}{\partial \lambda}, \tag{4.5}$$

with $k, k' = A, NA, r$. If (4.5) is positive (negative), then efficiencies become more (less) merger specific in response to market growth. Given that both non-dominant firms adopt the technology, i.e., (A, A) is the adoption equilibrium, market growth always makes efficiencies more merger specific. If (A, NA) is the adoption game outcome in the no-merger case, then efficiencies are initially never merger specific, and a growing market even increases the extent to which efficiencies are merger "unspecific". In the mixed strategy equilibrium, market growth has a positive effect on merger specificity. We conclude that our hypothesis that in growing markets efficiencies are less convincing can only be supported for for (A, NA). For (A, A) and (r, r), we find that the opposite holds: a growing market makes efficiencies more merger specific.

Turning to the non-dominant firms' incentive to merge, $\theta^{k,k'}$, we also find the effects of market growth unambiguous. The relevant measure becomes now $\partial \theta^{k,k'} / \partial \lambda$. If (A, A) is the adoption equilibrium, then non-dominant firms are less inclined to merge with growing markets, i.e., $\partial \theta^{A,A} / \partial \lambda < 0$. The opposite holds for (A, NA). In the mixed strategy equilibrium, (r, r), the marginal effect of market growth depends on c and s. For sufficiently high (low) efficiency levels s, non-dominant firms' incentive to merge is increased (decreased). Again, our presumption that growing markets make mergers less attractive cannot be generally supported.

Strategic Efficiency Claims. We examine whether or not the non-dominant firms have an incentive to claim efficiency gains when they propose a merger. Making use of the fact that merging firms face the burden of proof when claiming efficiencies, according to both US merger guidelines and EC merger guidelines, we make the following assumption: when the non-dominant firms claim efficiency gains, then they provide the antitrust authority with correct and relevant information.[35]

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[35] This assumption considerably simplifies our analysis because it does not account for a possible strategic

We assume the same decision rule of the competition authority as in Section 4.5, namely, if claimed efficiencies are substantial and merger specific, the antitrust authority evaluates the merger proposal based on $\Delta SW^{k,k'}$. On the contrary, if the non-dominant firms do not claim efficiencies, or if efficiencies are not accepted, then the antitrust authority performs its competitive assessment using ΔSW^0. We say that the merging firms claim efficiency gains if the following two criteria are cumulatively met: *i)* $\Delta SW_k > 0 > \Delta SW^0$ and *ii)* efficiencies are weakly merger specific. Otherwise, efficiency gains are not claimed. By doing so, we implicitly postulate that the non-dominant firms have complete information about social welfare and merger specificity. Thus, they are able to use the efficiency defence strategically in order to possibly manipulate the antitrust authority's decision on the approval of the merger. However, we continue to restrict our attention only to cases in which a merger is proposed. It can be shown that for (A, NA) and (r, r) efficiencies are never claimed. If (A, A) is the adoption outcome, then efficiencies are only claimed for sufficiently high efficiency levels, s. Otherwise, non-dominant firms prefer not to claim efficiencies when proposing a merger.

The most surprising finding is that the non-dominant firms have no incentives to claim efficiencies in most cases. There are two possible explanations. First, non-dominant firms do not make use of the efficiency defense because efficiencies are simply not merger specific. This is true for (A, NA). The proposed merger is continued to be always approved when proposed, and it does not cause any type II errors. Second, the non-dominant firms induce the antitrust authority to approve their proposal for larger combinations of c and s possibly leading to type II errors. In other words, the authority is manipulated to approve mergers which are in fact welfare decreasing. The remaining two cases, (A, A) and (r, r), reflect such scenarios.

Besides Röller's (2011) reasoning that efficiencies may signal a weak case, we offer a

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misreport of relevant information by the merging firms. In that case, we would have to analyze a Bayesian game. At the same time, it allows us to concentrate on strategic efficiency claims which are our focus in this section.

further argument for the observation that the efficiency defense has played a minor role in phase II mergers. Our argument relies on a strategic refusal to claim efficiency gains in order to manipulate the antitrust authority's decision.

4.7   Conclusion

In the first part of this chapter, we analyze the welfare effects of a merger when efficiencies are exogenous. For relatively small non-dominant firms, we demonstrate that a non-monotone relationship between efficiency gains and social welfare exists. The key driving forces of this result are the externality on rivals' profits and its magnitude compared to $\Delta \pi_m$ and ΔCS. This is specific for catch-up mergers involving non-dominant firms with relatively small pre-merger market shares.[36] Our results stand in contrast to symmetric oligopoly markets where efficiencies, which reduce the market price, always increase social welfare as well. The general wisdom that efficiencies due to mergers, involving small (non-dominant) firms, are per se welfare enhancing does not hold in our set up. Moreover, antitrust authorities heavily relying on concentration indices as first screening devices and presuming a monotone relationship between social welfare and claimed efficiencies tend to misjudge proposed mergers. Therefore, they may run into danger committing type I errors, i.e., approving merger proposals, although they decrease social welfare.

In the second part, we extend the analysis by introducing endogenous efficiencies, where firms can choose whether or not to implement a more efficient technology incurring F. Thereby, we explicitly account for the *without* merger case, i.e., the counterfactual, by allowing firms to realize efficiencies without having to merge. First, we examine under which conditions efficiencies can be classified as merger specific given our definitions in Section 4.2. We show that in the merger case firms do not necessarily exhibit larger incentives to realize efficiency gains compared to the no-merger case. Whether or not efficiencies are

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[36] For instance, an often taken route in the literature is to assume identical (symmetric) firms. Efficiency gains then induce a new market structure where the merged firm obtains the largest market share. It is easily shown that in those scenarios the non-monotonicity result of Proposition 4.2 disappears.

weakly merger-specific considerably depends on the outcome of the adoption game in the no-merger subgame. One important implication of our analysis is that antitrust authorities should carefully evaluate efficiency arguments brought forward by the merging firms because efficiencies the incentives to implement efficiencies can be larger without a merger.

Second, the initial merger decision is endogenized, and the welfare effects of a merger with endogenous efficiencies are analyzed. We demonstrate that in most of the cases a merger proposal is not accompanied by merger specific efficiencies and an approval at the same time. We take this finding to be indicative for the observation that the efficiency defense has rather played a minor role.

Finally, we turn to the current practice by examining the substantial plus specific test (SST) from a welfare perspective. We demonstrate that the SST contradicts a sole social welfare standard, and thus results in both type I and type II errors. Taking all these findings into account, we cast serious doubts on the effectiveness of the current efficiency defence in merger control.

Appendix

In this Appendix we provide the omitted proofs.

Proof of Proposition 4.1. We derive the critical values stated in the proposition and their properties. It is straightforward to calculate $\Delta\pi_d = (q_d^{**})^2 - (q_d^*)^2$, $\Delta\pi_m = (q_m^{**})^2 - 2(q_n^*)^2$, and $\Delta CS = \left[(2q_d^{**} + q_m^{**})^2\right]/2 - \left[2(q_d^* + q_n^*)^2\right]$ (the values of firms' equilibrium quantities are stated in Section 4.3). Solving $\Delta\pi_d = 0$ yields two zeros $c_A = (1 - 5s)/3$ and $c_B = (5s - 9)/13$. Obviously, the second root is not feasible. Rewriting the first root yields $\widetilde{s}(c) := (1 - 3c)/5$. Note that $\partial\widetilde{s}(c)/\partial c < 0$. It is easily checked that $\Delta\pi_d < 0$ holds if $s > \widetilde{s}(c)$, while the opposite is true for $s < \widetilde{s}(c)$.

Inspecting next $\Delta\pi_m = 0$, we get two roots $c_C = 1/3 - 5s(5 + 4\sqrt{2})/7$ and $c_D = 1/3 - 5s(5 - 4\sqrt{2})/7$. Again, the second root is never feasible. Rewriting the first root gives $\widehat{s}(c) := 7(1 - 3c)/\left[15(5 + 4\sqrt{2})\right]$. Note that $\partial\widehat{s}(c)/\partial c < 0$. It follows that $\Delta\pi_m < 0$ if $s < \widehat{s}(c)$, while the opposite holds for $s > \widehat{s}(c)$.

The ordering $\widehat{s}(c) < \widetilde{s}(c)$ follows from noting that $\lim_{s\to 0} c_A = \lim_{s\to 0} c_C = 1/3$ together with $|\partial c_A/\partial s| = 5/3 < 5(5 + 4\sqrt{2})/7 = |\partial c_C/\partial s|$.

Finally, examining $\Delta CS = 0$, we get two zeros $c_E = (1 - 5s)/3$ and $c_F = (31 + 5s)/13$. Obviously, the second one is not feasible. The first zero gives $\widetilde{s}(c) := (1 - 3c)/5$. It is easily checked that $\Delta CS > 0$ holds, if $s > \widetilde{s}(c)$, while the opposite is true for $s < \widetilde{s}(c)$.

Proof of Proposition 4.2. Calculating $\Delta SW = 2\Delta\pi_d + \Delta\pi_m + \Delta CS = 0$, we get two roots

$$c_G(s) = \left(67 - 575s + 40\sqrt{322s^2 + 2s + 1}\right)/321 \text{ and} \tag{4.6}$$

$$c_H(s) = \left(67 - 575s - 40\sqrt{322s^2 + 2s + 1}\right)/321. \tag{4.7}$$

Note that $\lim_{s\to 0} c_G = 1/3$ and $\lim_{s\to 0} c_H = 9/107$. Note also that $\partial c_G/\partial s|_{\lim_{s\to 0}} = -5/3 < 0$. Hence, both roots cut through the feasible set. Moreover, $\partial c_H/\partial s < 0$ is always true. Hence, for all $c < 9/107$ there exists a unique critical value $\widetilde{\widetilde{s}}(c)$, with $\widetilde{\widetilde{s}}(c) := [c_H(s)]^{-1}$, for which $\partial\widetilde{\widetilde{s}}(c)/\partial c < 0$ holds. It is easily checked that $\Delta SW > 0$ if $s > \widetilde{\widetilde{s}}(c)$, while the opposite is true for $s < \widetilde{\widetilde{s}}(c)$.

Turning to $c_G(s)$, we obtain $\partial c_G/\partial s = 0$ at $s' = (5\sqrt{23} - 1)/322$, while $\partial^2 c_G/\partial s^2 > 0$ holds everywhere. Evaluating $c_G(s)$ at $s = s'$ gives $c_G(s') = (5\sqrt{23}/23 + 3)/14 < 1/3$, so that c_G reaches its (global) minimum in the feasible set. Hence, $c_G(s)$ cuts fully through the feasible set over the interval $s = (0, s')$ with a strictly negative slope. Considering $c_G(s)$, we get that $c_G(s = c) > c$ holds if

$$\frac{40\sqrt{322c^2 + 2c + 1} - 896c + 67}{321} > 0. \tag{4.8}$$

Inequality (4.8) indeed holds. This follows from noticing that the nominator of (4.8) does not have a real root. It is then straightforward to check that the nominator is strictly positive for all $s \in (s', 1/2]$. Hence, the inverse of $c_G(s)$ is a correspondence which assigns to all $c > c_G(s')$ exactly two values $\underline{s}(c)$ and $\overline{s}(c)$, with $\underline{s}(c) < \overline{s}(c)$. From the strict convexity of $c_G(s)$ it follows that $\partial \underline{s}(c)/\partial c < 0$ and $\partial \overline{s}(c)/\partial c > 0$, for all $c > c_G(s')$. It is easily checked that $\Delta SW < 0$ if $s \in (\underline{s}(c), \overline{s}(c))$, while the opposite is true for $s \in (0, \underline{s}(c)) \cup (\overline{s}(c), c)$.

Finally, the intervals stated in the proposition follow from noting that $c_G(s') > \lim_{s \to 0} c_H(s)$. Hence, we can distinguish three different intervals depending on c as stated in the proposition.

Proof of Lemma 4.1. The merged firm's incentive, $\phi_m = (q_m^{**}(A))^2 - (q_m^{**}(NA))^2$, can be rewritten as $\phi_m = 3s\left[2(1 - 3c) + 3s\right]/16$ (the equilibrium outputs of the merged firm are stated in the main text). Hence, the efficiency is (strictly) implemented if and only if $F < \phi_m = 3s\left[2(1 - 3c) + 3s\right]/16$. The properties $\phi_m > 0$, $\partial \phi_m/\partial s > 0$, and $\partial \phi_m/\partial c < 0$ follow immediately.

Proof of Lemma 4.2. Using (4.1) we can directly calculate the non-dominant firms' $(n = 3, 4)$ equilibrium outputs depending on their adoption decisions (the first argument of $q_n(\cdot, \cdot)$ stands for firm n's and the second argument for firm n''s, $n \neq n'$, adoption decision): $q_n^*(NA, NA) = (1 - 3c)/5$, $q_n^*(A, NA) = (1 - 4(c - s) + c)/5$, $q_n^*(NA, A) = (1 - 3c - s)/5$, and $q_n^*(A, A) = (1 - 3(c - s))/5$. Accordingly, firms' equilibrium profit levels are given by $\pi_n^*(k, k') = (q_n^*(k, k'))^2$. Calculating the profit differentials stated in the lemma, we obtain that $0 < \pi_n^*(A, A) - \pi_n^*(NA, A) < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ always holds. The first

inequality is obvious, and the second inequality follows from

$$\pi_n^*(A, A) - \pi_n^*(NA, A) - [\pi_n^*(A, NA) - \pi_n^*(NA, NA)] = -8s^2/25 < 0.$$

Given that ordering, it is obvious that (A, A) is the only Nash equilibrium if $F < \pi_n^*(A, A) - \pi_n^*(NA, A)$, while (NA, NA) must be the only Nash equilibrium whenever $F > \pi_n^*(A, NA) - \pi_n^*(NA, NA)$. If F lies in between both values (i.e., $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$), then only two pure strategy Nash equilibria exist, where one firm adopts and the other firm abstains from adopting the technology. Moreover, in that interval there is a unique symmetric Nash Equilibrium in mixed strategies where both firms choose the same probability distribution r (stated in the main text). Then, the equilibrium probability r, with which each firm chooses the strategy A, follows from an indifference condition, for instance, $E(\pi_n(A, r) = E(\pi_n(NA, r)$, where E is the expectations value operator. We then obtain the following equilibrium mixing strategy r

$$r = \frac{\pi_n^*(A, NA) - \pi_n^*(NA, NA) - F}{[\pi_n^*(A, NA) - \pi_n^*(A, A)] + [\pi_n^*(NA, A) - \pi_n^*(NA, NA)]}. \tag{4.9}$$

In the assumed interval, $\pi_n^*(A, A) - \pi_n^*(NA, A) < F < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$, both the numerator and the denominator are always positive. Moreover, r (as given by (4.9)) is monotonically decreasing in F. It approaches zero, if $F \to \pi_n(A, NA) - \pi_n(NA, NA)$, and it approaches one, if $F \to \pi_n^*(A, A) - \pi_n^*(NA, A)$. Because of the symmetry of the adoption game, (4.9) gives us the unique mixed strategy equilibrium (r, r).

