

Unsorg, Maximiliane; Stadler, Manfred

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Manager Delegation, Owner Coordination and Firms' Investment in Automation

Manfred Stadler* and Maximiliane Unsorg†

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Abstract

This paper studies the combined effects of mixed ownership structures and manager delegation on firms' investment in automation processes in a multi-stage triopoly game. We show that, in accordance with empirical evidence, firms owned by common shareholders invest less in automation and realize lower profits compared to a firm owned by independent shareholders. Direct collusion of owners in terms of coordinated investment increases the profits, the one of the independent firm even more than the profits of the commonly owned firms. Delegation of operational decisions to managers results in higher investment and lower profits. In markets with favorable technological opportunities for automation, common ownership combined with manager delegation leads to the highest social welfare.

Keywords: Manager Compensation, Common Ownership, Cost-Reducing Investment

JEL classification: G32, L22, L24, M52, O31

*University of Tübingen, School of Business and Economics, Germany (e-mail: manfred.stadler@uni-tuebingen.de)

†University of Tübingen, School of Business and Economics, Germany (e-mail: maximiliane.unsorg@uni-tuebingen.de)

1 Introduction

The development of industrial production technologies is characterized by a continuing process of automation. The steam engine, the combustion motor, electrification, the assembly line, electronic control and nowadays digitization of smart factories are milestones of technological improvements. Progress in automation does not fall like manna from heaven, but is the result of costly investment reducing the marginal cost of production.

In the theory of industrial organization, usually, the analysis of cost-reducing investment is analyzed with models of multi-stage games where firms first invest in cost-reducing activities, then install capacities and finally engage in price competition. As it has been shown by Kreps and Scheinkman (1983) for homogeneous markets and by Maggi (1999) for heterogeneous markets, the last two stages can be reduced to a standard game of quantity competition, if one applies the rule of efficient consumer rationing in the out-of-equilibrium case of excess demand. The resulting first-investment-then-quantity-setting game was first analyzed by Brander and Spencer (1983). Since firms' investment activities are observable and incur sunk cost, investment expenditures are treated as strategic and quantities as tactical decision variables of the game which is solved in terms of a subgame perfect Nash equilibrium. The main result is that firms apply the (top dog) strategy of an aggressive overinvestment in cost-reducing activities, even if thereby reducing their profits.

This basic model has been extended in several directions. Delbono and Denicolo (1990) complementarily analyzed the mode of price competition without any capacity precommitment and derive the opposite (puppy dog) strategy of an inoffensive underinvestment. However, in many industries the production technology is characterized by a strong precommitment value of capacities, supporting the mode of quantity competition.

D'Aspremont and Jacquemin (1988, 1990), Henriques (1990), De Bondt et al. (1992), Kamien et al. (1992), Suzumura (1992), Vonortas (1994), and Amir (2000) built on the same approach but interpreted cost-reducing investment as R&D expenditure devoted to process innovations. This allows for a more extensive analysis of R&D cooperation and research joint ventures - anti-competitive measures which are of particular importance in the presence of input and output spillovers of R&D.

The practical relevance of strategic investment in cost reduction is indisputable. Low marginal cost of production are a key factor for the competitiveness of rival firms, especially in industries where advanced technology plays a crucial role. The EU's industry with the highest development activity is the motor vehicle market. Indeed, this industry is responsible for about 33% of total spending in development (European Automobile Manufacturers' Association, 2021). On top of that, the EU is the world region with the highest investment in the automobile market. Being highly dependent on technology, car producers have the urge to invest a lot in cost-reducing processes.

In 2014 Daimler achieved a prize for its engagement in process improvements for climate protection. Daimler had introduced a production-ready thermal spraying method for coating cylinder drilling in car engines reducing friction within the engines themselves (Form Werkzeug, 2014). A method initially used for a small range of luxury cars was then introduced to the whole production process to enter serial production, thereby reducing unit production cost. In 2021, BMW introduced the so called CFRP¹ sandwich roof in serial production, leading to a more efficient co-working of humans and robotics in cockpit manufacturing (Branchenblatt der Kunststoffindustrie, 2021). In the same year, Tesla dropped the information that it brought a new machinery into operation which accelerates the production process, reduces the time needed for production and makes a large number of processes and robotics obsolete (Tesla Mag, 2021).

These examples have in common that process improvements are important firm strategies, even if being very costly. Not only in the automobile industry, coordinated procurement investments or even joint ventures offer firms the opportunity to share risk, boost their balance sheet, achieve scale economies and last but not least allow for reductions of their marginal production cost. Not surprisingly, common procurement investments can often be observed when firm owners find it in their very interest to cooperate in specific development projects. Therefore, we will study the role of a coordinated investment in cost-reducing processes. However, in contrast to the models in the tradition of Kamien et al. (1992), we assume that only firms commonly owned by the same shareholders can participate in this procurement cooperation.

A complementary contribution to the theory of strategic games was added by Vickers (1985), Sklivas (1987), and Fershtman and Judd (1987, 2006), who studied the role of managers in quantity (capacity) and price competition. Publicly traded firms are typically run by managers who have their own interests which do not coincide with the objectives of the firm owners. Under the assumption of irreversible and observable compensation contracts with fixed and performance-dependent components, the delegation of quantity decisions leads to compensation schemes that induce the managers to behave more aggressively than profit maximizers, i.e. to choose higher production quantities.

Jansen et al. (2009, 2012) compared alternative specifications of the performance-dependent component of the compensation scheme. The first part of the performance-dependent component is the firm's own profit. In the basic models cited above, the second part is sales or revenue.² As an alternative, Jansen et al. (2007), Ritz (2008), and Kopel and Lambertini (2013) considered market-share evaluation, whereas Salas Fumas (1992), Aggarwal and Samwick (1999), Miller and Pazgal (2001, 2002), and Chirco et al. (2011) studied relative-profits evaluation. Even if the latter two types of compensation

¹CFRP stands for carbon fiber reinforced polymer, an extremely strong and light fiber-reinforced plastics containing carbon fibers.

²Both versions lead to the same market outcome if marginal production costs are scale-invariant and of equal size.

schemes dominate in generating higher equilibrium firm profits, problems of observability and verifiability lead in practice to the widespread application of sales as the second component (see, e.g. Murphy, 1985; Jensen and Murphy, 1990; Conyon, 1997).

