Essays in industrial economics

Labor market imperfections, cartel stability, and public interest cartels

Treuren, L.M.

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This dissertation bundles three essays that contribute to a wider understanding of the measurement, consequences, and prevention of market imperfections. The first essay introduces a method to measure the firm-level relation between the marginal revenue contribution of employees and their compensation. This method is applied to firm-level data on the Dutch economy over the years 2007 to 2018. Employees tend to be overcompensated on the margin relative to their revenue contribution, and this overcompensation is related to high margins in the market for materials. The second essay compares the stability of collusive agreements in the first-price sealed-bid auction and the English auction in a laboratory experiment. Bidding rings are more often stable in the English auction, a finding suggested by theory but so far not reported in the empirical literature. The third essay investigates whether allowing firms to form voluntary agreements can increase their standard of corporate social responsibility. In a model of oligopolistic competition, it is shown that unless firms can benefit at the expense of consumers, voluntary agreements will not promote corporate social responsibility.

Leonard Treuren (1991) holds a BSc in Economics and Business from the University of Amsterdam, an MSc in Economics from the University of Amsterdam, and an MPhil in Economics from the Tinbergen Institute. He wrote this PhD dissertation between 2017 and 2021 at the Department of Economics of the University of Amsterdam. He currently works as a postdoctoral research scholar at the Department of Economics of the KU Leuven.

Essays in Industrial Economics

Leonard Michaël Treuren

787

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Universiteit van Amsterdam

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Essays in Industrial Economics

Labor market imperfections, cartel stability, and public interest cartels

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Universiteit van Amsterdam op gezag van de Rector Magnificus

prof. dr. ir. K.I.J. Maex

ten overstaan van een door het College voor Promoties ingestelde commissie, in het openbaar te verdedigen in de Agnietenkapel

op maandag 18 oktober 2021, te 14:00 uur

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Acknowledgements

So here we are, six years after I entered the Tinbergen Institute for the first time. I assumed that there I would complete my understanding of economics and subsequently take on the role of oracle, counseling widely on industrial organization. However, I gradually discovered that being an academic is more like participating in the well-known Dutch game show ”Te land, ter zee en in de lucht” (”By land, by sea, and through the air”). The aim of the show is to complete a trial in a home-made car, boat, or plain. Typically, the contestants end up crashing in the water, but once in a while a team makes it all the way to the bell at the end of the trial.

The first step towards success in this show, is determining what type of vehicle to build. Many designs never make if off the drawing board. As I quickly found out, abandoning a project after months of work is common. Once in a while, a design looks promising and building commences. Soon, unforeseen problems start popping up, and new parts are required. The building takes much longer than was anticipated when preparing the design. Many social events are cancelled, for which I apologize.

From time to time, a vehicle is completed and an attempt at the trial is made in front of the audience – advisors, colleagues, conference participants, friends, and family. Most attempts end with the contestants crashing into the water, forcing them to go back to the drawing board to determine the appropriate adjustments. Ever so rarely, the trial is completed and the bell is rang. This provides a great high that unfortunately doesn’t last very long at all, so that successful contestants appear to be people that enjoy the process leading up to the bell rather than just it’s ringing.

Over the past years I have learned that I tremendously enjoy the process of doing academic research. The list of things that are still to be learned appears never-ending, but looking back makes clear how much one grows each year. This endless pursuit is tremendously stimulating, and I hope to participate for many years to come. This book bundles some of the first steps of my pursuit. These steps would not be possible without the help of many others, so that acknowledgements are in order.

First, I would like to thank my advisors Maarten Pieter Schinkel and Sander Onderstal. Maarten Pieter, you continue to inspire me on a daily basis. Your knack for applying sensible economics to real-world situations has provided me many insights during our countless phone calls discussing our joint work, or simply the latest misguided policy initiatives. Sander, your keen eye for detail has changed the way I look at writing and reading for the better. Whenever I ignore the gentle suggestions you give me, one week later I find out you were right all along. I thank both of you for giving me the freedom to work on whatever I felt like, while nudging me in the right direction when I strayed too far off track. I hope to continue to learn from you in the future.

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This dissertation would not have been possible without the support of friends and family. Having a circle of great people outside of economics was central to not being completely absorbed by it, and an important reason for me to stay in the Netherlands the past six years. I thank in particular the extended Boterneus family – Albert, Fabian, Frank, Jasper, Joris, Leon, Luc, Lucas, Michiel, Niels, Ruard, Ynte – for an endless amount of great memories and a fantastic place to come home to at the end of the day. Joris, thank you for taking on the role of paranymph. I cherish your endless enthusiasm, enjoy witnessing your own academic path, and look forward to our next drunk disagreement on some random topic. Good friends dating back to high school or even primary school – Ruben Demuyt and Ruben Hebing – early studies and rowing – Bart, Daan, and Simon – and work – Melin and Vincent – are greatfully acknowledged.

Finally, I want to thank my family, Hilda, and her family. Mum and dad, thank you for always giving me the freedom to pick my own path. I have invariably felt supported in what I do – although I'm afraid I still can't tell you when I'll get a "real job". The start

of my academic journey coincided with an even more important beginning – the start of my journey with Hilda. Six years later, you continue to make me laugh, and inspire me with your attitude towards live and your kindness. Thank you for always standing by my side. I love you.

Amsterdam, August 2021

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Chapter 1

Introduction

This dissertation consists of three chapters dealing with industrial economics. Industrial economics (also known as industrial organization) can be defined as "*the economics of markets and industries and their participants, and public policy towards these entities*" (Stigler, 1988, p.1733). It emerged from microeconomics during the early parts of the twentieth century, inspired by the work of Chamberlin (1933) and Robinson (1933), although contributions that are still relevant today date back to at least Cournot (1838).[1]

Much of industrial economics concerns itself with departures from the model of perfect competition so widely studied in economics.[2] Under the assumptions of perfect competition, among other things, consumers view goods offered by different firms as perfect substitutes, and markets adjust frictionlessly to an equilibrium at which firms make zero economic profit. This theoretical ideal, rather rare in practice, serves as a useful benchmark against which to measure what economists refer to as "market imperfections". Examples of market imperfections include the ability of firms to increase their prices profitably above the competitive benchmark price, for instance due to firms forming a cartel, or the existence of product differentiation such that consumers do not see all products as perfect substitutes. All chapters in this dissertation are related to market imperfections, be it through their measurement, their prevention, or their consequences.[3]

Chapter 2 is titled **"Wage markups, wage markdowns, and their relation**

[1] See Chapter 1 of Martin (2002) for a short history.