Proof of Proposition 4.3. We have to compare $\phi_m = 3s \left[2(1 - 3c) + 3s\right]/16$ and $\pi_n^*(A, NA) - \pi_n^*(NA, NA)$ (see the Proof of Lemma 4.1 and 4.2 for the value of ϕ_m and firms' equilibrium quantities in case of no merger). We obtain $\pi_n^*(A, NA) - \pi_n^*(NA, NA) = 8s(1 + 2s - 3c)/25$. We then get that $\phi_m - [\pi_n^*(A, NA) - \pi_n^*(NA, NA)]$ has a unique zero at $s = \widehat{\widehat{s}}(c) := 22(1 - 3c)/31$. Clearly, $\widehat{\widehat{s}}(c) > 0$ and $\partial\widehat{\widehat{s}}(c)/\partial c < 0$. It is then easily checked that $\phi_m > \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ if and only if $s < \widehat{\widehat{s}}(c)$. Given that $s < \widehat{\widehat{s}}(c)$ holds, we can find values of F, with $\pi_n^*(A, NA) - \pi_n^*(NA, NA) < F < \phi_m$, such that the efficiency is implemented only if there is a merger; in other words, in those instances the efficiencies are strongly merger specific according to Definition 4.2.

Proof of Proposition 4.4. The proof follows from calculating the sign of $\Psi^{k,k'}$ for cases

i)-iii) stated in Lemma 4.2.

Case i). With $\phi_n^{A,A} =: \pi_n^*(A,A) - \pi_n^*(NA,A) = 8s\,(1 - 3c + s)\,/25$, calculating $\Psi^{A,A} = $

$\phi_m - \phi_n^{A,A}$, we obtain the expression $s\,[22(1 - 3c) + 97s]\,/400$ which is strictly positive for

all feasible c.

Case ii). With $\phi_n^{A,NA} := \pi_n^*(A,NA) - \pi_n^*(NA,A) = s\,(2(1 - 3c) + 3s)\,/5$, calculating

$\Psi^{A,NA} = \phi_m - \phi_n^{A,NA}$, we obtain $\Psi^{A,NA} = -s\,(2(1 - 3c) + 3s)\,/80 < 0$.

Case iii). We have to examine $\Psi^{r,r} := \phi_m - \phi_n^{r,r}$, with $\phi_n^{r,r} := E\pi_n^*(A,r) + F - \pi_n^*(NA,A)$.

In the mixed strategy equilibrium each firm is indifferent between any pure strategy, given

that the other firm plays the equilibrium mixed strategy, r. The expected profit in the mixed

strategy equilibrium can be, for instance, derived from $E\pi_n^*(A,r)$, which is the expected

profit of firm n, when n plays the pure strategy A and firm n' $(n' \neq n)$ plays the equilibrium

mixed strategy, r. We then get

$$E\pi_n^*(A,r) = r\,[\pi_n^*(A,A) - F] + (1 - r)\,[\pi_n^*(A,NA) - F]. \tag{4.10}$$

Using the definition of $\phi_n^{A,A}$ and defining $\phi_n^{NA,NA} := \pi_n^*(A,NA) - \pi_n^*(NA,NA)$, we can

write the equilibrium mixed strategy as

$$r = \frac{\phi_n^{NA,NA} - F}{\phi_n^{NA,NA} - \phi_n^{A,A}}. \tag{4.11}$$

Substituting (4.11) into (4.10) it is straightforward to obtain

$$\phi_n^{r,r} = \pi_n^*(A,NA) - \pi_n^*(NA,A) - \frac{\phi_n^{NA,NA} - F}{\phi_n^{NA,NA} - \phi_n^{A,A}}\,[\pi_n^*(A,NA) - \pi_n^*(A,A)].$$

We then obtain

$$\frac{\partial \phi_n^{r,r}}{\partial F} = \frac{\pi_n^*(A,NA) - \pi_n^*(A,A)}{\phi_n^{NA,NA} - \phi_n^{A,A}} > 0,$$

so that incentives are increasing in F in the mixed strategy equilibrium. In contrast, ϕ_m is

independent of F, so that $\partial \phi_m / \partial F = 0$ holds. Hence, setting $\phi_m = \phi_n^{r,r}$, and solving for F,

we get a unique solution

$$F = \widetilde{F} := \phi_n^{NA,NA} - \frac{(\phi^{NA,NA} - \phi^{A,A})(\phi_m - \pi_n^*(A,NA) + \pi_n^*(NA,A))}{\pi_n^*(A,NA) - \pi_n^*(A,A)}. \tag{4.12}$$

We have to consider the relevant interval of case *iii)* which we can write as $\phi_n^{A,A} < F < \phi_n^{NA,NA}$. We now show that $\widetilde{F}$ lies always in that interval. Inspecting $\phi_n^{A,A} < \widetilde{F}$, we get the condition $\phi_m > \pi_n^*(A, A) - \pi_n^*(NA, A) = \phi_n^{A,A}$. Further, $\widetilde{F} < \phi_n^{NA,NA}$ implies $\phi_m < \pi_n^*(A, NA) - \pi_n^*(NA, A) = \phi_n^{A,NA}$. As we have shown in case *i)* and case *ii)* of this proposition, both conditions are fulfilled. Finally, calculating $\partial \widetilde{F}/\partial s$ by using (4.12) we obtain the expression

$$\frac{-864c^3 + 3348c^2s + 864c^2 - 4104cs^2 - 2232cs - 288c + 1673s^3 + 1368s^2 + 372s + 32}{25\left(7s - 6c + 2\right)^2}.$$

The sign of that expression depends on the sign of the numerator which we define by $\delta(c, s)$. We show that $\delta(c, s) > 0$ holds, so that $\partial \widetilde{F}/\partial s > 0$ follows.

Ancillary Claim. $\delta(c, s) > 0$.

Proof. We successively differentiate $\delta(c, s)$ with respect to s.[37] This yields $\delta'(c, s) = 3348c^2 - 8208cs - 2232c + 5019s^2 + 2736s + 372$, $\delta''(c, s) = 10\,038s - 8208c + 2736$, and $\delta'''(c) = 10\,038$.

Since $\delta''(c, s)$ is increasing in s, we evaluate $\delta''(c, s)$ at $s = 0$. We get $\delta''(c, s = 0) = -8208c + 2736$ which is clearly decreasing in c and positive, i.e., $\delta''(c, s = 0) > 0$, for all $0 \leq c < 1/3$. It follows that $\delta''(c, s) > 0$ always holds. Evaluating $\delta'(c, s)$ at $s = 0$ we get $\delta'(c, s = 0) = 3348c^2 - 2232c + 372$. Then, it is found that $\partial \delta'(c, s = 0)/\partial c = 0$ at $c = 1/3$ and $\partial^2 \delta'(c, s = 0)/\partial^2 c > 0$ constituting a global minimum of $\delta'(c, s = 0)$ at $c = 1/3$. Hence, $\delta'(c = 1/3, s = 0) = 0$ and $\delta'(c, s) > 0$ holds everywhere. Finally, we get $\delta(c, s = 0) = -32\left(3c - 1\right)^3$ which is strictly positive for all $0 \leq c < 1/3$. Hence, $\delta(c, s) > 0$ holds for all feasible c and s.

Proof of Proposition 4.5. The proof follows from calculating the sign of $\theta^{k,k'}$ for all cases *i)-iv)* stated in Lemma 4.2.

Case i). When both firms adopt in case of no merger, then $\theta^{A,A} = \pi_m^{**}(A) - 2\pi_n^*(A, A) + F$. Obviously, $\theta^{A,A}$ increases in F. If $F \to 0$, we get $\theta^{A,A}(F \to 0) = -7\left(1 - 3c + 3s\right)^2/400 <$

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[37] We define $\delta'(\cdot) := \partial \delta(\cdot)/\partial s$, $\delta''(\cdot) := \partial^2 \delta(\cdot)/\partial s^2$ and so on.

0. Define $F' := -\theta^{A,A}(F \to 0)$. Hence, $\theta^{A,A} < 0$ holds for $F < F'$. Moreover, F' lies in the feasible set, if

$$F' < \pi_n^*(A, A) - \pi_n^*(NA, A). \tag{4.13}$$

Calculating the difference $\pi_n^*(A, A) - \pi_n^*(NA, A) - F'$, we get the expression $8s(1 - 3c + s)/25 - [71 - 3(c - s)]^2/400$ which has two roots $c_I(s) = (1 - 13s)/3$ and $c_J(s) = (7 + 5s)/21$. The latter one is not feasible. The former root, $c_I(s)$, is feasible and monotonically decreasing in s. It is then easily checked that (4.13) holds for $s > s_I(c) := (1 - 3c)/13$. If, otherwise, $s < s_I(c)$, then $\theta^{A,A} < 0$ is always true where $s_I(c) = [c_I(s)]^{-1}$.

Case ii). In both pure strategy equilibria of this interval only one firm adopts. Hence, $\theta^{A,NA} = \pi_m^{**}(A) - F - [\pi_n^*(A, NA) - F + \pi_{n'}^*(NA, A)]$. Clearly, F cancels out, so that the sign of $\theta^{A,NA}$ only depends on c and s. Substituting the profit levels we obtain that two roots $c_K(s) = (7 - 47s)/21$ and $c_L(s) = (1 - s)/3$. It follows that $\lim_{s \to 0} c_K = \lim_{s \to 0} c_L = 1/3$, $\partial c_K/\partial s = -47/21 < -1/3 = \partial c_L/\partial s$. The latter inequality implies $c_K(s) < c_L(s)$. Note also that $\lim_{s \to 0} \theta^{A,NA} < 0$ for all $c < 1/3$. Define $s_K := [c_K(s)]^{-1}$ and $s_L := [c_L(s)]^{-1}$. It is then easily checked that $\theta^{A,NA} < 0$ if $s < s_K$ or if $s > s_L$, while $\theta^{A,NA} > 0$ holds for $s_K < s < s_L$.

Case iii). If the mixed strategy equilibrium is played in the adoption game, then $\theta^{r,r} = \pi_m^{**}(A) - F - 2E\pi_n^*(NA, r)$. Using (4.10) and (4.11), we can rewrite this equality as

$$\theta^{r,r} = \pi_m^{**}(A) + F - 2\left[\pi_n^*(A, NA) - \frac{\phi_n^{NA,NA} - F}{\phi_n^{NA,NA} - \phi_n^{i)}}[\pi_n^*(A, NA) - \pi_n^*(A, A)]\right]. \tag{4.14}$$

We obtain

$$\frac{\partial \theta^{r,r}}{\partial F} = -\frac{\pi_n^*(NA, NA) - \pi_n^*(NA, A)}{\phi_n^{NA,NA} - \phi_n^{A,A}} < 0.$$

Hence, merger incentives are monotonically decreasing in F. Using (4.14) to solve for $F = \widetilde{\widetilde{F}}$ such that $\theta^{r,r}(\widetilde{\widetilde{F}}) = 0$, we get

$$\widetilde{\widetilde{F}} = \frac{\left(\phi_n^{NA,NA} - \phi_n^{A,A}\right)\left(\pi_m^{**}(A) - 2\pi_n^*(A, NA)\right) + 2\phi_n^{NA,NA}[\pi_n^*(A, NA) - \pi_n^*(A, A)]}{2[\pi_n^*(A, NA) - \pi_n^*(A, A)] - \left(\phi_n^{NA,NA} - \phi_n^{A,A}\right)}. \tag{4.15}$$

Note that the denominator is always positive which follows from

$$2\left[\pi_n^*(A, NA) - \pi_n^*(A, A)\right] > \left(\phi_n^{NA,NA} - \phi_n^{A,A}\right) \Rightarrow$$

$$\pi_n^*(A, NA) - \pi_n^*(A, A) > -\left[\pi_n^*(NA, NA) - \pi_n^*(NA, A)\right].$$

Inspecting the lower bound of the interval and using (4.15), we get that $\widetilde{\widetilde{F}} > \pi_n^*(A, A) - \pi_n^*(NA, A)$ holds if

$$\pi_m^{**}(A) - \pi_n^*(A, A) - \pi_n^*(NA, A) > 0. \tag{4.16}$$

Inserting the profit levels into the left-hand side of (4.16), we obtain the expression

$$-\frac{63}{400}c^2 - \frac{129}{200}cs + \frac{21}{200}c + \frac{13}{80}s^2 + \frac{43}{200}s - \frac{7}{400}$$

which has two roots: $c_I(s) = (1 - 13)s/3$ and $c_M(s) = (3 + 5s)/21$. Only the former is feasible. Define $s_I(c) := [c_I(s)]^{-1} = (1 - 3c)/13$. It is then easily checked that $\widetilde{\widetilde{F}} > \pi_n^*(A, A) - \pi_n^*(NA, A)$ holds for all $s > s_I(c)$. If, otherwise, $s < s_I(c)$, then $\theta^{r,r} < 0$ is always true.

We turn to the upper bound. We obtain that $\widetilde{\widetilde{F}} < \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ holds if

$$\pi_m^{**}(A) - \pi_n^*(A, NA) - \pi_n^*(NA, NA) < 0. \tag{4.17}$$

Substituting the profit levels, we get that inequality (4.17) holds for all feasible c and s. Hence, when F approaches the upper bound of the considered interval, then $\theta^{r,r} < 0$ is always true. We finally, calculate $\partial\widetilde{\widetilde{F}}/\partial s$ and obtain the expression

$$3 \cdot \frac{-513c^3 + 1476c^2s + 513c^2 - 852cs^2 - 984cs - 171c + 161s^3 + 284s^2 + 164s + 19}{50\left(3s - 6c + 2\right)^2}.$$

The denominator of that expression is always positive, so the sign of $\partial\widetilde{\widetilde{F}}/\partial s$ depends on the sign of the numerator which we define by $\eta(c, s)$. We show that $\eta(c, s) > 0$ holds, so that $\partial\widetilde{\widetilde{F}}/\partial s > 0$ follows.

Ancillary Claim. $\eta(c, s) > 0$.