Usually, manager delegation is not restricted to price or quantity decisions, but also involves investment decisions. Zhang and Zhang (1997) with correction in Kopel and Riegler (2006) considered the effects of strategic delegation on firms' R&D investments when they compete in quantities. Mitrokostas and Petrakis (2014) analyze the effects of full delegation of quantity and investment decisions and partial delegation where only the quantity decision is delegated. A comprehensive overview of the key mechanisms of strategic delegation in the modes of quantity and price competition with and without strategic investment is given by Kopel and Pezzino (2018).

All these articles neglect the possibility of mergers and the existence of common-owner structures. For the effects of mergers on R&D investment and innovation, Federico et al. (2018) found in a numerical solution of their oligopoly model that price coordination for the products of the merged firm tends to stimulate innovation, whereas in contrast internalization of the innovation externalities reduces the innovation activity. Davidson and Ferret (2007) and Motta and Tarantino (2021) analyzed for the modes of price and quantity competition the effects of further explanatory factors on the investment levels of the merged and non-merged firms.

In many industries, institutional investors such as Vanguard, BlackRock or the Capital Group hold shares of several, but not all firms in a relevant market and are, therefore, common owners of rival producers. López and Vives (2019) and Vives (2020) derived predictable hypotheses on the influence of common ownership structures on cost-reducing R&D investment in the presence of spillovers. However, they do not take into account strategic delegation of automation decisions to managers. This is obviously a gap in the literature, since in all industries where automation plays an important role, as for example in the automobile industry, investment decisions are made by managers and not by the firm owners themselves.

To the best of our knowledge, multi-stage games *combining* common ownership with delegation of investment and quantity (capacity) decisions to managers have not been considered so far. Therefore, the most important contribution of our paper is to study the role of mixed ownership structures in strategic models where operational decisions are delegated to managers. Of course, common ownership gives the shareholders an incentive to collude. Even if collusion in price or quantity competition is excluded by antitrust authorities, collusion in terms of coordinated investment is often allowed when public interest is presumed. This is typically the case with the current investment activities in digitization. If such a collusion is not allowed, coordinated designs of the manager-compensation contracts provide a further and more sophisticated alternative to the direct coordination of firms' investment behavior.

Neus and Stadler (2018) and Neus et al. (2020) studied the influence of common owner structures on the strategic design of manager-compensation contracts. They have shown that, in the mode of quantity competition, owner coordination leads to compensation schemes that induce managers to act less aggressively in their output behavior.³ The impact of such a coordinated design of compensation schemes on the investment decisions of managers has not been studied so far. This is astonishing since the empirical effects of common ownership on the competitive behavior of firms have proven to be strong (see, e.g. Antón et al., 2021; Schmalz, 2021).⁴ Therefore, we aim to identify the influence of common holdings on investment in automation in particular.

Motor vehicles are an appropriate example of an industry, where investment decisions in automation, manager delegation and common ownership are inextricably intertwined. The ownership structure of car-producing firms is strongly influenced by passive investment funds. Neto et al. (2020) have shown that large institutional investors such as Vanguard or BlackRock hold significant amounts of shares in many of the car-producing firms. Considering the global automobile market, Vanguard holds shares in BMW, Mercedes-Benz, Volkswagen, Ford, Toyota, Renault, Hyundai, Stellantis, Daimler Trucks, Volvo, Tesla, Mazda, General Motors, Nissan, Honda and Suzuki. BlackRock has invested in BMW, Mercedes-Benz, Volkswagen, Ford, Daimler Trucks, Tesla, Mazda and General Motors while also the Capital Group has some shares in Ford, Renault, Stellantis, Daimler Trucks, Volvo and Tesla. Even if the shares are varying, there exists an important overlap of producing firms in their portfolio which cannot be neglected.⁵

Several studies have addressed the influence of ownership in the automobile industry showing that institutional investors play a decisive role (see Borghi et al., 2013; Castellanos, 2013, 2014). Some firms, Volkswagen (Porsche Holding and State of Lower Saxony together hold 73%) or BMW, where also roughly 46% belong to two independent owners, can be considered as being controlled by independent owners while others are dominated by common holdings. Neto et al. (2020) provide an illustrative overview of the ownership structures in the automobile industry. This evidence justifies our assumption of an asymmetric ownership structure with a mix of common and independent shareholders.

To summarize: As many other industries, the automobile market is characterized by a complex intra- and inter-firm organization structure where manager delegation and common ownership interact in determining the firms' strategical and tactical decisions. These

³Furthermore, Neus et al. (2020) have shown that if at least 80% of the firms are commonly owned by the same decisive group of shareholders, firm profits increase due to coordination of common owners. In our triopoly model with two common owners, we are not able to endogenize the mixed ownership structure in terms of profitability, but treat it as an exogenously given assumption.

⁴Antón et al. (2021) have shown that common ownership even in terms of minority shareholdings effects market outcomes. When we use the notation common owners, we refer to a "decisive group of shareholders" instead of "minority shareholdings". Therefore, we differ from Antón et al. (2021) by not assuming the portfolio as the objective function of one institutional owner, but rather firm profit as the objective function of a decisive group of shareholders.

⁵Data retrieved from www.marketscreener.de on March, 15 2022.

decisions do not only include capacity installation and price setting, but also investment in cost-reduction. The question of how strategic delegation and common ownership jointly affect the decisions on cost-reducing investment, production capacities and prices has not been studied so far. In order to fill this gap, we present several versions of a multi-stage market game to gain insight into the institutional determinants of investment in automation. Due to the contemporary discussion on digitization, for the time-being the last step of automation in smart factories, such analyses are not only interesting from a theoretical point of view, but also of direct relevance for antitrust authorities.

We use a stylized framework of a homogeneous triopoly market and find that the two firms, coordinating their investment strategies, behave less aggressively by investing less in cost-reducing activities and consequently installing lower capacities compared to the independent firm. Without such a coordination, delegation of investment decisions to managers leads to higher expenditure due to their biased incentives towards higher production. Coordination of common owners via manager delegation induces commonly owned firms to invest less in cost-reducing activities than in all other cases.