[2] Indeed, Schmalensee (1987, p.803) states that "*industrial organization...may be broadly defined as the field of economics concerned with markets that cannot easily be analyzed using the standard textbook competitive model*".

[3] Each of the three chapters uses a distinct methodology. Chapter 2 applies econometric techniques – based on a theoretical structure – to observational data, Chapter 3 consists of a randomized controlled laboratory experiment, and Chapter 4 utilizes oligopoly theory. For a discussion of empirical industrial organization applied in the competition policy practice, see my Preadvies (in Dutch) "Elf adviezen voor het gebruik van empirische methoden voor mededingingsbeleid" with Joris Pinkse and Jurre Thiel – Pinkse et al. (2020).

to imperfections in markets for materials". It connects to a large and expanding literature suggesting that oligopsony power is prevalent in the U.S. (e.g. Ashenfelter et al. (2010); Azar et al. (2020)). Oligopsony power can cause wages to drop below the marginal revenue product of labor – wage markdowns occur. However, several literatures, including work on rent-sharing (e.g. Kline et al. (2019)) and labor unions (e.g. Breda (2015)), point to mechanisms that could increase employees' wages above the marginal revenue product of labor – wage markups occur. Concerns about limited competition in labor markets have reached the policy debate, and have led to calls for antitrust remedies (e.g. Naidu et al., 2018). Documenting wage markups and wage markdowns across the economy is crucial to determine correct policy responses, if any.

In this chapter, an approach is introduced to identify the firm-level relationship between the marginal revenue product of labor and the wage. This method is used to describe wage markups and wage markdowns in the Netherlands over the years 2007 to 2018, using a sample of 1,162,506 observations covering 458 4-digit industries. In a perfectly competitive labor market, the firm-level ratio of the marginal revenue product of labor to the wage – the labor wedge – is equal to unity, as firms hire employees up to the point that their marginal revenue product equals the going wage. Wage markdowns (labor wedge above one) and wage markups (labor wedge below one) suggest allocative inefficiency (Petrin and Sivadasan, 2013).

The labor wedge is identified by rewriting it as the firm-specific ratio of the revenue elasticity of labor to the labor share of revenue. This approach does not require making any assumptions on imperfections in input or output markets, nor does the method require making assumptions on firm conduct. The labor share is observed in the data, and the revenue elasticity of labor is obtained by estimating a revenue function. To deal with endogeneity of inputs in the revenue function, the control function approach due to Olley and Pakes (1996) is employed.

A main advantage of this approach, over the prevalent approach to identifying the labor wedge, is that I do not need to assume away imperfections in other input markets. In fact, I use the same approach to identify the ratio of the marginal revenue product of materials to the price of materials – the materials wedge – and provide evidence of substantial materials market imperfections in the Netherlands. These results caution against the commonly used identifying assumptions that materials are frictionlessly adjustable and that firms are price takers for materials.

I show that most firms pay a wage that *exceeds* the marginal revenue product of labor. This result stands in sharp contrast to the results of Hershbein et at. (2020), who report that the average plant's marginal revenue product of labor is 53 percent higher than the wage – a finding which is interpreted as evidence of significant oligopsony power in the U.S. My results suggest that U.S.-based oligoposony results do not transfer to the European context. A potential explanation is the institutional setting in the Netherlands, where – in line with much of Europe – measures such as collective bargaining agreements are prevalent compared to the U.S. (OECD, 2020).

Large cross-sectional dispersion of the labor wedge is documented with both wage markdowns and wage markups being commonly observed. This dispersion is due to the spread of the labor wedge *within* narrowly defined 4-digit industries, not *between* industry variation. The labor wedge is strongly negatively related to the labor share, while a clear correlation with the revenue elasticity of labor is not observed. This suggests that variation in firm-level labor shares can explain within-industry variation of the labor wedge. However, mechanisms put forward in the literature to explain the falling labor share in the U.S. are unrelated to the labor wedge. Neither substitution of labor for capital (e.g. Karabarbounis and Nieman (2014)), nor "superstar firms" with high market shares (e.g. Autor et al. (2020)), nor labor productivity (e.g. Kehrig and Vincent (2021)) appear to be related to labor wedges in the Netherlands. Variation in the labor share, and hence the labor wedge, is primarily due to wage variation.

Wages, and the labor wedge, are related to imperfections in the materials market. Firms that have a high marginal revenue product of materials relative to the price of materials they pay, pay higher wages. To obtain this result, I apply the proposed method to the materials market in order to estimate the materials wedge – the ratio of the marginal revenue product of materials to the price of materials. Firms in the Netherlands tend to pay less for their materials than the marginal revenue generated by those materials – the materials wedge exceeds unity in 81 percent of all firm-year instances.

The results presented in this chapter suggest that on the margin employees benefit at the expense of employers in the Netherlands, while employers benefit on the margin at the expense of suppliers of materials. Possible mechanisms for these findings should be studied in further work. One explanation in line with the data is that firms have buyer power in the market for materials, and cross-subsidize wages with the rents generated in the materials market. This is consistent with Morlacco (2020), who reports substantial buyer power in the market for imported intermediate inputs in France, and Dobbelaere and Wiersma (2020), who report that reduced tariffs on intermediate inputs due to trade liberalization reduced labor wedges in China.

Chapter 3, titled **"Cartel stability in experimental first-price sealed-bid and English auctions"**, is joint work with Jeroen Hinloopen and Sander Onderstal. In this chapter, we compare stability of collusive agreements in first-price sealed-bid auctions and

English auctions using laboratory experiments. A cartel agreement is said to be stable if all parties involved in the agreement stick to it.[4]

The two most commonly used auction formats in practice are the first-price sealed-bid auction and the English auction. The received wisdom is that in settings where bidders are likely to form a bidding ring, auctioneers are well-advised to use the first-price sealed-bid auction rather than the English auction (e.g. Klemperer (2002); OECD (2006)). Indeed, Robinson (1985) formally shows that stable cartel agreements can never emerge as an equilibrium outcome in a first-price auction, while cartel agreements can be either stable or unstable in English auctions. Robinson's (1985) results do not offer much guidance on equilibrium selection in the English auction. As an infinite number of equilibria exist where collusive agreements are unstable in English auctions, it becomes an empirical question which equilibria are selected in practice, and hence whether the two auction formats actually differ in terms of cartel stability.