Proof. We successively differentiate $\eta(c, s)$ with respect to s. This yields $\eta'(c, s) = 1476c^2 - 1704cs - 984c + 483s^2 + 568s + 164$, $\eta''(c, s) = 966s - 1704c + 568$, and $\eta'''(c, s) = 966$. Hence,

$\eta''(c, s)$ is increasing in s. Evaluating $\eta''(c, s)$ at $s = 0$, we get $\eta''(c, s = 0) = -1704c + 568$. Clearly, $\eta''(c, s = 0) > 0$ for all $0 \leq c < 1/3$. Hence, $\eta''(c, s) > 0$ holds everywhere. Evaluating $\eta'(c, s)$ at $s = 0$, we get $\eta'(c, s = 0) = 1476c^2 - 984c + 164$. We get that $\partial \eta'(c, s = 0)/\partial c = 0$ at $c = 1/3$. As $\partial^2 \eta'(c, s = 0)/\partial c^2 > 0$ holds, $\eta'(c, s = 0)$ reaches a global minimum at $c = 1/3$. Evaluating $\eta'(c, s)$ at $s = 0$ and $c = 1/3$ we get $\eta'(c, s) = 0$. Hence, $\eta'(c, s) > 0$ holds everywhere. Then, we get $\eta(c, s = 0) = 19 (1 - 3c)^3$ which, of course, is strictly positive for all $0 \leq c < 1/3$. This proves the claim.

Case iv). When both firms do not adopt the efficiency in case of no merger, then $\theta^{NA,NA} = \pi_m^{**}(A) - F - 2\pi_n^*(NA, NA)$. Note that $\theta^{NA,NA}$ is monotonically decreasing in F. Evaluating $\theta^{NA,NA}$ at the lower bound $F = \pi_n^*(A, NA) - \pi_n^*(NA, NA)$ we get the expression

$$-(7 - 42c + 63c^2 + 66sc - 22s + 31s^2)/400 \tag{4.18}$$

which has no real root. Instead, we ask whether (4.18) has a global maximum or global minimum using the Hessian and calculating its determinant. It can be checked that (4.18) exhibits a global maximum at $c = 0$ and $s = 11/33$ where it takes the value $-7/900$. It follows that $\theta^{NA,NA} < 0$ holds for all c and s.

Proof of Proposition 4.6. The proof follows from calculating the sign of $\Delta SW^{k,k'}$ for cases *i)-iv)* stated in Lemma 4.2. Consumer surplus in case of no merger, $CS^*(k, k') = [Q(k, k')]^2/2$, depends on the non-dominant firms' adoption decisions $k, k' = A, NA, r$. Note that $Q^*(k, k') = 2q_d^*(k, k') + q_n^*(k, k') + q_{n'}^*(k', k)$, $n \neq n'$. We stated the values of $q_n^*(k, k')$ in the proof of Lemma 4.2. Using (4.1), we obtain for the dominant firms' equilibrium outputs the values $q_d^*(A, A) = (1 + 2(c - s))/5$, $q_d^*(A, NA) = (1 + 2c - s))/5$, and $q_d^*(NA, NA) = (1 + 2c)/5$.

Case i). When (A, A) is the equilibrium in the adoption game, then $\Delta SW^{A,A} = SW^{**} - F - SW^{A,A}$, with $SW^{A,A} = 2\pi_d^{A,A} + 2\pi_n^{A,A} + CS^{A,A} - 2F$.[38] Using the value of SW^{**} from

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[38] Profits and consumer surplus are derived from $\pi_d^{*,i)} = [q_d^*(A, A)]^2$, $\pi_n^{*,i)} = [q_n^*(A, A)]^2$, and $CS^{*,i)} = [Q^*(A, A)]^2/2$.

the Proof of Proposition 4.2, we obtain $\Delta SW^{A,A} = (-321c^2 + 642cs + 134c - 321s^2 - 134s - 9)/800 + F$ which has two zeros $c_N(s, F) = s + (67 - 20\sqrt{2}\sqrt{321F + 2})/321$ and $c_O(s, F) = s + (67 + 20\sqrt{2}\sqrt{321F + 2})/321$. The second solution is not feasible which follows from noting $c_O(s, F = 0) = 1/3$ together with $\partial c_O(s, F)/\partial F > 0$. Turning to the first root, $c_N(s, F)$, we get that $c_N(s, F \to 0) = s + 9/107$. Hence, $c_N(s, F)$ cuts through the feasible set. It is easily checked that $\Delta SW^{A,A} > 0$ for $c > c_N(c, F)$. Because of $\partial c_N(s, F)/\partial F < 0$ the constraint becomes less binding when F increases. Taking the inverse of $c_N(s, F)$ we get the critical value $s_N(c, F) = c + (20\sqrt{2}\sqrt{321F + 2} - 67)/321$. It then follows that $\Delta SW^{A,A} > 0$ for $s < s_N(c, F)$, while the opposite holds for $s > s_N(c, F)$. Clearly, $\partial s_N(c, F)/\partial F > 0$.

Case ii). When only one firm adopts the efficiency in the no merger case, then $\Delta SW^{A,NA} = SW^{**} - F - SW^{A,NA}$, where $SW^{A,NA} = 2\pi_d^{A,NA} + \pi_n^{A,NA} + \pi_{n'}^{A,NA} + CS^{A,NA} - F$, with $n \neq n'$.[39] We then get

$$\Delta SW^{A,NA} = (-321c^2 - 254cs + 134c - 49s^2 + 58s - 9)/800$$

which has two roots $c_L(s) = (1 - s)/3$ and $c_P(s) = (9 - 49s)/107$.[40] Both roots cut through the feasible set with negative slope. It is easily checked that $\Delta SW^{A,NA} > 0$ if $c_P(s) < c < c_L(s)$, while the opposite is true if $c < c_R(s)$ or if $c > c_L(s)$. Taking the inverse, gives the critical values $s_L(c) = 1 - 3c$ and $s_P(c) = (9 - 107c)/49$, and the result stated in the proposition follows.

Case iii). When the mixed strategy equilibrium holds in the adoption game, then $\Delta SW^{r,r} = SW^{**} - F - SW^{r,r}$, where $SW^{r,r} = 2\pi_d^{r,r} + 2\pi_n^{r,r} + CS^{r,r}$ is the expected social welfare in the no merger case. Using Table 4.1, expected firms' profits and expected

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[39] Profits and consumer surplus follow from $\pi_d^{*,ii)} = [q_d^*(A, NA)]^2$, $\pi_n^{*,ii)} = [q_n^*(A, NA)]^2$, $\pi_{n'}^{*,ii)} = [q_{n'}^*(NA, A)]^2$ and $CS^{*,ii)} = [Q^*(A, NA)]^2/2$

[40] Note that $c_L(s)$ and thus $s_L(c)$ are identical with the threshold values in in case *ii)* of Proposition 4.5.

consumer welfare are given by

$$\pi_d^{r,r} = r^2\pi_d^*(A,A) + 2r(1-r)\pi_d^*(A,NA) + (1-r)^2\pi_d^*(NA,NA),$$

$$\pi_n^{r,r} = r^2\pi_n^*(A,A) + (1-r)r\pi_n^*(A,NA) + (1-r)r\pi_n^*(NA,A) + (1-r)^2\pi_n^*(NA,NA),$$

$$CS^{r,r} = \frac{r^2\left[Q^*(A,A)\right]^2 + 2(1-r)r\left[Q^*(A,NA)\right]^2 + (1-r)^2\left[Q^*(NA,NA)\right]^2}{2}.$$

Using our previous results, we then obtain

$$\Delta SW^{r,r} = \frac{5}{16}s - \frac{5}{16}c - F - \frac{23}{16}cs + \frac{23}{32}c^2 + \frac{23}{32}s^2 + \frac{15}{32} - \frac{\varphi}{800s^2},$$

$$\text{with } \varphi = 1875F^2 + 4400Fcs - 3000Fs^2 - 800Fs + 3392c^2s^2$$

$$- 3392cs^3 - 1408cs^2 + 1152s^4 + 704s^3 + 448s^2.$$

Note that $\partial\Delta SW^{r,r}/\partial F = (16s - 75F - 88cs + 44s^2)/(16s^2)$ is strictly negative. Hence, $\Delta SW^{r,r}$ is maximal in F at the lower bound. Evaluating $\Delta SW^{r,r}$ at $F = \pi_n^*(A,A) - \pi_n^*(NA,A)$, we get the expression

$$-\frac{321}{800}c^2 - \frac{63}{400}cs + \frac{67}{400}c - \frac{13}{160}s^2 + \frac{61}{400}s - \frac{9}{800}$$

which has two zeros

$$c_R(s) = \frac{67}{321} - \frac{400}{321}\sqrt{-\frac{66}{625}s^2 + \frac{24}{125}s + \frac{1}{100}} - \frac{21}{107}s \text{ and}$$

$$c_S(s) = \frac{400}{321}\sqrt{-\frac{66}{625}s^2 + \frac{24}{125}s + \frac{1}{100}} - \frac{21}{107}s + \frac{67}{321}.$$

The second solution is not feasible. This follows from $c_S(s \to 0) = 1/3$ and

$$\partial c_S(s)/\partial s = -\frac{1}{107}\frac{21\sqrt{-264s^2 + 480s + 25} - 640 + 704s}{\sqrt{-264s^2 + 480s + 25}} > 0.$$

The latter inequality follows from noticing that the term, $-640 + 704s$, of the nominator is strictly negative (the term below the root sign, $-264s^2 + 480s + 25$, is always positive). The first solution, $c_R(s)$, is monotonically decreasing in s; i.e.,

$$\partial c_R(s)/\partial s = -\frac{1}{107}\frac{21\sqrt{-264s^2 + 480s + 25} - 704s + 640}{\sqrt{-264s^2 + 480s + 25}} < 0,$$

where the sign follows from noting that the term, $-704s + 640$, of the numerator is strictly positive (the term below the root sign, $-264s^2 + 480s + 25$, is always positive). Moreover $c_R(s = 0) = 9/107$. Hence, $c_R(s)$ cuts through the feasible set with negative slope.

Evaluating $\Delta SW^{r,r}(s \to 0)$ when $F \to \pi_n^*(A,A) - \pi_n^*(NA,A)$, we get the expression $-\frac{321}{800}c^2 + \frac{67}{400}c - \frac{9}{800}$ which is negative for $c < c_R(s)$. Hence, $\Delta SW^{r,r} > 0$ if $c > c_R(s)$, while the opposite holds for $c < c_R(s)$. Defining the inverse as $s_R(c) := [c_R(s)]^{-1}$, we arrive at the ordering stated in the proposition. Finally, evaluating $\Delta SW^{r,r}$ at the upper bound $F = \pi_n^*(A,NA) - \pi_n^*(NA,NA)$, we again obtain a threshold value with qualitatively the same property as $s_R(c)$; yet, that threshold value is even more binding for $\Delta SW^{r,r} > 0$ to be true because $\Delta SW^{r,r}$ is minimal in F at the upper bound.

Case iv). When (NA,NA) is the equilibrium in the adoption game, then $\Delta SW^{NA,NA} = SW^{**} - F - SW^{NA,NA}$, with $SW^{NA,NA} = 2\pi_d^{NA,NA} + 2\pi_n^{NA,NA} + CS^{NA,NA}$. It follows from Proposition 4.3 that the merged firm's incentive, ϕ_m, is positive over the interval $F \in (\pi_n^*(A,NA) - \pi_n^*(NA,NA); \phi_m)$ if $s < \widehat{s}(c) = 22(1-3c)/31$ holds. Obviously, $\Delta SW^{NA,NA}$ equals the change in social welfare form Section 4.3 used in Proposition 4.2 except that the cost of technology adoption has to be subtracted. We get

$$\Delta SW^{NA,NA} = -\frac{321}{800}c^2 - \frac{23}{16}cs + \frac{67}{400}c + \frac{23}{32}s^2 + \frac{5}{16}s - \frac{9}{800} - F.$$

Taking the inverse of $\widehat{s}(c)$, we obtain the identical condition $c < \widehat{c}(s) := (22 - 31s)/66$ which proves easier to compare with the relevant threshold values (4.6) and (4.7) (see Proof of Proposition 4.2). Inspection of the difference $\widehat{c}(s) - c_H(s)$ yields the expression $3111s/2354 + 40(\sqrt{322s^2 + 2s + 1} + 1)/321$ which is strictly positive for all s. Hence, $\widetilde{\widetilde{s}}(c) < \widehat{s}(c)$ always holds.

We turn to the second critical value (4.7). Inspection of the difference $c_G(s) - \widehat{c}(s)$ yields the expression $40(\sqrt{322s^2 + 2s + 1} - 1)/321 - 3111s/2354$ which obtains two zeros at $s_U = 0$ and at $s_V = \frac{139\,040}{1516\,373} \approx 0.092$. It is then easily checked that $c_G(s) - \widehat{c}(s) > 0$ for all $s > s_V$, while the opposite holds for $s < s_V$. Note also $c_G(s)$ reaches its global minimum (where $\partial c_G/\partial s = 0$ holds) at $s' = (5\sqrt{23} - 1)/322 \approx 0.071$ (see Proof of Proposition 4.2). Note that $c_G(s')$ lies in the feasible set which is also true for $c_G(s_V) = \widehat{c}(s_V)$. As $s_V > s'$, we obtain the interval $(c_G(s'), \widehat{c}(s_{UU}))$ for which $\Delta SW^{NA,NA} > 0$ holds if $s \in (0, \underline{s}) \cup (\overline{s}, \widehat{s})$, while the opposite holds for $s \in (\underline{s}, \overline{s})$. The presence of the constraint $c < \widehat{c}(s)$, is therefore, the only difference of the social welfare comparison between $\Delta SW^{NA,NA}$ and ΔSW. Note

that $\partial \Delta SW^{NA,NA}/\partial F < 0$ which implies that the space of feasible combinations of c and s gets smaller when the fixed cost of technology adoption increases.

Proof of Proposition 4.7. We start with the adoption game outcome (A, A) where both non-dominant firms decide to implement the new technology. For (A, A) to be an equilibrium, the fixed cost of technology adoption must fulfill $0 \leq F \leq F_L = \frac{8}{25}s\left(s - 3c + 1\right)$. We further know that $\Delta SW_0 > 0$ only if $c > 9/107$. Thus, we have to prove if for $0 < c < 9/107$ there are combinations of F and s for which $\Delta SW_{A,A}$ is positive leading to an efficiency claim by the non-dominant firms. The non-dominant firms claim efficiencies if $F > F^* = \frac{1}{800}s\left(321s + 80\right)$ and $s > \widetilde{s}_{A,A}(c)$. The latter inequality stating that efficiencies have to be sufficiently large so that an proposed merger is approved was already derived in Proposition 4.5. Since $F^*(s = 0) = F_L(s = 0) = 0$ and $0 < \frac{dF^*}{ds} < \frac{dF_L}{ds}$ in conjunction with $\frac{d^2 F^*}{ds^2} > 0$ and $\frac{d^2 F_L}{ds^2} > 0$, i.e. F^* and F_L are convex in s, it is assured that $F^* < F_L$ for all admissible efficiency levels s.