In general, social welfare is higher when owners delegate operational decisions to managers compared to a firm organization without delegation. Whether social welfare is maximized under coordinated or non-coordinated delegation depends on the cost of investment. If technological opportunities for automation are favorable, coordinated delegation leads to maximum welfare. For high investment costs, however, non-coordinated delegation yields a higher welfare. Scenarios with owner-controlled firms always lead to a lower welfare.

The rest of the paper is organized as follows: Section 2 develops the theoretical model, where we distinguish between four scenarios of (i) independent owners making the operational decisions themselves (section 2.1), (ii) common owner coordination with respect to the investment activities (section 2.2), (iii) independent owners setting incentives for their managers by designing their compensation contracts (section 2.3) and, finally, (iv) common ownership and coordinated manager delegation (section 2.4). Section 3 compares the different scenarios and presents a welfare analysis. Section 4 concludes the paper.

2 The Game-Theoretical Model

Our model aims to capture the combined effect of an asymmetric ownership structure with a mix of common and independent shareholders and the necessity to delegate all operational decisions to specialized managers. Therefore, we integrate different approaches provided by the theory of industrial organization. In order to keep the model tractable, we restrict our analysis to a homogeneous triopoly market, characterized by the standardized

inverse demand function

$$p = \alpha - Q,$$

where $\alpha > 0$ measures market size and $Q = \sum_{i=1}^3 q_i$ denotes aggregate production of firms $i = 1, 2, 3$. Their marginal capacity-installing and production costs are determined by $c_i = \bar{c} - x_i$, where \bar{c} is the given upper limit of marginal cost (including constant unit cost of capacity installation) without any investment activity of firms. A reduction x_i of the marginal production cost causes investment expenditures $\gamma x_i^2/2$, where the investment-cost parameter will be restricted to $\gamma > (15 + \sqrt{153})/8 \approx 3.42$.⁶

We distinguish four scenarios of multi-stage games: (i) the benchmark without cooperation or delegation, (ii) collusive investment decisions, (iii) non-coordinated delegation, and (iv) coordinated delegation. In the first two scenarios, owners decide themselves on the amount of investment in automation. In the last two scenarios, the firms' owners decide on the strategic contract parameters of the compensation schemes for their managers, who in turn decide on the levels of investment.

In all variations of the model, owners or managers, respectively, decide in the second to last stage on production capacities. In the last stage, according to the Kreps and Scheinkman (1983) approach with an application of the rule of efficient consumer rationing in the out-of-equilibrium case of excess demand, they set equilibrium prices which satisfy the market-clearing condition. We are able to prove that this continues to hold in the asymmetric cases with mixed ownership structures in the triopoly market. This result allows us to solve for a simple quantity-setting model in the next to last stage.

2.1 Owner-Controlled Independent Firms

In this benchmark scenario, owners do not coordinate or delegate decisions to managers. We consider a three-stage game where owners themselves decide on cost-reducing investment x_i in the first stage, on capacities q_i in the second stage, and on the market-clearing prices $p = \alpha - q_1 - q_2 - q_3$ in the third stage. Then, the owners reduced-form profit functions in the second stage read

$$\pi_i = (\alpha - (\bar{c} - x_i) - q_1 - q_2 - q_3)q_i - \frac{\gamma}{2}x_i^2, \quad (1)$$

$i, j, k = 1, 2, 3; i \neq j \neq k$. Profit maximization with respect to the capacities q_i leads to the equilibrium outcome

$$q_i = \frac{1}{4}(\alpha - \bar{c} + 3x_i - x_j - x_k). \quad (2)$$

⁶This restriction on γ is necessary to guarantee positive equilibrium production levels in all scenarios.

Capacities are increasing in the own investment but decreasing in the rivals' investments. Substituting the capacities (2) into the profit functions (1) yields the reduced-form profit functions in the first stage of the game

$$\pi_i = \frac{1}{16}(\alpha - \bar{c} + 3x_i - x_j - x_k)^2 - \frac{\gamma}{2}x_i^2. \quad (3)$$

Profit maximization with respect to the cost reduction x_i gives the symmetric equilibrium values

$$x^0 = \frac{3}{(8\gamma - 3)}(\alpha - \bar{c}). \quad (4)$$

The investment expenditures are decreasing in the cost parameter γ reflecting unfavorable technological opportunities for automation. The more costly the automation of the production process, the less firms engage in such investment activities. This strategic behavior implies the equilibrium capacities

$$q^0 = \frac{2\gamma}{(8\gamma - 3)}(\alpha - \bar{c}),$$

the market-clearing prices⁷

$$p^0 = \bar{c} + \frac{(2\gamma - 3)}{(8\gamma - 3)}(\alpha - \bar{c}),$$

and the firm profits

$$\pi^0 = \frac{\gamma(8\gamma - 9)}{2(8\gamma - 3)^2}(\alpha - \bar{c})^2. \quad (5)$$

An increase in γ (within the permitted parameter range) causes higher marginal production costs and, hence, lower capacities, higher prices and higher profits. In the limit case of $\gamma \rightarrow \infty$, the market outcome converges to the solution of a standard Cournot triopoly, where firms do not invest in cost-reducing activities at all, i.e. $c = \bar{c}$. However, favorable technological opportunities, measured by lower γ -values, trigger the top-dog effect of an aggressive overinvestment in cost reduction, leading to higher capacities, lower prices and lower profits.

2.2 Investment Coordination of Owner-Controlled Firms

When several but not all firms in the market are owned by common shareholders, these owners are often allowed to coordinate their firms' investment behavior. We capture this

⁷The equilibrium conditions in the last stage read $2q_i + q_j + q_k \leq \alpha - \bar{c} + x_i$, $i, j, k = 1, 2, 3$, $i \neq j \neq k$, and are satisfied as inequalities as soon as the capacity installing costs are positive.

scenario by assuming that firms 1 and 2 are commonly owned and engage in a collusive investment (CI), while firm 3, owned by independent shareholders, is not involved in this arrangement (NI). Anti-trust authorities prevent collusion in capacity and price decisions, so that the reduced-form profit functions are still given by (3).