The experimental literature finds little evidence of cartel stability differing between the first-price sealed-bid auction and the English auction. However, the experimental designs of existing work differs from the theoretical setting of Robinson, making a direct test of his findings challenging. In Hu et al. (2011) bidding rings are stable by construction, in Llorente-Saguer and Zultan (2017) a second-price sealed-bid auction is used instead of an English auction, and in Agranov and Yariv (2018) costless side-payments are allowed.

In this chapter we compare cartel stability between first-price sealed-bid auctions and English auctions by closely following (a discrete version of) Robinson's (1985) framework. We impose non-binding collusive agreements on groups of three bidders and subsequently let individual bidders decide whether, and how much, to bid in an experimental auction. Bidders are informed about each other's heterogenous values. We run two experiments, varying the auction format and whether the bidders are randomly matched to new bidders in each subsequent auction.

Using laboratory experiments to address our question has at least three advantages over using field data. First, the auction format is typically not varied exogenously in the field, making comparisons difficult. Second, deciding to form a collusive agreement and reaching such an agreement involve selection. Such selection can be eliminated in the lab by imposing collusive agreements. Third, as collusion in auctions is illegal, available data on bidding rings is not representative of collusion in auctions in general.

We find that bidding rings are more often stable in the English auction than in the

[4] Collusive agreements in real-world auctions, so-called bidding rings, are prevalent. Agranov and Yariv (2018) report that since 1994, around 30 percent of all antitrust cases filed by the U.S. Department of Justice involve collusion in auctions.

first-price sealed-bid auction. Although non-collusive equilibria are regularly achieved in the English auction, equilibria with stable agreements are also frequently observed. This result holds true regardless of the re-matching protocol in place. In addition, the first-price sealed bid auction outperforms the English auction in terms of revenue and revenue spread, providing additional reasons for an auctioneer to prefer the first-price sealed bid format.

We find that Robinson's (1985) result holds up in a simple experimental setting. Our experiment is a first step in addressing why Robinson's (1985) intuition does not hold in more complicated experimental settings. Future work could isolate other aspects of a bidding ring – selection into the agreements, information revelation, agreement formation – and combine these building blocks to improve our understanding of the relation between auction format and auction outcomes.

Chapter 4, titled **"Corporate social responsibility by joint agreement"**, is joint work with Maarten Pieter Schinkel. Industry-wide voluntary agreements have recently been advocated as a means for corporations to take more corporate social responsibility (CSR).[5] In this chapter, we theoretically analyze whether allowing firms to form anti-competitive agreements can lead to increased CSR efforts, and whether such agreements benefit consumers or society at large.[6]

When CSR efforts in the market are not welfare-maximizing, proponents of allowing firms to make anti-competitive agreements believe that coordination could increase CSR. This could be the case, for instance, when production generates negative externalities that are mitigated by CSR efforts. When governments fail to provide such coordination, collaboration is thought to help. However, companies increasingly recognize that (some) consumers turn away from products that are seen as unjust, unfair and unsustainably manufactured. This allows firms to monetize a comparative advantage in CSR on their rivals (Porter and Kramer, 2006). Coordination therefore risks eliminating competition on CSR, which could reduce CSR efforts.

In Chapter 4, we study different types of joint CSR agreements in a model of oligopolistic competition with goods that are differentiated, including by the CSR efforts of their manufacturer. Firms play a sequential game. In Stage 1, firms invest in CSR efforts, after

[5]For instance, Nidumolu et al. (2014) claim that business collaboration is imperative to advancing sustainability. Henderson (2020) calls for such "industry-wide cooperation" to stop environmental degradation and economic inequality.

[6]Chapter 4 extends on Treuren and Schinkel (2018), which generalizes the duopoly results of Schinkel and Spiegel (2017) to n firms, showing that the small parameter space in which a production cartel can promote sustainability to the benefits of consumers is specific to the duopoly case – and the firms would not benefit, so would not voluntary propose such an agreement.

which CSR becomes public knowledge. In Stage 2, firms select their output. Fixed costs are increasing in CSR efforts and consumers have some willingness to pay for CSR. Firms maximize profits. We compare the benchmark case where firms select both CSR and output non-cooperatively to three different anti-competitive agreements. In a CSR agreement, firms jointly set CSR efforts and subsequently compete on the output market. In a production agreement, firms non-cooperatively select CSR investments and subsequently select output jointly. In a full agreement both strategic variables are coordinated.

We find that CSR agreements and full agreements *reduce* CSR efforts compared to the non-cooperative benchmark. The reason is that CSR coordination eliminates CSR as a dimension of competition, which allows firms to jointly profit from lower CSR investment costs. A production agreement *increases* CSR efforts compared to the non-cooperative benchmark. The reason is that investing in CSR allows a firm to increase its market share, and as a production agreement decreases conditional quantities in Stage 2 attracting additional customers is more valuable in a production agreement than in the benchmark.

All agreements that are profitable to firms decrease consumer welfare, and all agreements decrease total within-market welfare. That is, all agreements, profitable or not profitable, create a within-market deadweight loss. This means that there is no way for firms to compensate consumers so that they are indifferent between an agreement and the non-cooperative benchmark. Consumer compensation is one of the criteria that need to be fulfilled for an anti-competitive agreement to be exempted from European cartel legislation. Production agreements – essentially hard-core cartels – can therefore not be exempted from cartel law in an attempt to increase CSR efforts through coordination.

To exempt production agreements from cartel law, out-of-market benefits such as externalities would need to be taken into account. In that case, a production agreement could increase total welfare as it decreases negative externalities compared to the benchmark by increasing CSR and decreasing output. We note that CSR agreements and full agreements tend to increase the presence of negative externalities, as they decrease CSR efforts compared to the benchmark. Finally, we show that any regulated CSR level provides higher within-market welfare compared to that an output-coordinating agreement that provides the same CSR level. This raises questions about the necessity of anti-competitive agreements in the first place.

Our results are robust to allowing firms to be intrinsically motivated to invest in CSR, to varying consumers' willingness to pay for CSR, to allowing marginal costs to change with CSR efforts, to allowing firms to set prices in Stage 2 of the game instead of quantities, to allowing for partial agreements that leave a competitive fringe, and to an alternative preferences structure due to Salop (1979).