Given that (A, NA) and (NA, A), respectively, is the adoption game equilibrium the proof is straightforward. Since efficiencies are never weakly merger specific (see Proposition 4.3), efficiency gains are never claimed by assumption. Using both Proposition 4.4 and the fact that $\Delta SW_0 > 0$ for $c > 9/107$ it can be immediately checked that the merger is always approved because we have $\Delta SW_0 > 0$ whenever $\theta_{A,NA} > 0$. The same reasoning holds when (r^*, r^*) is the adoption equilibrium.

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Chapter 5

Competition in Germany's Minute Reserve Power Market: An Econometric Analysis

5.1   Introduction

Due to economical infeasibility of storing electricity, the balance between production and consumption has to be maintained in the electricity grid at each point in time. This constitutes one of the major tasks of a transmission system operator (TSO) whose responsibility is to ensure system stability by procuring so-called (electricity) reserve power.[1] For this reason, generation units are obliged to reserve some fraction of their capacity which can be used then by TSOs to restore frequency and load in the electricity grid.[2] Imbalances between supply and demand can be caused by e.g., incorrect demand predictions, stochastic fluctuations of renewable energy sources, especially wind, and (or) breakdowns of generation units. In addition to functioning wholesale electricity markets, the provision of ancillary services such as frequency control is a crucial element for ensuring system stability.

In Germany, as well as in all other 33 member states of the European Network of Transmission System Operators for Electricity (ENTSO-E), three different 'qualities' of reserve power are used: 1.) primary control power (PCP), 2.) secondary control power (SCP), and 3.) minute reserve power (MRP) (tertiary control power). Moreover, two types of SCP and MRP have to be distinguished: *incremental* reserve power and *decremental* reserve power. While the former is used when the demand for electricity exceeds the supply of electricity, the latter is needed when more electricity is supplied than consumed. The prices charged for each of the reserve power products are two-part. The so-called capacity price is paid for the basic provision of potential reserve power, while the operational price covers actual production. Hence, the capacity price reflects the suppliers' opportunity cost of having committed not to use the reserved fraction of capacity for e.g., offerings on

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[1] The term (electricity) reserve power builds on the fact that certain fractions of generating capacities have to be reserved for frequency control purposes. Alternative expressions are balancing power and frequency control power. However, we maintain the term (electricity) reserve power throughout the rest of the paper.

[2] According to the European Network of Transmission System Operators for Electricity (ENTSO-E) the power line frequency must be 50 Hz. Whenever there are deviations exceeding certain predefined threshold levels (+/-10 mHz), reserve power is needed to restore the desired value of 50 Hz.

electricity wholesale (spot) markets. The focus of our analysis is on MRP capacity prices for both incremental and decremental MRP. It should be noted that MRP becomes relevant only if PCP and SCP were insufficient to restore the desired power line frequency of 50 Hz. Hence, generation units offering MRP face relatively the lowest technical requirements with respect to the delivery date.

The German market for reserve power was subject to two important regulatory changes in recent years. The first regulatory change focused on the synchronization and standardization of the four distinct and time-separated control areas (regional markets). More precisely, a common web-based tendering platform (www.regelleistung.net) was launched as a result of the Energy Industry Act of July 7, 2006 (see BNetzA, 2006, 2007a, and 2007b). Previously, each of the four TSOs[3] procured reserve power in its own control area at various times using bilateral contracts with affiliated generation plants. Later, in 2001 and 2002, respectively, the German Federal Cartel Office replaced the bilateral contracts by procurement auctions, while the four control areas remained distinct and time-separated. By introducing a common web-based tendering platform, the control areas were synchronized and standardized in time and place on December 1, 2006, for MRP, and one year later, on December 1, 2007, for PCP and SCP.[4] According to the German Federal Network Agency (Bundesnetzagentur, BNetzA), the aim of this reforms was to foster competition and to increase efficiency by eliminating strategic behavior and facilitating market entry (see BNetzA, 2006).

The second regulatory change comprised gradual interconnection and cooperation of the four TSOs in order to realize synergies (see BNetzA, 2010). Whereas market synchronization and standardization aimed at increasing market efficiency by promoting competition and reducing the possibilities of strategic behavior, the second regulatory change solely tackles the inefficient use of reserve capacities. It is designed to exploit benefits from inter-

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[3] The four German TSOs are ENBW Transportnetze AG, Amprion GmbH, TenneT TSO GmbH, and 50Hertz Transmission GmbH.

[4] It should be noted that MRP is procured daily, while a monthly auction is used for PCP and SCP. Since June 27, 2011, both PCP and SCP are procured based on a weekly auction.

connection without directly affecting the competitive process. The reform concerned only SCP and MRP. To illustrate things, consider the following example. Imagine that one control area exhibits excess electricity supply, while another control area has excess demand for electricity. Assume that the resulting frequency deviations are independent and equal in amount. Based on the 'old' regulatory framework, each TSO would have to procure decremental MRP and incremental MRP, respectively, to eliminate the resulting frequency deviations. With interconnection and cooperation, there is no need to procure any kind of MRP, since the excess production of one control area completely offsets the excess consumption of the other. Hence, such compensating deviations can be managed internally through joint TSO balancing without involving MRP suppliers, and thus the MRP market. One implication is that a generation unit, which has been formerly prequalified for only one regional market, is now automatically able to offer SCP and MRP in all four control areas. In other words, there is one merit order including all four control areas which results in one market price rather than four market prices.

The related literature on competition in electricity reserve markets is rather scarce. Most papers studying the efficiency of the MRP market in Germany approach the market design theoretically. On the one hand, these papers focus on the possibility of strategic and collusive behavior given the procurement auction design (see e.g., Müller and Rammerstorfer, 2008). On the other hand, they either study optimal decision rules for network operators and reserve capacity suppliers (see Swider, 2006, and Swider and Weber, 2007) or analyze productive efficiencies (Swider and Ellersdorfer, 2005).

The second strand of literature uses econometric analysis to evaluate the effects of the structural reforms, while solely focusing on the synchronization of the MRP markets. Growitsch et al. (2007) analyze the reform's effect on both incremental and decremental MRP prices. They perform time series analyses testing for a structural break when the common web-based tendering platform for MRP was launched. In addition to the incremental and decremental MRP price time series, they use data on electricity spot market prices. They find that the launch of the common web-based tendering platform had no significant effect

on incremental and decremental MRP prices, i.e., no evidence for structural breaks. Growitsch and Weber (2008) analyze the spread between incremental MRP prices and electricity spot market prices. They apply a mean reversion model to test whether the degree of market integration between the MRP market and the spot market has increased due to the new market design. They show that the MRP market has become more efficient, although the price spread has increased over time. Finally, Riedel and Weigt (2007) provide an correlation analysis where they study the dependence between the four German regional markets and their relationship to the electricity spot market.

We extend these papers in four directions. First, we created a unique dataset for the period from January 1, 2006, to September 30, 2010, to apply panel data models accounting for unobserved heterogeneity between the four German control areas. Second, we estimate causal effects by performing instrumental variable techniques. In doing so, we control for endogeneity of the wholesale electricity (day-ahead) spot market price using German weather data as instruments. Third, we also consider the synchronization of the PCP markets and SCP markets as well as the interconnection of the four TSOs, and ask whether they had an impact on MRP prices. However, our main focus is on the launch of the common web-based tendering platform for MRP because it is natural to expect a direct effect on MRP prices. We perform Chow tests to check whether or not each of the reforms led to a significant change of MRP prices. It is straightforward that a reform is classified as successful only if it leads to a significant structural change, and if its effect on MRP prices is negative. Finally, we quantify the reforms' joint success in the MRP market by comparing the actual MRP prices with the counterfactual scenario, i.e., estimated MRP prices given that there were no reforms at all.

We find that market synchronization and standardization significantly decreased both incremental MRP prices and decremental MRP prices. This result cannot be confirmed for the second regulatory change. More precisely, TSO interconnection and cooperation partially also led to an increase of MRP prices or did not significantly affect MRP prices at all. Hence, the effect is ambiguous. Nevertheless, the reforms' joint effect on MRP prices is

negative which led to considerable savings in each of the four regional markets. Finally, we discuss the issues of these savings to result in welfare gains. We offer several arguments why the reforms in the MRP markets can only serve as complementary elements of a regulation designed to increase overall efficiency in the electricity sector.

The remainder of the chapter is structured as follows. Section 5.2 provides a brief overview of the regulatory changes. Section 5.3 contains the main part of our analysis: we present the data and perform an econometric analysis to evaluate the reforms' effects on MRP prices. Finally, the reforms' success is quantified, and some welfare implications are discussed. Section 5.4 concludes the chapter.

5.2 Regulatory Changes in the German Electricity Reserve Power Markets

The synchronization and standardization of the electricity reserve power markets in Germany started on December 01, 2006, when a common web-based tendering platform was launched for MRP. The timing of auctions, the prequalification procedure,[5] and the selection of reserve power providers in merit orders were specified and standardized. Whereas the auctions were time-separated before December 1, 2006, the new market design harmonized and synchronized the procurement auctions, while each TSO continued to procure MRP for its own control area. Hence, the four distinct regional markets remained. Moreover, the new market design prescribed that the procurement auction closes before the electricity (day-ahead) spot market on the European Energy Exchange (EEX). The purpose was to prevent reserve capacity suppliers from knowing their opportunity costs when offering capacities on the MRP market, and thus to avoid or, at least, to limit strategic behavior.

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[5]Prequalification means the procedure of evaluating whether or not a generation unit meets the required criteria to be approved to offer electricity reserve power. It has been changed by reducing the minimum quantity to be supplied, allowing joint capacity offerings, and using specified publication obligations in order to facilitate market entry. For a more detailed discussion see BNetzA (2006).

The procurement auction after December 1, 2006, can be basically characterized as a *i)* repeated (daily), *ii)* day-ahead, *iii)* multi-unit (incremental and decremental), *iv)* one-sided (only reserve capacity supplier make offers), *v)* multi-part (capacity price and operating price), and *vi)* pay-as-bid auction (see e.g., Müller and Rammerstorfer, 2008).[6] The market synchronization was completed on December 1, 2007, when joint web-based tendering platforms were also launched for PCP and SCP. In contrast to MRP, the procurement auction was initially held monthly, and the prequalification procedures are more restrictive due to the inherently higher technical requirements of PCP and SCP.[7]

The four TSOs started to interconnect and to cooperate before the German Federal Network Agency published its decision in March 16, 2010, which obliged the TSOs to do so in order to realize synergies. Initially, two alternative concepts were discussed to reduce the inefficient use of reserve power capacity in the SCP market.[8] On the one hand, one central and overriding TSO was proposed which should control the frequency in all four control areas. This alternative was favoured by Amprion which is the TSO of the integrated German electricity company RWE. However, the remaining TSOs (ENBW Transportnetze, TenneT TSO, and 50Hertz Transmission) supported the second alternative which consisted of a cooperation and interconnection of all four TSOs in order to realize synergies. ENBW Transportnetze, TenneT TSO, and 50Hertz Transmission started to cooperate and to interconnect their operations before March 16, 2010. In doing so, they preempted the Federal Network Agency's decision, and thereby made the installation of one central TSO more difficult. In result, the second alternative was put in place by the Federal Network Agency, and Amprion was forced to join the existing TSO network in 2010 (see BNetzA, 2010).

The process of cooperation and interconnection, which initially concerned the SCP mar-

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[6] Note that the procurement auction for PCP cannot be classified as a multi-unit auction, since incremental and decremental reserve power are not distinguished in primary control.

[7] Note that the procurement auctions for PCP and SCP are held weekly since June 27, 2011. Our dataset does not include this change in market design.

[8] A more detailed discussion can be found in e.g., BNetzA (2010).

ket, was realized gradually, and it comprises four modules. In a first step, the TSOs had to eliminate the use of opposed SCP and to ensure that they determine the required reserve capacity by jointly balancing all four control areas (modules 1 and 2, M1 and M2). In a second step, the TSOs had to start to procure SCP jointly and to use one merit order for all control areas (modules 3 and 4, M3 and M4). Finally, Amprion was forced to join the existing TSO-network at the latest on May 31, 2010. However, Amprion already joined in April, 2010. On July 1, 2010, the reform was extended to the MRP market, and the TSOs began to cooperate and interconnect their operations while procuring MRP.

To get a better overview, we provide the following table which summarizes and illustrates the sequence of reforms encompassed by the regulatory changes in the German electricity reserve power markets.

Table 5.1: Sequence of reforms in the German electricity reserve market

Synchronization		Interconnection and Cooperation					
12.1.2006	12.1.2007	12.17.2008	5.1.2009	7.1.2009	10.1.2009	4.15.2010	7.1.2010
MRP	PCP+SCP	Module 1	Module 2	Module 3	Module 4	Amprion	MRP
reform 1	reforms 2+3	reform 4	reform 5	reform 6	reform 7	reform 8	reform 9

In the next section, we ask whether or not each of the political reforms led to increased competition in the MRP market. Thereby, we measure increases in competition by reductions in both incremental MRP prices and decremental MRP prices. Our focus is especially on the introduction of the new market design for MRP on December 1, 2006. Moreover, we test if the four control areas have become more integrated due to the reforms. Finally, we quantify the reforms' joint success in reducing MRP prices by comparing the actual prices after the first reform on December 1, 2006, with those prices which would have been realized without the reforms.