The owners of firms 1 and 2 jointly maximize the sum of their profits, while firm 3 maximizes its individual profit. The equilibrium investment behavior can be calculated as

$$x^{CI} = \frac{(2\gamma - 3)}{(8\gamma^2 - 13\gamma + 3)}(\alpha - \bar{c}), \quad (6)$$

$$x^{NI} = \frac{3(\gamma - 1)}{(8\gamma^2 - 13\gamma + 3)}(\alpha - \bar{c}), \quad (7)$$

where the investment of the commonly owned firms, $x_1 = x_2 = x^{CI}$, is lower than the investment of the independent firm, $x_3 = x^{NI}$. A comparison with the benchmark case shows that $x^{CI} < x^0 < x^{NI}$ holds for all permitted γ -values. The colluding firms reduce their investment activities, whereas the independent firm invests a higher amount. As a consequence, the market is now characterized by an asymmetric cost structure of the firms. Correspondingly, the equilibrium capacities of the firms,

$$q^{CI} = \frac{\gamma(2\gamma - 3)}{(8\gamma^2 - 13\gamma + 3)}(\alpha - \bar{c}),$$

and

$$q^{NI} = \frac{2\gamma(\gamma - 1)}{(8\gamma^2 - 13\gamma + 3)}(\alpha - \bar{c}),$$

differ, too. It can be shown that the relation $q^{CI} < q^0 < q^{NI}$ generally holds. Thus, due to high investment in automation, the independent firm is the biggest one. In the last stage of the game, all firms set the market-clearing price

$$p^I = \bar{c} + \frac{(2\gamma^2 - 5\gamma + 3)}{(8\gamma^2 - 13\gamma + 3)}(\alpha - \bar{c}),$$

so that the profits amount to

$$\pi^{CI} = \frac{\gamma(2\gamma - 1)(2\gamma - 3)^2}{2(8\gamma^2 - 13\gamma + 3)^2}(\alpha - \bar{c})^2 \quad (8)$$

for the commonly owned firms and

$$\pi^{NI} = \frac{\gamma(8\gamma - 9)(\gamma - 1)^2}{2(8\gamma^2 - 13\gamma + 3)^2}(\alpha - \bar{c})^2 \quad (9)$$

for the independent firm. Compared to the benchmark case, the coordination of the

common owners reduces the intensity of competition and thus leads to higher profits for all firms in the market. However, corresponding to the well-known effect from the merger literature (see Salant et al., 1983), the independent firm realizes a higher profit gain than the coordinated firms, i.e. $\pi^0 < \pi^{CI} < \pi^{NI}$. Finally, the result of higher prices, $p^0 < p^I$, clearly indicates a loss of consumer surplus due to the partial collusion.

2.3 Independent Owners and Manager Delegation

Usually, institutional owners cannot run their firms by themselves. Instead, they have to delegate the operational decisions to specialized managers. However, managers have their own interests which do not coincide with the owners' objectives. The focus of this scenario is, therefore, on pure manager delegation, while common ownership is neglected for now. In order to compare this scenario with the other ones, we have to adapt the existing duopoly models, as summarized e.g. by Kopel and Pezzino (2018), to our triopoly setting.

Following the tradition of Vickers (1985), we assume that the firm owners offer their managers observable and irreversible compensation contracts.⁸ The linear compensation schemes specify the managers' payments according to

$$s_i = a_i + b_i \psi_i,$$

$i = 1, 2, 3$. The parameter a_i denotes the fixed salary for the manager of firm i and $b_i > 0$ denotes a weight parameter which, in combination with a_i , guarantees that the total payment s_i equals an exogenously given market-specific level $s_i = \bar{s}$. The performance-dependent component of payment consists of a weighted sum of the measures profit π_i and sales q_i , i.e.

$$\begin{aligned} \psi_i &= \pi_i + \kappa_i q_i \\ &= (\alpha - \bar{c} + x_i - q_1 - q_2 - q_3 + \kappa_i) q_i - \frac{\gamma}{2} x_i^2, \end{aligned} \tag{10}$$

$i, j, k = 1, 2, 3$; $i \neq j \neq k$, where κ_i is the strategic contract parameter set by the owners of firm i . Maximizing the managers' objective functions with respect to the capacities leads to the equilibrium levels

$$q_i = \frac{1}{4}(\alpha - \bar{c} + 3x_i - x_j - x_k + 3\kappa_i - \kappa_j - \kappa_k). \tag{11}$$

Substituting (11) into (10) leads to the reduced-form objective functions of the man-

⁸If one of these assumptions is relaxed, manager-compensation contracts can no longer act as commitment devices (see Katz, 1991).

agers

$$\psi_i = \frac{1}{16}(\alpha - \bar{c} + 3x_i - x_j - x_k + 3\kappa_i - \kappa_j - \kappa_k)^2 - \frac{\gamma}{2}x_i^2.$$

Maximization with respect to the cost-reducing activities gives the managers' investment decisions

$$x_i = \frac{3}{(8\gamma - 3)} \left[\alpha - \bar{c} + \frac{3(2\gamma - 1)}{(2\gamma - 3)}\kappa_i - \frac{2\gamma}{(2\gamma - 3)}(\kappa_j + \kappa_k) \right], \quad (12)$$

which depend positively on the weight parameter κ_i of the own manager's compensation contract, but negatively on the weight parameters of the rivals' contracts. Zero values of the κ -variables would induce the investment levels (4) of the benchmark model. However, positive equilibrium weights of the sales components induce higher investment in automation.

Substituting the investment levels (12) into (11) and then both expressions into (1) leads to the owners' reduced-form profit functions

$$\pi_i = \frac{\gamma}{2(8\gamma - 3)^2} \left[\alpha - \bar{c} + \frac{3(2\gamma - 1)}{(2\gamma - 3)}\kappa_i - \frac{2\gamma}{(2\gamma - 3)}(\kappa_j + \kappa_k) \right] \left[(8\gamma - 9)(\alpha - \bar{c}) + \frac{2\gamma(21 - 8\gamma) - 9}{(2\gamma - 3)}\kappa_i - \frac{2\gamma(8\gamma - 9)}{(2\gamma - 3)}(\kappa_j + \kappa_k) \right]. \quad (13)$$

In the first stage of the game, the owners strategically decide on the weight parameters κ_i of the compensation contracts. The first-order conditions can be solved in terms of the symmetric subgame perfect weight parameters

$$\kappa^* = \frac{(16\gamma^2 - 18\gamma + 9)}{(80\gamma^2 - 66\gamma + 9)}(\alpha - \bar{c}) > 0.$$