Our findings are in line with the broader empirical literature and caution against the use of cartels to increase CSR efforts. The timing of this chapter coincides with a surge of (European) interest in allowing anti-competitive agreements to promote CSR efforts by policymakers and legal scholars (see contributions in Holmes et al., 2021). Even European competition authorities are getting involved, risking that competition authorities will be forced to explicitly make normative calls on redistribution between different groups in society (see the proposals in Authority for Consumers and Markets (ACM, 2021)). This chapter contributes to that debate by suggesting that relaxing cartel laws is not the appropriate tool to increase CSR.[7]

[7]Chapter 4 is motivated by, and in turn motivates, several policy contributions. In my Preadvies (in Dutch) "Beter geen mededingingsbeperkingen voor duurzaamheid" with Maarten Pieter Schinkel – Schinkel and Treuren (2020) – we critically assess the proposal of the ACM to welcome sustainability agreements. An extensive critical discussion of the wider green antitrust movement is offered in Schinkel and Treuren (2021b), and a more applied piece appeared on ProMarket.com as "Green antitrust: Why would restricting competition induce sustainability efforts?" – Schinkel and Treuren (2021c).

Chapter 2

Wage markups, wage markdowns, and their relation to imperfections in markets for materials*

2.1 Introduction

A rapidly growing literature suggests that oligopsony power is widespread in U.S. labor markets. Oligopsony power allows firms to pay lower wages by decreasing labor demand. One strand of this literature reports a negative correlation between labor market concentration and (posted) wages (e.g. Benmelech et al. (2020); Azar et al. (2020a); Azar et al. (2020b); Rinz (2020)), while a different branch of this literature documents finite firm-level labor supply elasticities (e.g. Staiger et al. (2010); Falch (2010); Ransom and Sims (2010); Goolsbee and Syverson (2019); Azar et al. (2019); Dube et al. (2020)).[1] Absent any other labor market imperfections, oligopsony power allows firms to pay a wage that lies below their marginal revenue product of labor – wage markdowns occur.

A different literature reports evidence of employees extracting rents from firms in the form of higher wages. Mechanisms include rent-sharing (e.g. Abowd et al. (1999); Card et al. (2014); Card et al. (2018); Kline et al. (2019)), minimum wages (e.g. Card and Krueger (1994); Machin et al. (2003); Draca et al. (2011); Autor et al. (2016)), and the presence of labor unions (e.g. Card (1996); Breda (2015)). Such market imperfections

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[1] See Manning (2021) for a recent overview of oligopsony findings.

could result in firms paying wages higher than their marginal revenue product of labor – wage markups occur. For instance, if a labor union is the sole supplier of labor, absent any other labor market imperfections, firms will be forced to mark wages up relative to marginal revenue products.

Documenting wage markups and wage markdowns across the economy is crucial to determine correct policy responses, if any. Concerns about limited competition in labor markets have reached the policy debate, and have led to calls for antitrust remedies (e.g. CEA (2016); Naidu et al. (2018)). Estimates of wage markups and wage markdowns are of particular interest to policymakers because they aggregate the effects of all underlying labor market imperfections on employees' compensation relative to their marginal revenue contribution. As different labor market imperfections can have offsetting effects on remuneration, focusing on individual imperfections may lead policymakers to undesirable conclusions.[2] This is especially relevant in the European context, as policies that can favor employees and therefore protect against oligopsony power – such as collective bargaining agreements and employment protection – are much more common in Europe than in the U.S. (OECD, 2020).[3]

In this chapter, an approach is introduced to identify the firm-level relationship between the marginal revenue product of labor and the wage. This method is used to describe wage markups and wage markdowns in the Netherlands over the years 2007 to 2018, using a sample of 1,162,506 observations covering 458 4-digit industries. In a perfectly competitive labor market, the firm-level ratio of the marginal revenue product of labor to the wage – the labor wedge – is equal to one, as firms hire employees up to the point that their marginal revenue product equals the going wage. Wage markdowns (labor wedges above one) or wage markups (labor wedges below one) suggest allocative inefficiency (Petrin and Sivadasan, 2013). Many phenomena can cause a firm to select its labor such that the labor wedge is not equal to unity. Examples include oligopsony power, unionized wage setting, hiring and firing costs, contracting problems, and non-optimal managerial decisions.

[2]For instance, Webber (2020) estimates firm-level labor supply elasticities using linked employer-employee data from the U.S. While he reports labor elasticities just above 1, he also finds that labor supply elasticities are associated with smaller changes in workers' earnings than would be suggested by monopsony models based on the estimated elasticities.

[3]An alternative to directly estimating wage markdowns and wage markups is to explicitly model several market imperfections at once. Kroft et al. (2020) quantify the importance of imperfect competition in the U.S. construction by estimating a model that allows for both wage-setting power and price-setting power. Lamadon et al. (2019) measure the extent of imperfect competition in the U.S. labor market while allowing for rent sharing and compensating differentials.

We identify the labor wedge by rewriting it as the firm-specific ratio of the revenue elasticity of labor to the labor share of revenue. This approach does not require any assumptions on imperfections in input or output markets, nor does the method require assumptions on firm conduct. The labor share is observed in the data, and the revenue elasticity of labor is obtained by estimating a revenue function. To deal with endogeneity of inputs in the revenue function, the control function approach due to Olley and Pakes (1996) is employed (see also Levinsohn and Petrin (2003)).

We show that most firms pay a wage that *exceeds* the marginal revenue product of labor. In 54 percent of all firm-year instances, wage markups occur. Our results stand in sharp contrast to the results of Hershbein et al. (2020), who report that the marginal revenue product of labor of the average U.S. plant is 53 percent higher than the wage – a finding which is interpreted as evidence of significant oligopsony power. Our results suggest that these U.S.-based oligoposony results do not transfer to the European context. A potential explanation can be found in the institutional setting of the Netherlands, where – in line with much of Europe – measures such as collective bargaining agreements are prevalent compared to the U.S. (OECD, 2020).

We document large cross-sectional dispersion of the labor wedge, with both wage markdowns and wage markups being commonly observed. This dispersion is due to labor wedge variation *within* narrowly defined 4-digit industries, not *between* industries. In addition, cross-sectional variation greatly exceeds time-series variation of the labor wedge. These findings point to the importance of firm-specific factors to explain dispersion of the labor wedge, rather than industry wide measures such as regulation, or country wide measures such as minimum wages.