Figure 5-1: Incremental MRP prices per control area
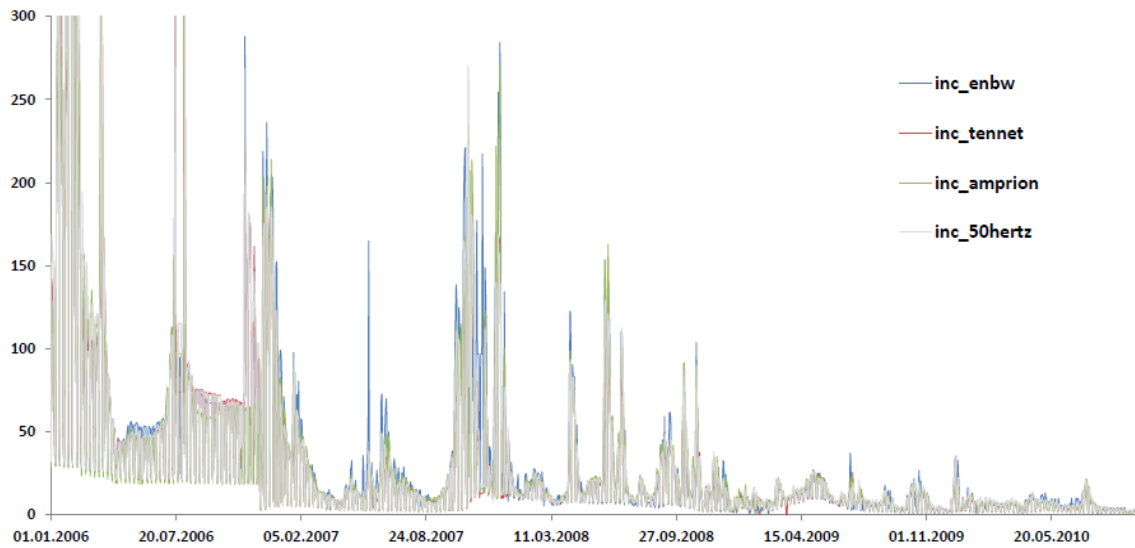
5.3 Econometric Analysis

5.3.1 Data

We created a unique panel dataset on both daily incremental MRP prices and daily decremental MRP capacity prices in Germany for the period between January 1, 2006, to September 30, 2010. Throughout the rest of our analysis, we refer to MRP capacity prices when using the term MRP prices. Incremental and decremental MRP prices are separately used as dependent variables to check whether or not the reforms led to increased competition which is reflected by lower prices in the four control areas. We calculated the MRP prices for each control area as weighted mean values, where capacities (in megawatt, MW) were used as weights. The data on MRP prices and MRP capacities were collected from the common web-based tendering platform for electricity reserve power (www.regelleistung.net). Figure 5-1 illustrates the incremental MRP prices in each control area from January 1, 2006, to September 30, 2010.

It can be seen that, on average, incremental MRP prices have fallen in each control area after the first reform on December 1, 2006. The same appears to be true for the price

volatility. However, further graphical inspection does not reveal any obvious effects of the remaining reforms. A very similar picture is offered when we shift our focus to decremental MRP prices which are presented in Figure 5-2.

Whereas graphical inspection supports the view that the first reform on December 1, 2006, had a negative effect on decremental MRP prices, it is difficult to observe any effects of the remaining reforms. Nevertheless, Figure 5-2 shows that on average decremental MRP prices slightly increased in April 2009 when Amprion joined the TSO network in the SCP market.

Our main explanatory variable is the electricity (day-ahead) spot market price for base load on the European Energy Exchange (EEX). Alternatively, we could have used data on over-the-counter (OTC) spot market prices. However, due to high correlation between EEX spot market prices and OTC prices, we had to choose one of the variables.[9] Other explanatory variables are the Western Texas Intermediate (WTI) oil price, the brown coal price and the natural gas price.[10] In addition, we control for seasonal variations leading to differences in electricity consumption by incorporating dummy variables into our regressions. More specifically, we consider both weakly seasonal variations and yearly seasonal variations. The former reflect variations between weekdays and weekends, while the latter represent variations between summertime, wintertime and the rest of the year.

Two instruments are used to account for endogeneity of the EEX spot price. The first instrument is a time series of the maximum daily wind strength (mws) in northern Germany. Since the largest part of wind power is produced in the north of Germany and wind power constitutes the most important renewable resource, we expect the EEX spot price to be negatively affected by the maximum daily wind strength.[11] A necessary prerequisite is that

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[9] It can be shown that our results hold when the OTC spot price is used as an explanatory variable instead of the EEX spot price. The results can be requested form the authors.

[10] Whereas the WTI oil price was collected from the website of the U.S. Department of Energy (energy.gov), the brown coal price and the natural gas price were available on Platts.

[11] In 2011, the share of wind power in gross total electricity production amounts to 8%, whereas the share

mws must be a good proxy for produced daily wind power which reduces the demand for electricity traded on the EEX.[12]

The second instrument contains rain data on the daily amount of precipitation for control area-representative German cities (Berlin, Cologne/Bonn, Nürnberg, and Stuttgart). The reasoning is as follows. It can be expected that the demand for electricity depends on weather, and thereby probably varies with the amount of precipitation. If this is true, then the wholesale market price will be inevitably affected by demand variations caused by changes in weather conditions.

5.3.2   Interrelationship between the Control Areas

To investigate whether or not the interrelationship between the four control areas changed due to the reforms, we construct a Vector Autoregressive Model (VAR). Instead of analyzing each reform individually, we simply consider the reforms' joint effect. Hence, we compare the interrelationship between the control areas before the first reform was put in place on December 1, 2006, with the interrelationship after December 1, 2006. Thereby, we estimate a VAR model of the following form:

$$y_t = A_1 y_{t-1} + ... + A_4 y_{t-4} + t + u_t.$$

In our basic VAR model, $y_t = (y_{1t}, y_{2t}, y_{3t}, y_{4t})'$ represents a vector of four observable endogenous variables, i.e., the observed prices on the four control areas, where t is a deterministic linear time trend. The term u_t is a standard unobservable white noise process with zero mean, and A_i is a parameter matrix (see Hamilton, 1994: 257-258). The VAR-system is estimated by feasible generalized least squares. Based on our estimations, we perform Granger-causality tests to check whether the price series of the regional operators

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of all renewables is 20% (see e.g., BDEW, 2011).

[12] If this condition is met, then it could be argued that mws should be included as an explanatory variable. As will be shown later, based on the Sargan-Hansen test, our analysis reveals that the instruments are correctly excluded, and thus constitute valid instruments.

influence each other as a measure of interrelationship. Granger-causality exists if a variable helps to improve forecasting another variable (see Lütkepohl, 2005: 41-43). Hence, Granger-noncausality can be expressed as

$$y_{1,t+h|\Omega_t} = y_{1,t+h|\Omega_t \setminus \{y_{2,s}|s \leq t\}}.$$

The series of the variable y_{2t} is not Granger-causal to y_{1t} if removing past information of y_{2t} from the information set has no effects on the optimal forecast of y_{1t}. Instead, Granger-causality exists if the equation holds for at least one step, h (see Lütkepohl, 2004: 144). To avoid spurious regressions, we first have to check whether the subscriber series of the competitors are stationary. Before estimating VAR models, it is very important to analyze the time series properties of the series, used in the analysis, because regressions of non-stationary time series on each other usually suffer serious spurious regressions problems. Accounting for these problems, one usually applies unit root tests. In our case, it is important to test on unit roots and structural breaks jointly because it is reasonable that changes in regulatory environments cause structural breaks in our data. To get statistically robust results, we apply unit root tests which additionally take into account structural breaks in the time series. We use the one break version of a unit root test developed by Clemente, Montanes, and Reyes (1998). The procedure to apply this test for two structural breaks starts with the estimation of the following regression:

$$y_t = \mu + \delta_1 DU_{1t} + \delta_2 DU_{2t} + v_t.$$

In this regression, $DU_{mt} = 1$ for $t > T_{bm}$, and 0 otherwise, for $m = 1, 2$. T_{b1} and T_{b2} are the breakpoints. The residuals obtained from this regression, v_t, are the dependent variables in the next equation to be estimated. In order to make the distribution of the test statistic tractable, the residuals have to be regressed on their lagged values, a number of lagged differences, and a set of dummy variables:[13]

$$v_t = \sum \varpi_{1i} DT_{b1,t-i} + \sum \varpi_{2i} DT_{b2,t-i} + \alpha v_{t-i} + \sum \theta_i \Delta v_{t-i} + e_t,$$

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[13] See Baum (2005) for a more detailed dicussion.

where $DT_{bm,t} = 1$ if $t = T_{bm}+1$, and 0 otherwise, for $m = 1, 2$. In a next step, the regression is estimated over feasible pairs of T_{b1} and T_{b2} to find the minimal t-ratio for the hypothesis $\alpha = 1$ which means the strongest rejection of the null hypothesis of the unit root. Because the minimal value of the t-ratio does not follow the standard Dickey-Fuller distribution, it is compared with the critical values calculated by Perron and Vogelsang (1992). The following table shows the results of the unit root tests.

Table 5.2: Clemente, Montanes, and Reyes Unit Root Test for incremental MRP prices

Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho - 1$	$const$
coefficient	-131.510	-0.145	169.004
t-statistic	-17.401	-5.545	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho - 1$	$const$
coefficient	-140.501	-0.139	174.999
t-statistic	-21.522	-5.893	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho - 1$	$const$
coefficient	-138.443	-0.139	160.687
t-statistic	-23.331	-5.591	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho - 1$	$const$
coefficient	-154.820	-0.139	188.510
t-statistic	-24.462	-5.806	
p-value	0.0000	-3.560	

The results of our tests are twofold: Firstly, the tests confirm our hypothesis that there is a structural break on December 1, 2006, when the new regulatory regime was in charge for the first time. Secondly, the four price series are non-stationary. The results have two consequences. The first consequence is estimating the VAR models in first differences to

avoid spurious regression problems. The second consequence is estimating our models for the time periods before and after the structural break separately to investigate differences caused by the new market design. The following tables repeat the analysis for decremental MRP prices.

Table 5.3: Clemente, Montanes, and Reyes Unit Root Test for incremental MRP prices

Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-74.905	-0.097	94.586
t-statistic	-39.938	-3.793	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-82.182	-0.094	100.370
t-statistic	-41.208	-3.571	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-74.459	-0.097	92.758
t-statistic	-43.254	-3.403	
p-value	0.0000	-3.560	
Unimplemented multicol	Unimplemented multicol		
$AR(2)$	DU_1	$rho-1$	$const$
coefficient	-81.138	-0.101	100.197
t-statistic	-240.852	-3.985	
p-value	0.0000	-3.560	

VAR models are quite sensible with regards to the lag length of the relevant time series. We base our lag length selection on three familiar information criteria. The standard information criteria Akaike, Hannan-Quinn, and Schwarz-Bayes all suggest an optimal lag length of four for the VAR model.

Table 5.4: Lag length selection

Lag	AIC	HQIC	SBIC
Unimplemented multicol			
4	36.578	36.891	37.363
Unimplemented multicol			
4	31.847	31.984	32.206
Unimplemented multicol			
4	32.934	33.247	33.719
Unimplemented multicol			
4	30.086	30.223	30.445

The following tables provide information on the results of our Granger causality tests between the price series for both incremental and decremental MRP as measures of the interrelationships between the four control areas.

Table 5.5: Granger-causality tests for incremental MRP prices before structural break

Lags	H_0	Granger-Causality
4	enbw $\rightarrow$ amprion	0.248 (0.619)
4	enbw $\rightarrow$ tennet	0.273 (0.602)
4	enbw $\rightarrow$ 50hertz	0.796 (0.372)
4	amprion $\rightarrow$ enbw	1.106 (0.293)
4	amprion $\rightarrow$ tennet	0.785 (0.376)
4	amprion $\rightarrow$ 50hertz	1.118 (0.290)
4	tennet $\rightarrow$ enbw	0.662 (0.416)
4	tennet $\rightarrow$ amprion	0.197 (0.657)
4	tennet $\rightarrow$ 50hertz	1.978 (0.160)
4	50hertz $\rightarrow$ enbw	0.356 (0.551)
4	50hertz $\rightarrow$ amprion	0.030 (0.863)
4	50hertz $\rightarrow$ tennet	0.547 (0.459)

For incremental MRP, Table 5.5 clearly shows that there is no interrelationship between the four regions before the change in market design on December 1, 2006. The result changes significantly after the launch of the common web-based tendering platform for MRP, as it can be immediately seen in Table 5.6.

Table 5.6: Granger-causality tests for incremental MRP prices after structural break

Lags	H_0	Granger-Causality
4	enbw $\rightarrow$ amprion	45.268 (0.000)*
4	enbw $\rightarrow$ tennet	56.443 (0.000)*
4	enbw $\rightarrow$ 50hertz	32.428 (0.000)*
4	amprion $\rightarrow$ enbw	48.289 (0.000)*
4	amprion $\rightarrow$ tennet	49.213 (0.000)*
4	amprion $\rightarrow$ 50hertz	39.942 (0.000)*
4	tennet $\rightarrow$ enbw	39.325 (0.000)*
4	tennet $\rightarrow$ amprion	15.960 (0.000)*
4	tennet $\rightarrow$ 50hertz	42.690 (0.000)*
4	50hertz $\rightarrow$ enbw	33.547 (0.000)*
4	50hertz $\rightarrow$ amprion	22.228 (0.000)*
4	50hertz $\rightarrow$ tennet	52.675 (0.000)*

After the structural break there is a statistical significant relationship between all incremental MRP price series of the four control areas. The implication is that including prices from other regions in the information set of an individual MRP price series provides better forecasts of future prices than just using past values of the own price series. As a result, the change in market design clearly has effects on the interrelationship of the four regional markets for incremental MRP. Finally, we extend our analysis on the series of decremental MRP prices in Germany.

Table 5.7: Granger-causality tests for decremental MRP prices before structural break

Lags	H_0	Granger-Causality
4	enbw $\rightarrow$ amprion	0.920 (0.337)
4	enbw $\rightarrow$ tennet	0.319 (0.572)
4	enbw $\rightarrow$ 50hertz	0.882 (0.348)
4	amprion $\rightarrow$ enbw	0.017 (0.898)
4	amprion $\rightarrow$ tennet	0.429 (0.513)
4	amprion $\rightarrow$ 50hertz	1.069 (0.301)
4	tennet $\rightarrow$ enbw	0.015 (0.903)
4	tennet $\rightarrow$ amprion	1.018 (0.313)
4	tennet $\rightarrow$ 50hertz	1.060 (0.303)
4	50hertz $\rightarrow$ enbw	0.054 (0.816)
4	50hertz $\rightarrow$ amprion	0.541 (0.462)
4	50hertz $\rightarrow$ tennet	0.372 (0.542)

Our analysis of Granger-causality between decremental MRP prices before the reform on December 1, 2006, yields the same results as before when incremental MRP prices were concerned. Before the structural break, there is no interrelationship between the four decremental MRP prices. Examining the interrelationship between decremental MRP prices after the structural break leads to the following results presented in Table 5.8.