The positive sign indicates compensation schemes which induce managers to act aggressively in terms of higher investment and capacity levels. The subgame perfect investment activity

$$x^* = \frac{18(2\gamma - 1)}{(80\gamma^2 - 66\gamma + 9)}(\alpha - \bar{c}), \quad (14)$$

is higher in comparison to the benchmark scenario, i.e. $x^0 < x^*$. The subgame perfect capacities are

$$q^* = \frac{12\gamma(2\gamma - 1)}{(80\gamma^2 - 66\gamma + 9)}(\alpha - \bar{c}),$$

and indicate an expansion, i.e. $q^0 < q^*$, due to delegation. These capacity levels imply

the prices⁹

$$p^* = \bar{c} + \frac{(8\gamma^2 - 30\gamma + 9)}{(80\gamma^2 - 66\gamma + 9)}(\alpha - \bar{c}),$$

and firm profits

$$\pi^* = \frac{6\gamma(2\gamma - 1)(16\gamma^2 - 42\gamma + 9)}{(80\gamma^2 - 66\gamma + 9)^2}(\alpha - \bar{c})^2. \quad (15)$$

The necessity of delegating operational decisions to managers induces more investment in automation leading to a capacity expansion. As a consequence, the resulting prices are lower, i.e. $p^* < p^0$. Therefore, delegation leads to a reduction of firm profits, i.e. $\pi^* < \pi^0$, but to an increase in consumer surplus.

2.4 Mixed Ownership and Manager Delegation

So far we derived two channels of how the intra-firm organization affects the firms' investment behavior. On the one hand, cooperation of common owners induces lower investment of the coordinated firms, but higher investment of the non-coordinated firm. On the other hand, delegation to managers leads to more investment. Since many technology-intensive industries are characterized by common ownership as well as by manager delegation, it is of particular interest to analyze the combined effects on investment.

To study this scenario, we follow Neus and Stadler (2018) and Neus et al. (2020) by assuming that the owners of firms 1 and 2 indirectly coordinate via the design of their manager compensation contracts.¹⁰ In this scenario, common owners maximize the sum of their joint profits $\pi_1 + \pi_2$, while the owners of the independent firm 3 decide on their compensation contract individually. The equilibrium contract parameters can be derived as

$$\kappa^C = \frac{3(8\gamma^2 - 30\gamma + 9)}{D}(\alpha - \bar{c})$$

for the coordinated firms ($\kappa_1 = \kappa_2 = \kappa^C$) and

$$\kappa^{NC} = \frac{(16\gamma^2 - 18\gamma + 9)(16\gamma^2 - 36\gamma + 9)}{3D}(\alpha - \bar{c})$$

for the non-coordinated firm ($\kappa_3 = \kappa^{NC}$), where $D \equiv 256\gamma^4 - 992\gamma^3 + 984\gamma^2 - 306\gamma + 27 > 0$. It can be shown for all permitted γ -values that the relation $0 < \kappa^C < \kappa^{NC}$ generally holds. Hence, the strictly higher incentive parameter set by the owners of the

⁹The equilibrium condition in the last stage read $2q_i + q_j + q_k \leq \alpha - \bar{c} + x_i + \kappa_i$, $i, j, k = 1, 2, 3$, $i \neq j \neq k$, and are satisfied as inequalities as soon as the capacity-installation costs are positive.

¹⁰This more sophisticated type of indirect coordination is hardly provable by the antitrust authorities and, therefore, allows the owners to avoid a strict supervision of their collusion activities.

independent firm induces its manager to act more aggressively than the managers of the commonly owned firms. The common owners of firms 1 and 2 reduce the incentives towards sales in order to soften competition due to their common interests, i.e. they induce their managers to behave less aggressively.

As a novel result of our model, we can now determine the cost-reducing investment levels

$$x^C = \frac{2(4\gamma - 3)(8\gamma^2 - 30\gamma + 9)}{D}(\alpha - \bar{c}), \quad (16)$$

$$x^{NC} = \frac{6(2\gamma - 1)(16\gamma^2 - 36\gamma + 9)}{D}(\alpha - \bar{c}). \quad (17)$$

The non-coordinated firm increases its investment in cost-reduction while the expenditures of the coordinated firms are reduced. The investment decisions of the firms colluding in their investment strategies lie in between, i.e. $x^C < x^{CI} < x^0 < x^{NI} < x^* < x^{NC}$. Indeed, the coordinated firms set the lowest investment levels of all scenarios. The capacity decisions of the firms are

$$q^C = \frac{4\gamma(4\gamma - 3)(8\gamma^2 - 30\gamma + 9)}{3D}(\alpha - \bar{c}),$$

$$q^{NC} = \frac{4\gamma(2\gamma - 1)(16\gamma^2 - 36\gamma + 9)}{D}(\alpha - \bar{c}).$$

We identify an expansion of capacities of the non-coordinated firm, while the coordinated firms behave less competitive. The capacity decisions show a similar pattern as the decisions on automation investments, $q^C < q^{CI} < q^0 < q^{NI} < q^* < q^{NC}$. Again, common ownership induces the coordinated firms to soften competition. The capacities of the coordinated firms are the lowest. The equilibrium prices are

$$p^C = \bar{c} + \frac{(128\gamma^4 - 768\gamma^3 + 1296\gamma^2 - 594\gamma + 81)}{3D}(\alpha - \bar{c}).$$

Hence, they are lower in comparison to owner decision but higher compared to delegation without owner coordination, i.e. $p^* < p^C < p^0 < p^I$. Finally this leads to the profits

$$\pi^C = \frac{2\gamma(4\gamma - 3)(8\gamma^2 - 30\gamma + 9)^2(32\gamma^2 - 60\gamma + 9)}{9D^2}(\alpha - \bar{c})^2 \quad (18)$$

for the coordinated firms and

$$\pi^{NC} = \frac{2\gamma(2\gamma - 1)(16\gamma^2 - 36\gamma + 9)^2(16\gamma^2 - 42\gamma + 9)}{3D^2}(\alpha - \bar{c})^2 \quad (19)$$

for the non-coordinated firm. The non-coordinated firm realizes a higher profit due to a higher investment in comparison to the commonly owned firms. Indeed, profits of

the commonly owned firms are reduced even below the level under delegation without owner coordination. In comparison to collusion in investment, we find that profits for the coordinated firms fall even below. The profit of the independent firm, however, exceeds the profits of independently acting owners, i.e. $\pi^C < \pi^* < \pi^0 < \pi^{CI} < \pi^{NI} < \pi^{NC}$.