Using non-parametric regressions, we show that the labor wedge is strongly negatively related to the labor share, while we do not observe a clear correlation with the revenue elasticity of labor. This suggests that variation in firm-level labor shares can explain within industry variation of the labor wedge. However, mechanisms put forward in the literature to explain the falling labor share in the U.S. are unrelated to the labor wedge in the Netherlands. Neither substitution of labor for capital (e.g. Karabarbounis and Neiman (2014)), nor "superstar firms" with high market shares (e.g. Autor et al. (2020)), nor labor productivity (e.g. Kehrig and Vincent (2021)) appear to be related to labor wedges. Variation in the labor share, and the labor wedge, results primarily from dispersion of wages.

Wages, and the labor wedge, are related to imperfections in the materials market.[4]

[4]In this chapter, as in the literature, the terms "materials" and "intermediate inputs" are used interchangeably.

We find that firms that have a high marginal revenue product of materials relative to the price of materials they pay, pay higher wages. These results are obtained by applying our method to the materials market in order to identify the materials wedge – the ratio of the marginal revenue product of materials to the price of materials. Firms in the Netherlands tend to pay less for their materials than the marginal revenue generated by those materials – the materials wedge exceeds unity in 81 percent of all firm-year instances. These results question the validity, at least in the Netherlands, of the common assumption used to identify the labor wedge: that materials are frictionlessly adjustable and that firms are price takers for materials. In addition, our findings suggest that a unified treatment of all input and output markets is needed to understand imperfections in one particular input market.

The results presented in this chapter suggest that, on the margin, employees benefit at the expense of employers in the Netherlands, while employers benefit at the expense of suppliers of materials. Possible mechanisms for these findings should be studied in further work. One explanation in line with the data is that firms have buyer power in the market for materials, and cross-subsidize wages with the rents generated in the materials market. This is consistent with Morlacco (2020), who reports substantial buyer power in the market for imported intermediate inputs in France, and Dobbelaere and Wiersma (2020) who show that reducing trade tariffs on intermediate inputs has decreased the labor wedge in China.

This chapter relates to the literature that uses cost minimization assumptions and production function estimation techniques to directly estimate the labor wedge (e.g. Lu et al. (2019); Mertens (2020b,c); Hershbein et al. (2020); Caselli et al. (2021); Brooks et al. (2021)), or closely related measures based on the marginal revenue product of labor and the wage (e.g. Dobbelaere and Mairesse (2013); Nesta and Schiavo (2019); Mertens (2020a); Dobbelaere et al. (2020); Dobbelaere and Wiersma (2020)). Most closely related is Hershbein et al. (2020), who estimate and describe plant-level labor wedges for U.S. manufacturing between 1976 and 2014, and find that most plants have wage markdowns. This literature is based on the so-called "production approach" originating in De Loecker and Warzynski (2012) and based on Hall (1988).

A main advantage of the approach used in this chapter over the prevalent cost minimization approach, is that we do not need to assume away imperfections in any input markets to identify the labor wedge. In fact, we use the same approach to identify the materials wedge, and as discussed above provide evidence of substantial materials market imperfections in the Netherlands. A second advantage of our method, is that our identification strategy relates the labor wedge to revenue elasticities instead of output elasticities.

In the presence of market power, multi-product firms, and/or unobserved output quantities, identifying revenue functions – and hence the labor wedge – is more straightforward than identifying production functions. In particular, identification of output elasticities is challenging when using a control function approach to estimate production functions in the presence of market power in input or output markets (e.g. Ackerberg et al. (2015); Gandhi et al. (2020)).

This chapter connects to an emerging literature on market imperfections in materials markets. Atalay (2014) finds evidence of significant dispersion in materials' prices within narrowly defined industries producing relatively homogeneous goods in the U.S., and shows that part of this dispersion can be explained by within-supplier markup differences. Morlacco (2020) provides evidence from French manufacturing that substantial buyer power exists in the market for imported intermediate input. Petrin and Sivadasan (2013) estimate the materials wedge for manufacturing plants in Chile, and find that these wedges are quantitatively small, providing little evidence of market imperfections. We show that the distribution of the materials wedge in the Netherlands is consistent with substantial buyer power in materials markets, that a negative relation exists between labor wedges and materials wedges, and that a positive relation exists between wages and materials wedges.

Finally, this chapter is related to the literature on misallocation. Petrin and Sivadasan (2013) show that the wedge between the value of an input's marginal product and its price is a measure of misallocation, and links increases in this wedge for labor to increases in severance pay. When firms are price takers in output markets, Petrin and Sivadasan's measure is identical to the labor wedge. A wider misallocation literature relies on assumptions on production, demand, and firm conduct to use dispersion in marginal revenue products of inputs as a sufficient statistic for misallocation (e.g. Hsieh and Klenow, for a discussion of this approach see Haltiwanger et al. (2018)). We measure the dispersion of the marginal revenue products of labor and materials controlling for other factors in so far as they shift input prices.

The remainder of this chapter is organized as follows. In Section 2.2, the interpretation of the labor wedge and our identification strategy is discussed. In Section 2.3, the data and relevant Dutch institutional factors are introduced. Section 2.4 gives the results, followed by concluding remarks in Section 2.5.

2.2 Estimating wage markups and wage markdowns

We use the ratio of a firm's marginal revenue product of labor and its wage – the labor wedge – to measure firm-level departures from perfectly competitive labor markets. In a perfectly competitive labor market this ratio is equal to one. Many phenomena can cause a firm to select its labor such that this ratio is not equal to unity. Examples include oligopsony power, unionized wage setting, hiring and firing costs, contracting problems, and non-optimal managerial decisions.

Let L_{it} denote the full-time equivalent (FTE) number of employees, R_{it} the revenue, and W_{it} the wage paid by firm i at time t. The labor wedge of firm i at time t, γ_{it}, is given by

$$\gamma_{it} = \frac{MRPL_{it}}{W_{it}}, \tag{2.1}$$

where $MRPL_{it} = \frac{\partial R_{it}}{\partial L_{it}}$. Assuming $MRPL_{it} > 0$ and $W_{it} > 0$ gives $\gamma_{it} > 0$. If $\gamma_{it} > 1$, firm i pays a wage below the marginal revenue product of labor – a wage markdown. Wage markdowns can occur, for instance, when a firm is a monoposonist in the labor market. If $\gamma_{it} < 1$, firm i pays a wage above the marginal revenue product of labor – a wage markup. Wage markups can occur, for instance, when employment and wages are determined by firms bargaining with a labor union. Equation (2.1) measures the extent of labor market imperfections in many well-known theoretical models in labor economics. Examples include the canonical Cournot oligopsony model, logit models of job differentiation as in Card et al. (2018), individual sequential bargaining as in Stole and Zwiebel (1996), and "on the job search" models as in Burdett and Mortensen (1998). The generality of γ_{it} implies that we do not need to commit to a particular model of wage formation *ex ante* when using γ_{it} to measure the marginal contribution to revenue of employees relative to their compensation. This makes the labor wedge a suitable measure to study large portions of an economy, as it is unlikely that labor markets operate identically in different industries and over time. In Appendix 2.B, equation (2.1) is derived in two different models of wage setting: an efficient bargaining model that results in wage markups, and a monopsonistic wage setting model that results in wage markdowns.