Table 5.8: Granger-causality tests for decremental MRP prices after structural break

Lags	H_0	Granger-Causality
4	enbw $\rightarrow$ amprion	0.248 (0.618)
4	enbw $\rightarrow$ tennet	4.117 (0.042)*
4	enbw $\rightarrow$ 50hertz	1.318 (0.251)
4	amprion $\rightarrow$ enbw	0.514 (0.473)
4	amprion $\rightarrow$ tennet	0.478 (0.490)
4	amprion $\rightarrow$ 50hertz	1.837 (0.175)
4	tennet $\rightarrow$ enbw	0.811 (0.368)
4	tennet $\rightarrow$ amprion	0.573 (0.449)
4	tennet $\rightarrow$ 50hertz	4.497 (0.034)*
4	50hertz $\rightarrow$ enbw	2.423 (0.120)
4	50hertz $\rightarrow$ amprion	1.300 (0.254)
4	50hertz $\rightarrow$ tennet	1.447 (0.229)

The set of Granger-causality tests for decremental MRP prices after the structural reform provides mixed results. In contrast to our results for incremental MRP prices, we do not find evidence for interrelationships between the series. Our tests only detect Granger-causality between ENBW and TenneT as well as 50Hertz and TenneT. We conclude that changes of interrelationships between the four regional markets for decremental MRP are less strong compared with incremental MRP.

VAR models, estimated in first differences, clearly measure short run relationships. Therefore, we additionally tested for cointegration between the four regional markets because there might be a long run interrelationship. However, we rejected all hypotheses of cointegration relationships between the four control areas.

5.3.3 Determinants of MRP Prices

Empirical Strategy

In the second part of our econometric analysis, we take advantage of the panel structure of our data. The main benefit of such a strategy is that it enables us to account for unobserved heterogeneity between the four control areas in Germany by including fixed effects in our panel regression. In order to analyze whether or not the structural reforms have fostered competition in the MRP markets, we begin by estimating separate regressions for incremental and decremental MRP prices for the periods before and after each reform. Thereby, we examine each of the nine reforms in isolation, while accounting for the remaining reforms via shift-dummy variables.[14] Our main focus is on the effects of the implementation of the common web-based tendering platform for MRP on December 1, 2006. The reason is that it is natural, by regulatory design, to suppose that this reform should have had a direct impact on the performance of the MRP markets. Nevertheless, we ask whether or not the other reforms had an impact on both incremental and decremental MRP prices, too. In addition to the separate regressions for each reform, we perform pooled regressions where we use the Chow test to investigate whether or not structural breaks occurred due to the reforms.

Taking the panel structure of our data into account, we can derive an adequate specification as

$$y_{it} = \alpha_{it} + \sum \beta_k x_{it,k} + \epsilon_{it}, \tag{5.1}$$

where y_{it} represents the incremental MRP prices and decremental MRP prices, respectively, and $x_{it,k}$ are explanatory variables. The error term is given by ϵ_{it} and the α's and the β's are parameters to be estimated. Assuming that α_{it} is fixed over time, but differs with cross-section units, the equation in (5.1) can be estimated using fixed effects controlling for

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[14]Note that reforms 2 and 3, reflecting the launch of common web-based tendering platforms for SCP and PCP, cannot be separately analyzed. The reason is that both reforms were simultaneously put in place on December 1, 2007. Thus, we rather test for eight than for nine structural breaks.

unobserved heterogeneity. Alternatively, we could assume that α_{it} can be composed into a common constant, α, and a unit specific random variable, v_i, so that $\alpha_{it} = \alpha + v_i$ holds. In this case, the equation in (5.1) would be estimated with the random effects model. However, we apply fixed effects (FE) because it seems to be a natural choice. Since unobserved heterogeneity between regions is usually constant over time, FE regressions present the more accurate approach. Moreover, we use instrumental variable techniques to account for possible endogeneity problems of the EEX electricity spot market price. It is reasonable to believe that there could be some feedback form the MRP market to the electricity wholesale market on the EEX. Intuitively, the reason is that, at least to some extent, generation units regard the market for MRP and the electricity wholesale spot market as substitutes; they can (partially) choose where to use their capacities. Hence, they will base their decision on the expected price gap between the MRP price and the EEX spot price. To avoid endogenous regressors, we instrument the EEX spot prices by using data on the daily maximum wind strength in northern Germany and the daily amount of precipitation in control area-specific German cities. The idea of such an approach is that there is no direct effect on MRP prices, but that there are massive effects on EEX spot prices. The first stage results of our FE two stage least squares regressions can be found in Appendix B.

The remaining explanatory variables comprise the WTI oil price, and dummy variables accounting for the seasonality of MRP prices which arises from differences in electricity consumption between summertime and wintertime as well as weekdays and weekends. Other potential exogenous variables, such as the natural gas price, the brown coal price, and the feed-in from wind energy, were not incorporated into our analysis due to problems of multicollinearity.[15]

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[15] The correlation between the WTI oil price and the natural gas price is .78. An obvious first explanation is the fact that, in Germany, the natural gas price is linked to the oil price by contractual arrangements (Ölpreisbindung). The WTI oil price and the brown coal price are also highly correlated (.76). The same is true for the relationship between the feed-in from wind energy and our instruments. Due to serious concerns with regards to multicollinearity issues, we decided to omit these variables.

Econometric Results

In this section, we present the results of our panel regressions. The Chow test, whose main idea is the comparison between the residual sum of squares of the pooled regression and the separate regressions, is used to determine whether or not the reforms had a statistically significant effect on MRP prices. To avoid spurious regressions problems, we run unit root tests for all variables.[16] Whereas both incremental and decremental MRP prices as well as the control area specific daily amount of precipitation are stationary, the WTI oil price, the EEX spot price, and the daily maximum wind strength in northern Germany are integrated of order one to eliminate non-stationarity. We start our analysis by focussing on the launch of the common web-based tendering platform on December 1, 2006. The remaining reforms are considered via regulatory shift-dummies.[17] First, we estimate the two separate panel regressions of incremental and decremental MRP prices for the time before and after the change in market design. The following table presents our results.

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[16] While both the Phillips-Perron test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test are used for the time series data (EEX spot price, WTI oil price, and mws), the Im-Pesaran-Shin unit root test is performed for the panel data (incremental and decremental MRP prices, (control area specific) daily amount of precipitation). Note that the Im-Pesaran-Shin test is a specifically tailored unit root test for panel data. For a more detailed discussion see Im et al. (2003). The results can be found in Appendix A.

[17] A list of all variables used in the panel regressions can be found in Appendix B.

Table 5.9: Separated panel regressions of incremental MRP prices (reform 1)

inc MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-1.29**	.5173	-.08	.1386
WTI oil	-2.77	3.7126	1.25***	.3804
dummy weekend	-109.89***	10.8148	-19.81***	1.6870
dummy summer	3.71	4.5535	-4.73***	.7951
dummy winter	143.72***	9.9697	8.98***	1.1913
dummy scp+pcp			-7.91***	1.3494
dummy M1			-19.18***	1.0292
dummy M2			10.21***	1.0053
dummy M3			-4.76***	.6655
dummy M4			-7.53***	.9172
dummy amprion			5.20***	.8057
dummy mrp2			0.01	.6672
Obs.	1332		5600	
R^2	.3710		.2258	
Residual sum of squares	8164675.77		4161996.74	
Weak identification test	25.681		88.075	
Sargan-Hansen p-value	.1684		.2354	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Note that the remaining regulatory dummies do not appear in the model for period 1, since the reforms, presented by these dummies, were put in place after December 1, 2006. We use two tests to evaluate our instrumental variables. The weak identification test supports the choice of our instruments, since it indicates small biases in both periods (less than 10 per cent). In addition, we report the Sargan-Hansen test on overidentification of

all instruments. The reported p-values do not allow a rejection of the null hypothesis so that our instruments can be classified as valid instruments.

The same procedure is performed with regards to decremental MRP prices. The two separate regressions are shown in Table 5.10.

Table 5.10: Separated panel regressions of decremental MRP prices (reform 1)

	Period 1		Period 2	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.22	.2161	.33***	.0902
WTI oil	.83	1.1043	.23	.1721
dummy weekend	65.08***	4.3103	15.11***	1.1808
dummy summer	10.69***	2.2489	-2.06***	..4602
dummy winter	-23.99***	2.0156	-3.08***	.6718
dummy scp+pcp			-6.05***	.4662
dummy M1			24.32***	1.455
dummy M2			14.33***	1-9131
dummy M3			-23.11***	1.3430
dummy M4			-4.52***	1.0208
dummy amprion			-8.16***	.9588
dummy mrp2			.7814	.7212
Obs.	1332		5600	
R^2	.4253		.2798	
Residual sum of squares	1574236.11		1551248.72	
Weak identification test	25.681		88.075	
Sargan-Hansen p-value	.8712		.0211	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

The EEX spot price has a significant impact on incremental MRP prices before the reform, but an insignificant effect after the reform. This result is reversed when decremental MRP prices are investigated. The WTI oil price has a statistically significant effect only on incremental MRP prices after the reform. Moreover, we find that the seasonal dummies exert a significant effect on both prices in both periods. The only exception builds the summer season with respect to incremental MRP prices.

Finally, we perform the Chow test to identify whether or not the reform created a structural break on December 1, 2006. Therefore, we run pooled regressions for both types of MRP prices which are used together with the separate regressions to calculate the Chow test statistics. The results are presented in the following table.

Table 5.11: Pooled regression and Chow test (reform 1)

	inc MRP		dec MRP	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.31	.2324	.18	.1476
WTI oil	.41	.6184	.12	.2621
dummy weekend	-36.27***	3.1620	22.97***	2.1021
dummy summer	-4.89***	1.2618	1.73	1.1721
dummy winter	29.13***	2.3387	-10.26***	.9089
dummy scp+pcp	-37.13***	1.7134	-43.46***	0.9764
dummy M1	-24..69***	1.4987	27.21***	1.4268
dummy M2	-21.74***	1.9931	8.52***	1.9789
dummy M3	-5.07***	1.1771	-23.74***	1.4014
dummy M4	-16.84***	1.7554	1.29	1.2139
dummy amprion	14.47***	1.6790	-12.95***	1.0891
dummy mrp2	.02	1.5994	-.28	.8905
Obs.	6932		6932	
R^2	.2594		.2818	
Residual sum of squares	17691582.32		8125882.28	
Weak identification test	110.687		110.687	
Chow test statistic	**214.63**		**779.61**	
Sargan-Hansen p-value	.0018		.0128	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity

robust.

Based on the Chow test statistics, we find strong evidence for a structural break for both incremental and decremental MRP prices. In other words, the launch of the common web-based tendering platform for MRP had a statistically significant effect on MRP prices. Thus, we have to extend our set of exogenous variables by a dummy variable which accounts

for the new market design introduced on December 1, 2006, and perform another pooled panel regression. The results are shown in Table 5.12.

Table 5.12: Pooled regression with regulatory dummy (reform 1)

	inc MRP		dec MRP	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2125	.20**	.0999
WTI oil	.69	.5864	.25	.1918
dummy weekend	-36.00***	2.8978	23.32***	1.3949
dummy summer	-5.17***	1.1658	1.35*	.6976
dummy winter	31.80***	2.1987	-6.73***	.7375
dummy mrp1	**-60.01***	2.7187**	**-79.17***	1.1646**
dummy scp+pcp	-8.68***	1.3610	-5.91***	.5110
dummy M1	-25.50***	1.5121	26.13***	1.4392
dummy M2	23.30***	1.9312	10.58***	1.9454
dummy M3	-4.96***	1.1660	-23.60***	1.3838
dummy M4	-18.28***	1.6790	-.61	1.0489
dummy amprion	15.84***	1.5482	-11.15***	1.0197
dummy mrp2	.07	1.1237	-.16	.8498
Obs.	6932		6932	
R^2	.3647		.6653	
Weak identification test	110.639		110.639	
Sargan-Hansen p-value	.1786		.1582	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

The launch of the new market design is reflected by the dummy variable *dummy mrp1*. The coefficients are significant and negative for both MRP prices indicating that the reform was successful in decreasing both MRP prices. We conclude that the launch of the common

web-based tendering platform for MRP has indeed increased competition and efficiency by significantly decreasing both incremental and decremental MRP prices. Finally, the choice of our instruments is supported by both the weak identification test and the Sargan-Hansen test on overidentification.

The same methodology is applied to investigate the remaining reforms' individual success. The results of our separate and pooled panel regressions can be found in Appendix B. We rather report the Chow test statistics and the coefficients of each reform's dummy variable. Tables 5.13 and 5.14 present our results.

Table 5.13: Each reform's effect on incremental MRP prices (Chow test)

	Synchronization		Interconnection and Cooperation					
	12.1.2006	12.1.2007	12.17.2008	5.1.2009	7.1.2009	10.1.2009	4.15.2010	7.1.2010
Reform	1	2+3	4	5	6	7	8	9
Chow stat.	214.63	79.05	45.46	18.69	17.07	18.61	6.13	1.63
coefficient	-60.01***	-8.68***	-25.50***	23.30***	-4.96***	-18.28***	15.84***	.07

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.14: Each reform's effect on decremental MRP prices (Chow test)

	Synchronization		Inteconnection and Cooperation					
	12.1.2006	12.1.2007	12.17.2008	5.1.2009	7.1.2009	10.1.2009	4.15.2010	7.1.2010
Reform	1	2+3	4	5	6	7	8	9
Chow stat.	779.61	37.07	55.25	8.22	16.89	5.17	6.00	1.16
coefficient	-79.17***	-5.91***	26.13***	10.58***	-23.60***	-.61	-11.15***	-.16

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

The first three reforms, which introduced a new market design for MRP, SCP and PCP on December 1, 2006, and December 1, 2007, respectively, were all successful in reducing MRP prices. This result is reflected by the existence of structural breaks and negative

coefficients. However, note that the first reform had a stronger impact on both MRP prices than reforms 2 and 3. This finding is straightforward, since these reforms did not directly affect the markets for MRP.

When we analyze the effects of the second regulatory change (reforms 4 to 9), we get mixed results. While there is empirical evidence that interconnection and cooperation of the four TSOs in the SCP market largely created structural changes, the effects on MRP prices were not throughout negative. For instance, module 2, i.e., the joint balancing of SCP, rather increased than decreased both incremental MRP prices and decremental MRP prices.

Finally, it seems to be surprising that interconnection and cooperation of the TSOs in the MRP market had no significant effect on MRP prices. However, it must be noted that our data encompasses only three months after reform 9 was put in place. Hence, one should be cautious when interpreting such a result because a different picture could be revealed if the data were extended in terms of time.

5.3.4 The Reforms' Joint Success and Some Welfare Implications

In a last step, we quantify the reforms' joint success by comparing the actual MRP prices, which were realized between December 1, 2006, and September 30, 2010, with the hypothetical prices which would have been realized if there were no reforms. Such a comparison necessitates an adequate construction of the counterfactual. To accomplish this goal, we use our basic FE model in (5.1) where we set an upper bound for the time variable to ensure that the FE model is restricted to the time before the first reform was put in place. Thus, we estimate incremental MRP prices and decremental MRP prices, respectively, using the following specification

$$y_{i\bar{t}} = \alpha_i + \sum \beta_k x_{i\bar{t},k} + \epsilon_{i\bar{t}}, \tag{5.2}$$

where $\bar{t} \in [1, 334]$ covers the period from January 1, 2006, to November 30, 2006. The estimated coefficients are then used to predict the hypothetical (counterfactual) MRP prices from December 1, 2006, to September 30, 2010. In addition, we use daily MRP quantities

in order to quantify the exact savings each TSO realized due to the reforms. The following table shows our results.