3 Intra-Firm Organization, Inter-Firm Competition and Welfare Implications

In this section we compare the derived results and complement our study by conducting a welfare analysis. Without owner coordination, the managers' incentives are such that they invest more in automation and install larger capacities than pure profit maximizers (owner-controlled firms) would do. Due to $\kappa^* > 0$, we derived incentives biased towards a more aggressive behavior of managers. Mixed ownership structures with independent owners of one firm and common owners of the other two firms alter the incentive structure. While the common owners decrease the weight put on sales, the owners of the independent firm increase it. Consequently, the managers of the commonly owned firms behave less aggressively in contrast to the manager of the independent firm, i.e. $\kappa^C < \kappa^{NC}$. The contract parameter in the case of delegation without common owners lies in between, i.e. $\kappa^C < \kappa^* < \kappa^{NC}$. This indicates a competition-softening behavior of the commonly owned firms.

Operational decisions are decisively influenced depending on whether firms are owner-controlled or manager-controlled. The novel set-up of our model allows us to derive the consequences from delegation of operational decisions (including cost-reducing investment) to managers as well as from mixed ownership structures. We find that commonly owned firms behave less efficient in terms of investing less in automation than the firm controlled by independent owners. This remarkable result is in line with empirical findings, provided e.g. by Schmalz (2021).

A quite similar pattern results for the scenario of coordinated investment, where we find lower investment levels of the coordinated firms and a higher investment of the independent firm. Again there exists a competition-softening effect of owner coordination resulting in low investments by coordinated firms. However, delegating operational decisions to managers without coordination leads, due to the biased incentives towards sales, to higher investment levels in comparison to owner-controlled firms.

Figure 1: Cost-Reducing Investment ($\alpha - \bar{c} = 1$)

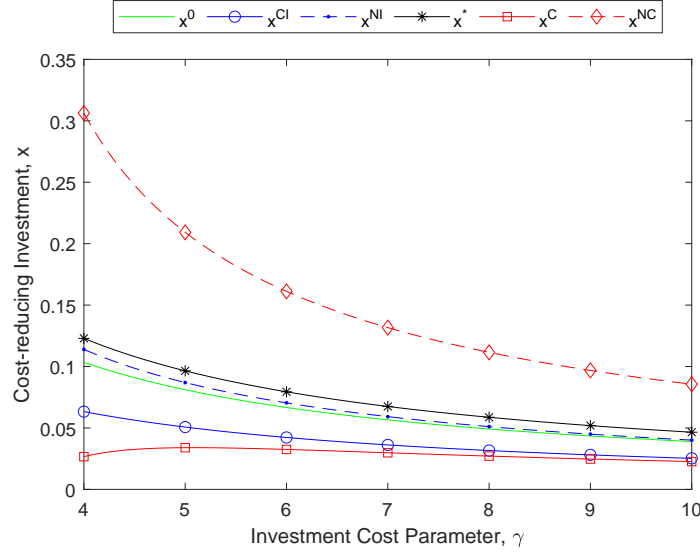


Figure 1 depicts the investment activities for our four scenarios. Firms decrease their cost-reducing investment when the investment-cost parameter γ is increasing. However, the investments of commonly owned firms in the last scenario are at first increasing in the investment-cost parameter γ as long as technological opportunities are favorable, while the independent firm in this scenario at first drastically reduces investment. With a further increasing investment-cost parameter all curves converge to rather similar levels.

The level of investment in automation directly influences the subsequent decisions on capacities and prices. Delegation of operational decisions to managers leads to an aggressive capacity expansion. However, if managers run a firm under common ownership, opposing effects are at work, since the incentives to reduce competition lead to lower capacities despite of delegation. The independent firm installs higher capacities and, therefore, becomes the largest player in the market due to its aggressive behavior in its investment and capacity decisions. We find a similar pattern for the capacities depending on the investment-cost parameter as depicted in Figure 1 for the investment levels. The convergence of the capacity levels with an increasing investment-cost parameter, however, is less pronounced.

The resulting prices especially depend on the intra-firm structure, i.e. whether firms are owner- or manager-controlled. The equilibrium prices are lower if all operational decisions are delegated to managers. As soon as owners exert the operational decisions by themselves, the resulting equilibrium prices are higher. Coordination of owners leads for both intra-firm structures (owner- vs. manager-controlled) to higher prices in comparison to non-coordinated owners.

An intra-firm organization with delegation of operational decisions to managers reduces profits for all firms in the mixed ownership structure and for the firms under common ownership in the mixed ownership structure. The independent firm always benefits

from the coordination of the rival firms' owners.

Figure 2: Profits ($\alpha - \bar{c} = 1$)

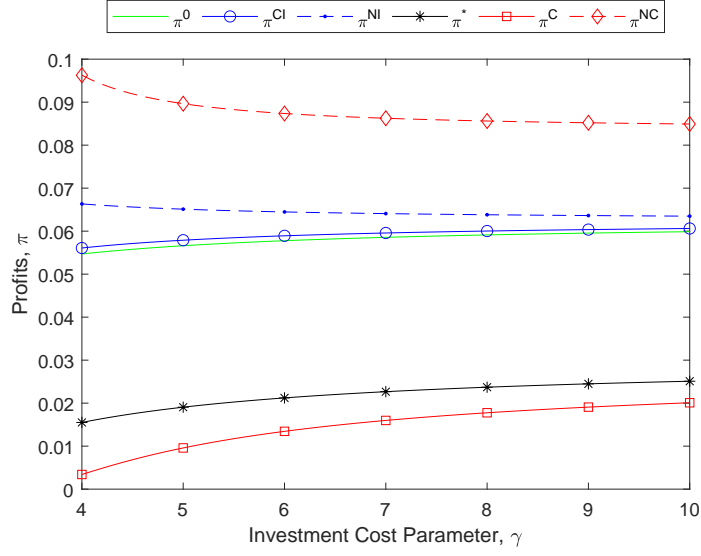


Figure 2 illustrates the firm profits depending on the investment-cost parameter. Prices are clearly increasing in the investment-cost parameter, especially the one in the case of mixed ownership structures undergoes a steeper increase compared to the other scenarios. The profits of the independent firm in both asymmetric scenarios, i.e. π^{NI} and π^{NC} , decrease in the investment-cost parameter. Whereas, the profit decrease of the independent firm in last scenario, π^{NC} , is more pronounced. This is due to the strong decrease in investment and capacities. All other profits are increasing due to the effect on prices.