The labor wedge aggregates the effects of all underlying departures from perfectly competitive labor markets on how employees are compensated relative to their contribution to revenue. Some of these departures operate at the firm-level, such as rent sharing, while others operate at the industry or even national level, such as minimum wages. However, γ_{it} should not be interpreted as a direct measure of underlying labor market imperfections for two reasons. First, effects of imperfections on the labor wedge might cancel out at the firm-level. For instance, Falch and Strøm (2007) show that the competitive wage can emerge as an equilibrium outcome in a model where wages are determined by a labor union bargaining with a monopsonist. Second, labor market imperfections that are completely priced in to the wage need not affect the labor wedge. For example, if hiring costs for temporary contracts are fully priced in to the wage of temporary employees, then firms will hire such employees up to the point where γ_{it} equals 1, absent other imperfections. Note finally that the value of γ_{it} does not inform us about the optimality of firms' or employees' behaviour. For instance, in the context of adjustment frictions in labor markets, it can be optimal for a firm to hoard labor in certain years such that the labor wedge is not equal to one. However, all else equal, in a given period firms prefer a higher γ_{it}, while employees prefer a lower γ_{it}.

For many firms, labor is heterogeneous with high-skilled employees contributing more to revenue, and receiving higher wages, than low-skilled employees. Such imperfectly substitutable employees could be hired on different labor markets, with different imperfections. Incorporating such heterogeneity into the analysis is straightforward if sufficient data is available, as the labor wedge can simply be estimated separately for each group of workers. At the scale of our analysis, such data is typically not available. Nonetheless, the labor wedge given in equation (2.1) still captures the heterogeneous actual firm-time specific labor wedges when there is unobserved heterogeneity in labor. In that case, γ_{it} is a weighted average of the labor wedges of the separate groups.[5]

2.2.1 Identifying labor wedges

We now discuss how the labor wedge can be identified in the data. Multiplying equation (2.1) by $\frac{L_{it}R_{it}}{L_{it}R_{it}}$ gives

$$\gamma_{it} = \frac{\theta_{it}^L}{LS_{it}}, \tag{2.2}$$

where θ_{it}^L is the revenue elasticity of labor, $\frac{\partial R_{it}}{\partial L_{it}}\frac{L_{it}}{R_{it}}$, and LS_{it} is labor's share of revenue $\frac{W_{it}L_{it}}{R_{it}}$. Note that no assumptions on firms conduct, or the nature of imperfections on any input or output markets, are required to establish equation (2). This implies that this method can be applied to identify wedges of inputs other than labor as well. The

[5] When the revenue elasticities of the different labor types sum to the revenue elasticity of all labor, these weights reduce to the labor types' shares of total labor costs. For instance, assume that there are two types of labor, denoted by superscripts τ_1 and τ_2. Then $\gamma_{it} = \frac{1}{W_{it}L_{it}}\left(W_{it}^{\tau_1}L_{it}^{\tau_1}\gamma_{it}^{\tau_1} + W_{it}^{\tau_2}L_{it}^{\tau_2}\gamma_{it}^{\tau_2}\right)$.

labor share of revenue can typically be obtained from firm-level income statements. The revenue elasticity of labor is not observed in our data, or typical firm-level datasets, so it needs to be estimated. Identification of the revenue elasticity is discussed in Section 2.2.3.

The identification strategy used in this chapter has several advantages over existing cost minimization approaches to estimating the labor wedge.[6] First, in contrast to the cost minimization approach our method does not require the existence of a frictionlessly adjustable input, for which firms are price-takers. In the cost minimization literature, the existence of such an input is crucial. Intermediate inputs is typically chosen as the freely adjustable input. However, Morlacco (2020) provides evidence that substantial buyer power exists in France for imported intermediate inputs. In Section 2.4.4, we apply our identification strategy to the materials market, and show that there exists substantial dispersion of the firm-level materials wedge in the Netherlands. This suggests that materials are not frictionlessly adjustable in our sample, so that the cost minimization approach is not appropriate.

A second advantage of the method used in this chapter, is that it requires an estimate of a revenue elasticity to identify the labor wedge instead of estimates of output elasticities, which are required when using the cost minimization approach. Estimating production functions is challenging in practice for at least three reasons. First, most firm and plant-level datasets do not contain data on output quantities, forcing researchers to use deflated revenue instead. This is well known to bias estimates of output elasticities (Klette and Griliches, 1996). Researchers using deflated revenue measures are either forced to make strong implicit assumptions on market conduct of firms, or explicitly model the demand side.[7] Second, even when output quantities are available, aggregating these quantities to the firm-level is challenging, but necessay, for multiproduct firms, as input data is very rarely available broken down by product (see De Loecker et al. (2016)). Third, even when output quantities are available and we only observe single-product firms, controlling for unobserved productivity in the presence of market power has proven difficult. The standard approach to estimate output elasticities currently used in the literature is the control function approach due to Olley and Pakes (1996) (see also Levinsohn and Petrin

[6]We refer here to papers that directly estimate the labor wedge (e.g. Lu et al. (2019); Mertens (2020b,c); Hershbein et al. (2020); Caselli et al. (2021); Brooks et al. (2021)), or closely related measures based on the marginal revenue product of labor and the wage (e.g. Dobbelaere and Mairesse (2013); Nesta and Schiavo (2019); Mertens (2020a); Dobbelaere et al. (2020); Dobbelaere and Wiersma (2020)), using a cost minimization framework. This cost minimization approach is discussed in Appendix 2.C.

[7]For example, De Loecker (2011) explicitly models the demand side.