Table 5.15: The reforms' joint success in the MRP markets (in million euros)

	Incremental MRP				Decremental MRP			
	ENBW	Tennet	Amprion	50Hertz	ENBW	Tennet	Amprion	50Hertz
Hypoth. costs	280.4	831.5	828.3	529.5	148.1	668.8	602	347.5
Actual costs	81.9	159.6	171.2	108.9	42	127.9	119.8	76.7
Savings	198.5	671.9	657.1	420.6	105.1	540.9	483.2	270.8

Since MRP prices constitute costs of maintaining the frequency level in the electricity grid, and thus, ensuring system stability, they are considered in the regulated grid usage fees charged by the TSO. Hence, MRP price reductions represent cost savings.[18] It can be immediately seen that the reforms jointly led to enormous savings in the markets for both incremental MRP and decremental MRP (1948.09m euros and 1399.97m euros, respectively). Nevertheless, it must be questioned if these savings inevitably led to an increase of consumer surplus, or even welfare gains. We invoke three major arguments which raise serious doubts.[19] First, there could be some room for strategic pricing. More precisely, MRP suppliers could charge higher operating prices to recoup their losses from decreased MRP capacity prices. Since we solely focus on MRP capacity prices, we are not able to derive any statements on this potential issue. However, it should be noted that, according to the German Federal Network Agency (see BNetzA, 2006), the TSOs only make use of less than 2% of the reserved MRP capacities which makes a recoupment by increasing operating prices more difficult.

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[18] Alternatively, these cost savings can be termed productive efficiency gains, although they were not entirely created by common means such as scale economies, process innovation, etc.

[19] Note that there are several other arguments, such as the relatively inelastic demand for electricity, the prevalence of vertically integrated electricity companies, etc., which also pose severe obstacles for the savings not to result in welfare gains.

Second, the demand for MRP is almost entirely driven by technical factors rather than market prices. Hence, price reductions should not trigger a demand effect in the MRP market. The only channels through which consumer surplus and (or) welfare could be increased are the electricity wholesale markets and retail markets. Necessary conditions for this to happen are a sufficiently high level of competition on the supplier side and a demand which is not entirely inelastic. The former condition leads us directly to our next argument.

Third, it can doubted that electricity wholesale markets and retail markets are sufficiently competitive so that productive efficiency gains are always, at least partially, passed through to consumers. If they are competitive, the savings will lead to lower wholesale and retail prices which, in turn, shifts the rent from suppliers to consumers. But for allocative effects to occur, there must be also a demand effect, i.e., higher demand for electricity resulting from decreased electricity prices. Otherwise, welfare gains will not be realized, regardless of the level of savings in the MRP market.

5.4 Conclusion

In this chapter, we evaluate the recent reforms in Germany's electricity reserve power markets with regards to their effects on incremental and decremental MRP prices. The reforms consisted of synchronization and standardization on the one hand, and TSO interconnection and cooperation on the other hand. The regulator's goal was to foster competition, to increase efficiency, and to realize synergies in the electricity reserve power markets.

In a first step, we apply time series techniques to investigate whether the reforms changed the interrelationships between the MRP price series of the four German control areas. We find strong evidence for interrelationships between all incremental MRP prices after the first structural reform was put in place. However, this result cannot be confirmed for decremental MRP prices. The regulatory changes had rather no effect on the relationship between decremental MRP prices suggesting that the control areas remained partly distinct.

In a second step, we use a unique panel dataset, accounting for unobserved heterogeneity and endogeneity, to check whether or not the reforms were successful in decreasing both

incremental and decremental MRP prices. It is demonstrated that the launch of common web-based tendering platforms for PCP, SCP, and MRP was successful in decreasing MRP prices. This result cannot be confirmed for the second regulatory change. We rather find mixed effects revealing that either some reforms had an adverse impact on MRP price, i.e., MRP prices were increased, or did not cause any significant structural changes at all. However, we show that the reforms were jointly successful in decreasing MRP prices leading to savings of 1948.09m euros and 1399.97m euros for incremental MRP and decremental MRP, respectively. Moreover, there is a good chance that the first reform on December 1, 2006, had a positive impact on wholesale market competition on the EEX. Since generation units, at least partly, regard the wholesale (day-ahead) spot markets and the MRP markets as substitutes, it is reasonable to suppose that synchronization and standardization reduced the suppliers' possibility of strategic pricing.

Although we find strong empirical evidence that efficiency gains were realized in terms of reduced MRP prices, there are good reasons which make welfare gains or, at least, increases in consumer surplus very difficult. We claim that the major dilemma of a regulation, tackling the efficiency of electricity reserve power markets, is that it hardly affects the performance in the electricity wholesale markets and retail markets, respectively.[20] Thus, the electricity reserve power reforms can only serve as complementary elements of a regulation which is designed to increase overall efficiency in the electricity sector. Further reforms are needed which especially focus on competition in wholesale markets and retail markets, consumer switching costs, and the effects of vertically integrated firms.

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[20] We admit that the first reform could have had a negative impact on wholesale electricity prices. However, we discussed several arguments which could have outweighed these effects possibly resulting in superfluous regulatory changes.

Appendix

Appendix A

In Appendix A, we present our results of the stationarity tests and unit root tests. We tested all relevant explanatory variables (WTI oil price, EEX spot price), both instruments (mws, inst_rain), and the dependent variables (incremental and decremental MRP prices). While the KPSS test and the Phillips-Perron test are performed with regards to time series, the Im-Pesaran-Shin unit root test is performed for the panel data. The latter tests the null hypothesis that all panels contain unit roots. Our results are presented in the following tables.

Table 5.16: KPSS test statistics (critical values: 10%: .119; 5% : .146; 2.5%: .176; 1% : .216)

Lag order	EEX spot	WTI oil	mws
0	5.97	9.69	.695
1	3.49	4.85	.44
2	2.57	3.24	.349
3	2.09	2.43	.301
4	1.78	1.95	.27
5	1.56	1.63	.247
6	1.38	1.4	.23
7	1.22	1.22	.216
8	1.1	1.09	.206
9	1.01	.981	.197
10	.93	.892	.19
11	.868	.819	.184
12	.815	.757	.179

Table 5.17: Phillips-Perron test

			critical values		
		test statistic	1%	5%	10%
EEX spot	Z(rho)	-494.797	-20.70	-14.10	-11.30
	Z(t)	-17.009	-3.43	-2.86	-2.57
WTI oil	Z(rho)	-6.075	-20.70	-14.10	-11.30
	Z(t)	-1.739	-3.43	-2.86	-2.57
mws	Z(rho)	-762.177	-20.70	-14.10	-11.30
	Z(t)	-21.850	-3.43	-2.86	-2.57

Table 5.18: Im-Pesaran-Shin unit root test for panel data

				critical values		
		test statistic	p-value	1%	5%	10%
inc MRP	t-bar	-15.6098		-2.40	-2.15	-2.01
	t-tilde-bar	-14.6164				
	Z-t-tilde-bar	-31.1422	.00			
dec MRP	t-bar	-16.2766		-2.40	-2.15	-2.01
	t-tilde-bar	-15.1603				
	Z-t-tilde-bar	-32.4367	.00			
inst_rain	t-bar	-34.1073		-2.40	-2.15	-2.01
	t-tilde-bar	-26.3799				
	Z-t-tilde-bar	-59.1424	.00			

Appendix B

List of variables used in the panel regressions.

Table 5.19: List of variables

Variable	Label; Type
incremental MRP price	inc MRP; dependent
decremental MRP price	dec MRP; dependent
EEX (day-ahead) spot price	EEX spot; explanatory
WTI oil price	WTI oil; explanatory
seasonal dummy weekend	dummy weekend; explanatory
seasonal dummy summer	dummy summer, explanatory
seasonal dummy winter	dummy winter; explanatory
reform 1	dummy mrp1; explanatory
reforms 2+3	dummy scp+pcp; explanatory
reform 4 (module 1)	dummy M1; explanatory
reform 5 (module 2)	dummy M2; explanatory
reform 6 (module 3)	dummy M3; explanatory
reform 7 (module 4)	dummy M4; explanatory
reform 8 (amprion joins TSO network)	dummy amprion; explanatory
reform 9	dummy mrp2; explanatory
daily maximum wind strength (mws)	mws; instrument
daily amount of precipitation	inst_rain; instrument

First stage results of the two stage least squares panel regressions.

Table 5.20: First stage regression

EEX spot	coeff.	std. err.
constant	-.06	.1857
mws	-.64***	.0478
inst_rain	.04	.0409
R^2	.0281	
F-test	88.77	
Obs.	6932	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

In the following, we present our results of the separated and pooled panel regressions of the remaining eight reforms. Note that reforms 2 and 3 cannot be analyzed individually because they were both realized on December 1, 2007.

Reforms 2 and 3. Launch of common web-based tendering platforms for PCP and SCP on December 1, 2007.

Table 5.21: Separate panel regressions of incremental MRP prices (reforms 2+3)

inc MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.63	.3938	-.03	.1006
WTI oil	-1.59	2.4768	1.15***	.3094
dummy weekend	-70.89***	5.9794	-12.54***	1.2538
dummy summer	-6.06**	2.2822	1.60*	.8526
dummy winter	73.81***	4.6210	2.17**	1.0257
dummy mrp1	-62.89***	2.6590		
dummy M1			-15.76***	1.0028
dummy M2			3.26***	.9479
dummy M3			-5.85***	.5393
dummy M4			-.13	.8806
dummy amprion			-.41	.7225
dummy mrp2			-1.78***	.4718
Obs.	2792		4140	
R^2	.3659		.2330	
Residual sum of squares	11660001.94		1469097.882	
Weak identification test	50.142		61.517	
Sargan-Hansen p-value				

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.22: Separate panel regressions of decremental MRP prices (reforms 2+3)

dec MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.01	.1635	.41***	.1124
WTI oil	.77	.6381	.24	.1823
dummy weekend	35.48***	2.5688	15.82***	1.5054
dummy summer	6.42***	1.2935	-2.81***	.5319
dummy winter	-2.73**	1.2892	-9.06***	.8375
dummy mrp1	-79.41***	1.1114		
dummy M1			25.77***	1.4318
dummy M2			11.38***	1.9128
dummy M3			-22.97***	1.3443
dummy M4			-2.26**	1.0657
dummy amprion			-10.63***	.9908
dummy mrp2			.97	.7279
Obs.	2792		4140	
R^2	.6934		31.97	
Residual sum of squares	2284341.64		1261832.913	
Weak identification test	50.142		61.517	
Sargan-Hansen p-value	1.455		0.940	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.23: Pooled regression and Chow test (reforms 2+3)

	inc MRP		dec MRP	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2131	.20**	.1002
WTI oil	.78	.5851	.31	.1941
dummy weekend	-36.03***	2.9046	23.30***	1.3978
dummy summer	-5.15***	1.1565	1.36*	.6985
dummy winter	31.61***	2.2072	-6.86***	.7405
dummy mrp1	-64.53***	2.6159	-82.18***	1.1248
dummy M1	-29.69***	1.4693	23.28***	1.4340
dummy M2	23.18***	1.9301	10.49***	1.9448
dummy M3	-4.94***	1.1668	-23.59***	1.3834
dummy M4	-18.19***	1.6758	-.55	1.0500
dummy amprion	15.75***	1.5481	-11.21***	1.0207
dummy mrp2	.06	1.1240	-.16	.8498
Obs.	6932		6932	
R^2	.3623		.6630	
Residual sum of squares	15233645.33		3812728.036	
Weak identification test	110.621		110.621	
Chow test statistic	79.05		37.07	
Sargan-Hansen p-value	1.268		2.867	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Reform 4. Module 1 of the gradual TSO interconnection and cooperation in the SCP market.

Table 5.24: Separate panel regressions of incremental MRP prices (reform 4)

inc MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.47*	.3010	-.03	.0338
WTI oil	.87	.8769	-.05	.0845
dummy weekend	-55.62***	4.8107	-5.60***	.3309
dummy summer	-1.88	1.6373	-.64***	.2236
dummy winter	47.34***	3.0998	-2.27***	.2466
dummy mrp1	-61.03***	2.6664		
dummy scp+pcp	-9.08***	1.4650		
dummy M2			1.99***	.4499
dummy M3			-5.59***	.4011
dummy M4			.4786	.3047
dummy amprion			-1.69***	.2340
dummy mrp2			-1.14***	.2452
Obs.	4320		2612	
R^2	.3347		.3978	
Residual sum of squares	14080010.38		45833.995	
Weak identification test	58.893		92.734	
Sargan-Hansen p-value	.0410		.1088	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.25: Separate panel regressions of decremental MRP prices (reform 4)

	Period 1		Period 2	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.003	.1242	.62***	.1650
WTI oil	.12	.2290	.28	.3408
dummy weekend	24.96***	2.0063	19.47***	1.7750
dummy summer	4.82***	.9212	-2.93***	.7388
dummy winter	.44	.8548	-18.51***	1.4367
dummy mrp1	-79.56***	1.1370		
dummy scp+pcp	-6.09***	.5070		
dummy M2			6.14***	2.1052
dummy M3			-22.93***	1.3718
dummy M4			2.06	1.2942
dummy amprion			-14.95***	1.1904
dummy mrp2			1.04	.7603
Obs.	4320		2612	
R^2	.7258		.3059	
Residual sum of squares	2608343.575		1034197.083	
Weak identification test	58.893		92.734	
Sargan-Hansen p-value	.1936		.4249	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.26: Pooled regression and Chow test (reform 4)

	inc MRP		dec MRP	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2137	.20**	.1019
WTI oil	.52	.6008	.42*	.2075
dummy weekend	-35.98***	2.9093	23.30***	1.4253
dummy summer	-3.52***	1.1691	-.35	.7229
dummy winter	29.80***	2.1605	-4.68***	.7206
dummy mrp1	-59.82***	2.7286	-79.37***	1.1688
dummy scp+pcp	-15.03***	2.7286	.59	.6391
dummy M2	3.28**	1.4039	31.10***	1.3607
dummy M3	-5.29***	1.1660	-23.26***	1.3624
dummy M4	-16.24***	1.6328	-2.71***	1.0437
dummy amprion	14.26***	1.5109	-9.53***	1.0107
dummy mrp2	-.41	1.1131	.32	.8489
Obs.	6932		6932	
R^2	.3541		.6420	
Residual sum of squares	15428142.02		4050659.052	
Weak identification test	110.587		110.587	
Chow test statistic	45.46		55.25	
Sargan-Hansen p-value	.2162		.2461	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Reform 5. Module 2 of the gradual TSO interconnection and cooperation in the SCP market.