Let us now evaluate the four scenarios on the basis of the resulting social welfare. First, we calculate the consumer surplus $CS = (\alpha - p)^2/2$ as

$$CS^0 = \frac{18\gamma^2}{(8\gamma - 3)^2}(\alpha - \bar{c})^2$$

for the basic scenario,

$$CS^I = \frac{4\gamma^2(3\gamma - 4)^2}{2(8\gamma^2 - 13\gamma + 3)^2}(\alpha - \bar{c})^2$$

for the scenario with collusive investment,

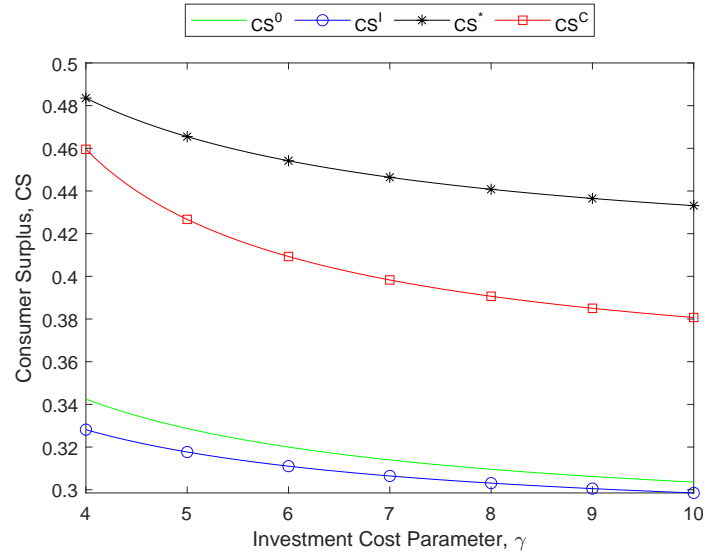
$$CS^* = \frac{648\gamma^2(2\gamma - 1)^2}{(80\gamma^2 - 66\gamma + 9)^2}(\alpha - \bar{c})^2$$

for the pure-delegation scenario, and

$$CS^C = \frac{8\gamma^2(160\gamma^3 - 552\gamma^2 + 414\gamma - 81)^2}{9D^2}(\alpha - \bar{c})^2$$

for the final scenario with common holdings and manager delegation. Figure 3 illustrates the consumer surplus which is decreasing in the investment-cost parameter. Intra-firm owner-manager structures lead to lower prices and, therefore, to higher consumer surpluses in comparison to the scenarios with owner-controlled firms. Mixed ownership structures, due to coordinated investment and common shares, increase prices and, thereby, reduce the consumer surplus in comparison to the respective symmetric ownership structure, i.e. $CS^I < CS^0 < CS^C < CS^*$.

Figure 3: Consumer Surplus ($\alpha - \bar{c} = 1$)



Consumer surplus is decreasing in the investment-cost parameter, due to the increase in prices. The consumer surplus under delegation decreases stronger under mixed ownership structures compared to independent owners. We find a divergence between these two curves. In contrast, the producer surplus is increasing in the investment-cost parameter, where the surplus of producers under delegation increases more with independent owners than with mixed ownership structures.

Finally, we calculate the social welfare $W = CS + \sum_{i=1}^3 \pi_i$ for each scenario as

$$W^0 = \frac{3\gamma(20\gamma - 9)}{2(8\gamma - 3)^2}(\alpha - \bar{c})^2$$

for the benchmark scenario,

$$W^I = \frac{3\gamma(20\gamma^3 - 59\gamma^2 + 50\gamma - 9)}{2(8\gamma^2 - 13\gamma + 3)^2}(\alpha - \bar{c})^2$$

for the scenario with collusive investment,

$$W^* = \frac{18\gamma(2\gamma - 1)(88\gamma^2 - 78\gamma + 9)}{(80\gamma^2 - 66\gamma + 9)^2}(\alpha - \bar{c})^2$$

for the delegation scenario and,

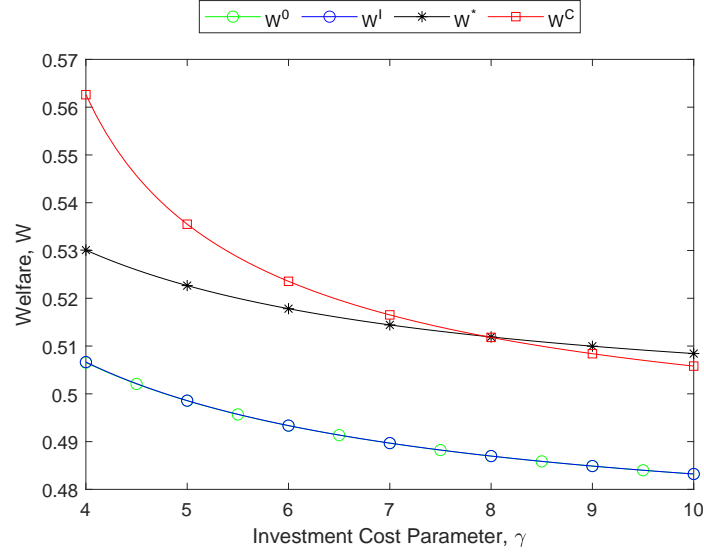
$$W^C = \frac{2\gamma A}{9D^2}(\alpha - \bar{c})^2$$

where $A \equiv 143360\gamma^7 - 1059840\gamma^6 + 2909952\gamma^5 - 3734208\gamma^4 + 2422224\gamma^3 - 796068\gamma^2 + 122472\gamma - 6561$, for the scenario that combines mixed ownership and manager delegation.

Delegation exhibits a strong influence on the social welfare. Indeed, welfare is lower for those scenarios with owner-controlled firms. However, due to the comparably high firm profits in the coordinated investment scenario, the welfare is slightly higher compared to a symmetric owner structure. Nevertheless, the extremely low consumer surplus under owner-controlled firms reduces social welfare.