(2003)). In this approach, unobserved productivity is controlled for by inverting a "control function" – in practice either a material demand function, or an investment function. When unobserved productivity is not the only omitted variable in the control function, for instance due to unobserved market power in the output market influencing demand for materials, output elasticities will be biased (see Ackerberg et al. (2015) and Gandhi et al. (2020)). This is relevant in my sample as market power exists in the Dutch economy (De Loecker and Eeckhout (2018); van Heuvelen et al. (2019)).

Identifying the labor wedge using equation (2.2) does require an estimate of the revenue elasticity of labor. However, as revenue is observed at the firm-level, estimation of a revenue function is not plagued by the output price bias that occurs when deflated revenue is used in the place of output quantities when estimating a production function. Second, revenue easily aggregates for multiproduct firms as it is always measured in monetary terms. Finally, when estimating a revenue function one needs to control for unobserved *revenue* productivity, while when estimating a production function one needs to control for unobserved *physical* productivity. Revenue productivity contains price variation unrelated to production, for instance due to variation in market power, while physical productivity does not.[8] When using the control function approach to estimate a production function, one therefore needs to control for price variation in the control function before it can be inverted. When inverting a a control function for unobserved revenue productivity, the separating of unobserved price variation from unobserved physical productivity is unnecessary.

A final advantage of the method used in this chapter compared to the cost minimization literature, is that no assumptions are needed on the behavior of firms. In particular, one does not need to assume that firms minimize their conditional cost function by optimally selecting a flexible input for which they are price takers. While cost minimization is admittedly a weak assumption, assuming it does imply a certain level of confidence in the managerial abilities of the firms under consideration. Our sample includes many small firms, some of which are loss-making and exit the market quickly. One possible explanation for this, which we would not like to rule out by assumption, is that such firms are mismanaged.

[8]Foster et al. (2008) show that this distinction matters in practice.

2.2.2 Estimating revenue elasticities of labor

We now turn to the estimation of the revenue elasticity of labor, θ_{it}^L, which is required to obtain an estimate of the labor wedge.[9] Consider the revenue function of a firm i at time t

$$R_{it} = F_{it}(K_{it}, L_{it}, M_{it})\Omega_{it}, \tag{2.3}$$

where K_{it} and M_{it} are capital and materials of firm i at time t, F_{it} is the function relating inputs to revenue, and Ω_{it} is Hicks-neutral revenue productivity which is potentially known to the firm at time t, but unobserved by the econometrician. Taking logs and allowing for log-additive mean-zero measurement error ϵ_{it} gives

$$r_{it} = f_{it}(k_{it}, l_{it}, m_{it}) + \omega_{it} + \epsilon_{it}, \tag{2.4}$$

where lowercase letters denote the natural logarithm of the concomitant uppercase letter. The main challenge to estimating equation (2.4) is controlling for unobserved (by the econometrician) revenue productivity – such as market power in the output market, or additional inputs – captured in ω_{it}. If a firm's inputs at time t are at least partially determined by decisions made after the firm observes ω_{it}, estimates of the revenue elasticities can be biased. This problem has long been recognized in the literature on production function estimation (Marschak and Andrews, 1994).

We use the control function approach, due to Olley and Pakes (1996) and Levinsohn and Petrin (2003), to deal with the correlation of unobserved revenue productivity and input choices. A static input demand equation, demand for materials, is used to control for ω_{it},

$$m_{it} = m_s(\omega_{it}, k_{it}, l_{it}), \tag{2.5}$$

where s indicates a 2-digit industry. Inverting equation (2.5) result in a control for ω_{it} based on observables which can be substituted into equation (2.4) under the so called "scalar unobservable" assumption – the assumption that revenue productivity ω_{it} is the sole unobservable in equation (2.5). In addition, $m_{it}(\cdot)$ needs te be one-to-one in ω_{it}. Note that revenue productivity ω_{it} potentially contains price variation due to market power in in- and output markets, so that controlling for such price variation is unnecessary to satisfy the scalar unobservable assumption.

[9] Appendix 2.D contains a more detailed description of the estimation routine.

To allow for firm-time specific revenue elasticities, a translog revenue function is used. As firm-level heterogeneity in productivity exists even in narrowly defined industries (Bartelsman and Doms (2000); Syverson (2011)), firm-level heterogeneity in revenue elasticities is to be expected. However, the standard choice for $f(\cdot)$, a Cobb-Douglas function estimated at the 2-digit industry level, generates revenue elasticities that are constant across the 2-digit industry level. The translog revenue function is given by

$$f_s(k_{it}, l_{it}, m_{it}) = \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_{kk} k_{it}^2 + \beta_{ll} l_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it}, \tag{2.6}$$

where s indicates the 2-digit NACE industry at which the revenue function is estimated, and the revenue elasticity of input $x_{it} \in \{k, l, m\}$ is given by $\theta_{it}^x = \frac{\partial f_s}{\partial x_{it}}$.

We follow the literature by assuming that revenue productivity evolves according to a first-order Markov process

$$\omega_{it} = g_s(\omega_{it-1}) + \xi_{it}, \tag{2.7}$$

where ξ_{it} is a mean zero productivity shock and $g_s(\cdot)$ a stochastically increasing function. The law of motion of revenue productivity given in equation (2.7) accounts for correlation over time of ω_{it}. Substituting equations (2.6), (2.7), and then (2.5) – inverted and lagged one period – into equation (2.4) gives the equation to be estimated.

We use the Wooldridge (2009) one-step estimator and obtain revenue elasticities by forming moments on the sum of the idiosyncratic revenue productivity innovation and the idiosyncratic measurement error in the revenue function, $\xi_{it} + \epsilon_{it}$. To form these moments, it is necessary to take a stand on the correlation between contemporaneous inputs k_{it}, l_{it}, and m_{it}, and $\xi_{it} + \epsilon_{it}$. We follow the literature and assume that $\mathbb{E}(k_{it}, (\xi_{it} + \epsilon_{it})) = 0$ due to adjustment frictions in capital.[10] Together, the following moments result

$$\mathbb{E}((\xi_{it} + \epsilon_{it})\mathbf{Z}_{it}) = 0, \tag{2.8}$$

where $\mathbf{Z}_{it}$ includes all terms in $g_s(\cdot)$, k_{it}, and interactions of contemporaneous capital with all lagged inputs.[11] The full unbalanced panel is used, and equation (2.4) is estimated separately for each 2-digit NACE industry. Estimates of revenue elasticities are reported in Table 2.8 of Appendix 2.D.

[10]This can be motivated by a law of motion of capital, such as $K_{it} = (1 - \delta)K_{it-1} + I_{it-1}$, where δ is depreciation and I_{it} is investment.