Table 5.27: Separate panel regressions of incremental MRP prices (reform 5)

inc MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	-.52*	.2774	-.04	.0401
WTI oil	.50	.7684	.14	.1097
dummy weekend	-51.23***	4.3000	-5.64***	.3749
dummy summer	-4.58***	1.6206	-.63***	.2232
dummy winter	38.72***	2.6567	.29	.3264
dummy mrp1	-60.47***	2.6918		
dummy scp+pcp	-8.87***	1.4172		
dummy M1	-27.35***	1.8033		
dummy M3			-5.55***	.4013
dummy M4			-.71**	.3086
dummy amprion			-.49**	.2389
dummy mrp2			-1.14***	.2440
Obs.	4860		2072	
R^2	.3294		.3787	
Residual sum of squares	14670335.1		36161.32659	
Weak identification test	71.072		59.844	
Sargan-Hansen p-value	.0472		.1599	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.28: Separate panel regressions of decremental MRP prices (reform 5)

dec MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	.17	.1199	.41**	.1730
WTI oil	.17	.2321	.51	.3369
dummy weekend	25.64***	1.8989	18.64***	1.7542
dummy summer	2.92***	.9269	-2.89***	.7289
dummy winter	-6.53***	.8599	-5.48***	1.5046
dummy mrp1	-79.15***	1.1482		
dummy scp+pcp	-5.91***	.5292		
dummy M1	26.47***	1.4673		
dummy M3			-22.87***	1.3440
dummy M4			-3.99***	1.2617
dummy amprion			-8.93***	1.1628
dummy mrp2			1.03	.7598
Obs.	4860		2072	
R^2	.6822		.3792	
Residual sum of squares	3211062.67		530979.0064	
Weak identification test	118.652		59.844	
Sargan-Hansen p-value	.2633		.1728	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.29: Pooled regression and Chow test (reform 5)

	inc MRP		dec MRP	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2132	.20**	.1005
WTI oil	.75	.5876	.27	.1942
dummy weekend	-35.99***	2.9088	23.33***	1.4019
dummy summer	-3.91***	1.1379	1.92***	.6958
dummy winter	30.27***	2.1251	-7.43***	.7094
dummy mrp1	-59.87***	2.7242	-79.11**	1.1638
dummy scp+pcp	-8.61***	1.3550	-5.88***	.5173
dummy M1	-18.00***	1.1956	29.54***	1.0723
dummy M3	9.87***	1.4534	-16.87***	1.2096
dummy M4	-16.73***	1.6026	.09	1.0387
dummy amprion	14.65***	1.4922	-11.69***	1.0134
dummy mrp2	-.29	1.1139	-.32	.8517
Obs.	6932		6932	
R^2	.3610		.6638	
Residual sum of squares	15263948.05		3804389.781	
Weak identification test	110.613		110.613	
Chow test statistic	18.69		8.22	
Sargan-Hansen p-value	.2893		.0973	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Reform 6. Module 3 of the gradual TSO interconnection and cooperation in the SCP market.

Table 5.30: Separate panel regressions of incremental MRP prices (reform 6)

	Period 1		Period 2	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.44*	.2684	-.02	.0381
WTI oil	-58	.7472	.11	.1094
dummy weekend	-47.95***	4.0388	-5.45***	.3718
dummy summer	-5.01***	1.4943	1.43***	.1987
dummy winter	38.60***	2.6521	.29	.3259
dummy mrp1	-60.47***	2.6878		
dummy scp+pcp	-8.88***	1.4056		
dummy M1	-27.39***	1.7694		
dummy M2	27.17***	2.3728		
dummy M4			-.68**	.2764
dummy amprion			-1.30***	.2499
dummy mrp2			-1.73***	.2441
Obs.	5104		1828	
R^2	.3378		.3037	
Residual sum of squares	14643256.98		27862.11986	
Weak identification test	74.936		55.682	
Sargan-Hansen p-value	.1003		.4825	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.31: Separate panel regressions of decremental MRP prices (reform 6)

dec MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	.13	.1184	.50***	.1736
WTI oil	.26	.2300	.09	.3127
dummy weekend	24.47***	1.8092	19.92***	1.8792
dummy summer	1.44*	.8772	.88	.6673
dummy winter	-6.95***	.8516	-5.45***	1.5201
dummy mrp1	-79.16***	1.1482		
dummy scp+pcp	-5.90***	.5219		
dummy M1	26.20***	1.4586		
dummy M2	10.42***	1.9783		
dummy M4			-1.40	1.2597
dummy amprion			-10.43***	1.1703
dummy mrp2			-.04	.7538
Obs.	5104		1828	
R^2	.6783		.2004	
Residual sum of squares	3290992.991		451933.4222	
Weak identification test	74.936		55.682	
Sargan-Hansen p-value	.3771		.0376	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.32: Pooled regression and Chow test (reform 6)

	inc MRP		dec MRP	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2125	.20**	.1011
WTI oil	.71	.5860	.34*	.1956
dummy weekend	-35.98***	2.8985	23.41***	1.4125
dummy summer	-5.30***	1.1609	.75	.7115
dummy winter	31.78***	2.1986	-6.87***	.7366
dummy mrp1	-60.01***	2.7186	-79.18***	1.1656
dummy scp+pcp	-8.68***	1.3610	-5.90***	.5115
dummy M1	-25.53***	1.5116	26.02***	1.4385
dummy M2	20.38***	1.8549	-3.34**	1.6992
dummy M4	-20.32***	1.5756	-10.32***	1.1817
dummy amprion	15.87***	1.5476	-10.97***	1.0201
dummy mrp2	.10*	1.1239	.01	.8501
Obs.	6932		6932	
R^2	.3646		.6579	
Residual sum of squares	15178941.18		3871125.102	
Weak identification test	110.650		110.650	
Chow test statistic	17.07		16.89	
Sargan-Hansen p-value	.2039		.0391	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Reform 7. Module 4 of the gradual TSO interconnection and cooperation in the SCP market.

Table 5.33: Separate panel regressions of incremental MRP prices (reform 7)

	Period 1		Period 2	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.37	.2541	.01	.0433
WTI oil	.62	.6959	.16	.1270
dummy weekend	-44.44***	3.7134	-5.03***	.4307
dummy summer	-4.18***	1.3598	.43*	.2351
dummy winter	38.84***	2.6531	.30	.3256
dummy mrp1	-60.47***	2.6896		
dummy scp+pcp	-8.89***	1.3960		
dummy M1	-27.22***	1.7394		
dummy M2	26.82***	2.2999		
dummy M3	-5.24***	1.4563		
dummy amprion			-.91***	.2444
dummy mrp2			-1.44***	.2356
Obs.	5472		1460	
R^2	.3488		.2862	
Residual sum of squares	14681311.1		22522.75589	
Weak identification test	82.792		41.969	
Sargan-Hansen p-value	.0977		.2107	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.34: Separate panel regressions of decremental MRP prices (reform 7)

	Period 1		Period 2	
dec MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	.14	.1128	.51**	.2014
WTI oil	.30	.2175	-.14	.3716
dummy weekend	24.51***	1.6709	18.69***	2.2552
dummy summer	1.53*	.8057	-.18	.7541
dummy winter	-6.92***	.8448	-5.43***	1.5246
dummy mrp1	-79.16***	1.1498		
dummy scp+pcp	-5.90***	.5215		
dummy M1	26.21***	1.4577		
dummy M2	10.38***	1.9771		
dummy M3	-23.60***	1.4004		
dummy amprion			-10.04***	1.1839
dummy mrp2			.25	.7430
Obs.	5472		1460	
R^2	.6779		0.1334	
Residual sum of squares	3338951.604		408832.7497	
Weak identification test	82.792		41.969	
Sargan-Hansen p-value	.4783		.0034	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.35: Pooled regression and Chow test (reform 7)

	inc MRP		dec MRP	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2128	.20**	.0999
WTI oil	.63	.5865	.24	.1917
dummy weekend	-36.10***	2.9035	23.32***	1.3954
dummy summer	-2.99***	1.0809	1.42**	.6614
dummy winter	30.62***	2.1405	-6.77***	.7261
dummy mrp1	-59.87***	2.7244	-79.16***	1.1647
dummy scp+pcp	-8.62***	1.3556	-5.91***	.5113
dummy M1	-24.65***	1.4659	26.16***	1.4337
dummy M2	21.59***	1.8509	10.52***	1.9348
dummy M3	-16.43***	1.2825	-23.99***	1.3746
dummy amprion	9.24***	1.1609	-11.37***	.8147
dummy mrp2	-.56	1.1065	-.18	.8475
Obs.	6932		6932	
R^2	.3612		.6653	
Residual sum of squares	15258684.48		3787078.516	
Weak identification test	110.523		110.523	
Chow test statistic	18.61		5.17	
Sargan-Hansen p-value	.1338		.1611	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Reform 8. Amprion joins the existing TSO network for the provision of SCP.

Table 5.36: Separate panel regressions of incremental MRP prices (reform 8)

	Period 1		Period 2	
inc MRP	coeff.	std. err.	coeff.	std. err.
EEX spot	-.30	.2165	-.08	.1706
WTI oil	.78	.6475	-.06	.1236
dummy weekend	-39.20***	3.0185	-4.48**	1.8628
dummy summer	-6.13***	1.3523	.44**	.2217
dummy winter	31.58***	2.1889		
dummy mrp1	-60.01***	2.7070		
dummy scp+pcp	-8.66***	1.3634		
dummy M1	-25.71***	1.5410		
dummy M2	23.68***	2.0085		
dummy M3	-4.80***	1.2844		
dummy M4	-18.82***	1.7901		
dummy mrp2			-1.44***	.2220
Obs.	6256		676	
R^2	.3550		.2352	
Residual sum of squares	15036328.52		6701.349721	
Weak identification test	109.583		4.690	
Sargan-Hansen p-value	.1536		.6436	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

Table 5.37: Separate panel regressions of decremental MRP prices (reform 8)

dec MRP	Period 1		Period 2	
	coeff.	std. err.	coeff.	std. err.
EEX spot	.20**	.1009	.81*	.4710
WTI oil	.27	.2098	-.40	.4121
dummy weekend	24.63***	1.4568	17.60***	5.2118
dummy summer	1.60**	.8010		
dummy winter	-6.67***	.7432		
dummy mrp1	-79.17***	1.1587		
dummy scp+pcp	-5.91***	.5193		
dummy M1	26.18***	1.4469		
dummy M2	10.47***	1.9592		
dummy M3	-23.63***	1.3983		
dummy M4	-.48	1.0749		
dummy mrp2			.25	.7490
Obs.	6256		676	
R^2	.6614		.0974	
Residual sum of squares	3706563.372		61309.88859	
Weak identification test	109.583		4.690	
Sargan-Hansen p-value	.2536		.1491	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity

robust.

Table 5.38: Pooled regression and Chow test (reform 8)

	inc MRP		dec MRP	
	coeff	std. err.	coeff.	std. err.
EEX spot	-.30	.2127	.20**	.1004
WTI oil	.65	.5862	.28	.1925
dummy weekend	-36.02***	2.8998	23.34***	1.4009
dummy summer	-4.29***	1.1422	.73	.6932
dummy winter	30.63***	2.1310	-5.91***	.7231
dummy mrp1	-59.90***	2.7218	-79.24***	1.1660
dummy scp+pcp	-8.64***	1.3566	-5.94***	.5041
dummy M1	-24.97***	1.4758	25.76***	1.4432
dummy M2	22.23***	1.8731	11.33***	1.9388
dummy M3	-5.12***	1.1655	-23.48***	1.3757
dummy M4	-12.93***	1.3293	-4.38***	.8726
dummy mrp2	10.55***	1.3442	-7.54***	.8848
Obs.	6932		6932	
R^2	.3624		.6629	
Residual sum of squares	15230160.9		3813722.428	
Weak identification test	110.649		110.649	
Chow test statistic	6.13		6.00	
Sargan-Hansen p-value	.1344		.1067	

*,**,*** statistically significant on the 10, 5, and 1% level. Standard errors are heteroskedasticity robust.

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Chapter 6

Conclusion

The first part of the thesis where we deal with managerial incentives in firms operating in a competitive environment reveals the following results. In a first step, we focus on the effects of partial public ownership (PPO). Given that the government does not partially own all firms in the market (asymmetric case), we show that whether or not PPO increases managerial incentives crucially depends on the level of competition. This result is essentially confirmed even if the government's primary concern is consumer protection rather than social welfare. We take this result to claim that there is no per se rule in evaluating the effects of PPO on productive efficiency. Rather, the level of competition has to be explicitly taken into account, irrespective of the government's primary objective.

In a second step, we focus on the effects of competition in markets where indirect network externalities prevail. For this purpose, we consider two-sided platforms each consisting of a principal-agent pair. We demonstrate that due to the existence of indirect network externalities the effects of competition on managerial incentives cannot be characterized by the *business stealing effect* and the *rent reduction effect*. Alternatively, we show that it is each platform's relative profitability and the groups' adoption possibilities which shape managerial incentives when competition becomes fiercer. The same holds when the impact of indirect network externalities is analyzed. Thereby, we present conditions under which sellers' investments in e.g., quality enhancement or cost reduction, and platform quality constitute substitutes or complements.

In the second part of the thesis, the effectiveness of regulation and antitrust in certain markets are concerned. First, we tackle the efficiency defence in merger control. More

specifically, we focus on the criterion of merger specificity which constitutes one of three criteria which have to be cumulatively met for claimed efficiencies to be accepted according to both the US merger guidelines and the EC merger guidelines. Solving the full game, where the merger decision and efficiencies are endogenous, we show that welfare enhancing merger proposals are largely not accompanied by merger specific efficiencies. We take these results to cast serious doubts on the effectiveness of the current efficiency defence.

Second, we analyze the success of the recent regulatory changes in the German electricity reserve power markets. Applying econometric analyses, we demonstrate that the market synchronization and the interconnection of the four TSOs led to a statistically significant decrease in prices for both incremental and decremental MRP. Nevertheless, we identify several factors which make welfare gains or, at least, increases in consumer surplus due to the reforms very difficult. We claim that the major dilemma of a regulation, tackling the efficiency of electricity reserve power markets, is that it hardly affects the performance in the electricity wholesale markets and retail markets, respectively.