Interestingly, the findings with respect to intra-firm structures where owners delegate the operational decisions to managers are ambiguous. For both scenarios, the welfare is higher in comparison to the owner-controlled scenarios. The remarkable findings concern the comparison between symmetric and mixed ownership structures under delegation. We find that for lower values of the investment-cost parameter, i.e. favorable technological opportunities for automation, welfare is higher under common ownership, while for higher values of γ welfare is higher under delegation without owner coordination. Figure 4 depicts the welfare ranking $W^0 < W^I < W^* < W^C$ for low values of γ and $W^0 < W^I < W^C < W^*$ for high values.

Figure 4: Social Welfare ($\alpha - \bar{c} = 1$)



The remarkable fact of a switch in the ranking of welfare under delegation with independent and mixed ownership structures requires a more profound investigation. Social welfare as measured by the sum of consumer and producer surplus depends on the patterns of these two measures in dependence of the investment-cost parameter. While the producer surplus under delegation with mixed ownership structures is higher than with independent ownership, the pattern of the consumer surplus for these two scenarios is reversed. However, the difference between the consumer surplus in these two cases is increasing, i.e. the consumer surplus under delegation with independent ownership is decreasing at a lower rate than under mixed ownership structures when the investment cost parameter is increasing. This is due to the steeper increase of the price under delegation in the scenario with mixed ownership in comparison to independent owners. Therefore, in markets with favorable technological opportunities for automation, welfare is higher for delegation with mixed ownership structures, since producer surplus is higher and the difference in consumer surpluses (independent owners vs. mixed ownership) is less pronounced. With less favorable opportunities this pattern is reversed, due to the divergence of the consumer surpluses under delegation with independent owners and mixed ownership.

Table 1: A Comparison of the Results

Variables	Relation Pattern
Contract Parameters	$\kappa^C < \kappa^* < \kappa^{NC}$
Investment	$x^C < x^{CI} < x^0 < x^{NI} < x^* < x^{NC}$
Capacities	$q^C < q^{CI} < q^0 < q^{NI} < q^* < q^{NC}$
Prices	$p^* < p^C < p^0 < p^I$
Profits	$\pi^C < \pi^* < \pi^0 < \pi^{CI} < \pi^{NI} < \pi^{NC}$
Welfare	$W^0 < W^I < W^* \leq W^C$

From a welfare-theoretical point of view, the frequently observed manager-controlled intra-firm structure dominates owner-controlled firm structures. In industries with favorable technological opportunities, such as the automobile market, common ownership structures lead to the highest welfare. A summary of the basic results for all analyzed scenarios is presented in Table 1.

4 Summary and Conclusion

Industries where firms intensively invest in automation and digitization, such as the motor vehicle market, are often characterized by a special structure of intra- and inter-firm organization. First, there exists a mixed ownership structure with several but not all firms being commonly held by the same (institutional) investors. Second, these investors cannot run the firms by themselves. Instead, the operational decisions must be delegated to specialized managers. However, managers have their own interests and decide according to the incentives given by their compensation schemes. Third, delegated decisions do not only include capacity-installing and price-setting but also investment activities in automation processes.

This paper, therefore, integrated different approaches of the theory of industrial organization in order to capture the combined effects of owner coordination and manager delegation on the firms' investment in cost-reducing automation processes. While the strategic effects of cost-reducing investment on quantity and price competition have been studied in detail, the mutual links to manager delegation on the one hand and to common ownership on the other hand have been neglected so far. The present paper aimed to fill this gap.

We analyzed different scenarios to capture the effects of manager delegation as well as mixed ownership structures in isolation and in a combined setting. We showed that firms being coordinated by common owners, behave less aggressively in terms of a lower investment in cost-reducing activities and, hence, smaller capacities in comparison to

the non-coordinated firm. In contrast, without coordination, manager delegation leads to higher investment in cost reduction as a consequence of compensation contracts, providing manager incentives for installing higher capacities.

As an alternative to direct coordination of investment, delegation allows the common owners to indirectly coordinate via the design of the manager-compensation schemes. Direct as well as indirect coordination leads to lower investment in cost-reducing activities and a decrease of production capacities. Therefore, common holdings are a decisive factor of explanation why some industries are characterized by low automation activity. Due to coordination, the intensity of inter-firm competition is reduced. There are less incentives to produce at lower marginal cost. With regard to the automobile market, we indeed see that the frequency of automation activities, especially of those with “stand-alone features” as the assembly line, is reduced. This is certainly due to a higher degree of difficulty with high-technology processes, but common ownership structures do exert an influence in terms of softened competition as well.

Direct coordination of firms via their investment decisions increase the profits, the one of the independent firm even more than the profits of the commonly owned firms. Without owner coordination, delegation per se reduces the firm profits. Indirect coordination of common owners via the compensation contracts for the managers further reduces the profits of the coordinated firms. However, the profit of the non-coordinated firm drastically increases.

Social welfare is crucially influenced by the intra-firm organization structure. In general, markets with owner-controlled firms are characterized by a lower welfare compared to structures where owners delegate operational decisions to managers. Whether social welfare is the highest under manager delegation with independent or with common owners decisively depends on how costly investment in automation is. For markets with favorable technological opportunities we showed that social welfare is highest under mixed ownership structures with some firms being commonly held by the same institutional owners. However, for markets with higher costs of investment, an ownership structure without common owners is preferred in terms of social welfare.

Our results suggest that firms organized by an internal structure of owners who delegate operational decisions to managers is most conducive to social welfare. A mixed ownership structure is only in favor of the independent firm which can realize high profits by a high investment in automation.

Due to its stylized structure, the presented model can be modified or extended in several directions. In industries not characterized by a precommitment value of capacities, for example IT markets, quantity (capacity) competition should be replaced by unrestricted price competition. Different degrees of product differentiation could be taken into account. Some automation activities, such as process innovations, require costly investment in research and development. Then, additionally, effects of technological input

and output spillovers as well as research joint ventures should be addressed. Furthermore, technological as well as market uncertainty should then be taken into account. More complex ownership structures where m out of n firms are commonly held by investors are of more relevance for empirical studies. Finally, alternative specifications of the manager-compensation contracts could be (re-)considered. All these interesting topics are left to future research.

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