[11]The function $g_s(m_s^{-1}(\cdot))$ is approximated by a third order polynomial in all arguments of $m_s^{-1}(\cdot)$.

2.3 Data and institutional setting

Our sample contains 1,162,506 firm-year observations over the period 2007 to 2018, spanning the majority of all non-financial firms located in the Netherlands with at least one employee on the pay roll. In Section 2.3.1, relevant institutional factors of the Netherlands are briefly considered. In Section 2.3.2, we outline the data sources and provide descriptive statistics.

2.3.1 Institutional setting

In the Netherlands, employees' compensation and labor market legislation is typically determined by collective bargaining and dialogue between federations of workers' unions, employer associations, and the government. Collective agreements are central to Dutch labor markets. Collective bargaining coverage in the Netherlands in 2016 was 78.6 percent, compared to an OECD average of 32.4 percent (OECD, 2019a).[12] Collective employment agreements specify a host of different pay scales that are determined by factors such as seniority, but typically leave an employer and employee some room to bargain about the actual scale that the employee is placed on.

Employment protection for employees is strong in the Netherlands, and the minimum wage is relatively high. On the OECD's strictness of employment protection scale, the Netherlands scores 3.44, substantially higher than the OECD average of 2.12 (OECD, 2019c).[13] In 2016, the real annual minimum wage in the Netherlands was 55.24 percent higher than the real annual minimum wage in the U.S.. Compared to Germany and the UK, the concomitant percentage differences are 6.77 and 20.53 (OECD, 2019b).[14] Unemployment rates as a percentage of the labor force increased following the financial crisis of 2007-2008, but at 5.3 percent remained relatively low on average throughout the sample period (OECD, 2019a).

A substantial gap exists between the net salary that employees receive and the labor

[12]The collective bargaining coverage is the share of all employees who's terms of employment are governed by at least one collective agreement. Collective bargaining coverage in 2016 was 56 percent for Germany, 26.3 percent for the UK, and 11.5 percent for the U.S..

[13]The strictness of employment scale refers to a six-point scale that measures the strictness of individual and collective dismissals of regular contracts, with higher scores indicating more employment protection. The scale weighs several factors, including the amount of severance pay upon dismissal and length of the notice period. For more details see (OECD, 2020). Scores for Germany, the UK, and the U.S., are 2.6, 1.35, and 0.09, respectively.

[14]Real annual minimum wages are computed by converting statutory minimum wages into a common hourly and annual pay period, and then converting the sums into a common currency unit (USD) using Purchasing Power Parities (PPPs) for private consumption expenditure.

expenditure per worker of the firm. This gap is due to mandatory social security contributions, such as pension contributions by both employers and employees, and high income tax rates. In 2019, 3 percent of total labor expenditure consisted of recruiting and on the job training costs. Mandatory social contributions from employers towards employees constituted another 21 percent of total labor expenditure, leaving gross salary at 76 percent of total labor expenditure. Employees' mandatory social security contributions and income taxes accorded for another 24 percent, leaving net salary at 52 percent of the total labor expenditure of the firm (CBS, 2020a, p.77).[15]

2.3.2 Data and descriptive statistics

We construct a yearly firm-level dataset covering the majority of all non-financial firms with at least one employee, located in the Netherlands, over the period 2007 to 2018, using non-public data obtained from Statistics Netherlands (CBS).[16] We combine data from the "General Firm Registry" (ABR) and the "Financial Statistics of Non-financial Firm" (NFO), two yearly firm-level datasets that use as primary sources registries from the Dutch Chamber of Commerce, the Dutch tax authority, and the Dutch Ministry of Finance. These datasets aim to document the universe of all non-financial firms located in the Netherlands. The ABR contains yearly data on the amount of full-time equivalent (FTE) employees of each firm, and the 4-digit NACE industry in which the firm is active. The NFO contains yearly balance sheet and income statement data from which we obtain revenue, the total expenditure on labor and materials, the book value of capital, and several measures of accounting profit.

To ensure high data quality, the CBS routinely contacts firms when reporting errors are suspected. In addition, we remove outliers and observations that report internally inconsistent statistics. We further restrict the sample to firm-year observations that have sufficient information to construct labor and materials wedges. In particular, only observations with positive revenue, capital, and labor expenditure, and at least one FTE employee on the pay roll, are included. Appendix 2.A provides a detailed overview of all variables and the sample selection procedure.

All results are constructed only for employees on a firm's pay roll, as data on both labor expenditure and employment cover only the employees that are on a firm's pay roll.[17]

[15] These percentages vary slightly each year as the relative sizes of different contributions vary. For instance, in 2018 net wages made up 51 percent of total labor expenditure (CBS, 2019, p87).

[16] Under certain conditions, these data are accessible for research. See https://www.cbs.nl/en-gb/our-services/customised-services-microdata for details.

[17] This includes the revenue elasticity of labor, as unobserved employment through tempo-

We do not observe labor expenditure or employment for workers hired through temporary employment agencies. However, such workers *are* used to calculate labor wedges of the temporary agencies themselves. It is however not unlikely that the the marginal revenue products of such workers to the employment agency are lower than the marginal revenue products of such workers to the firms that temporarily use their employment. This could result in firms holding labor market power over temporary workers from employment agencies, without this being reflected in those firms' estimated labor wedges.

Total labor expenditure is used to construct our labor compensation variable, as total labor expenditure captures a firm's labor cost more accurately than net or gross salary for employees. Firms can be expected to attempt to equalize the marginal revenue product of labor and the per-employee variable expenditure on labor, not the immediate take-home wage of the employee. With slight abuse of terminology, we refer to the labor expenditure per FTE employee as "wage", in order to remain in line with the cost minimization literature that refers to total labor expenditure in this fashion.[18] We construct the wage W_{it} as the ratio of a firm's total expenditure on labor and its FTE employees. Wage W_{it} should therefore be interpreted as the average labor expenditure per full-time equivalent worker in firm i at time t. To decompose the estimated labor wedge, γ_{it}, into the marginal revenue product of labor and the wage, W_{it} is used.

We use Eurostat's NACE Rev. 2 industry classification throughout this chapter (Eurostat, 2008). The most aggregated industry classification is the NACE section (one or more 2-digit NACE codes), while NACE divisions (2-digit), NACE groups (3-digit) and NACE codes (4-digit) are increasingly dis-aggregated classifications.[19] All NACE divisions (2-digit NACE codes) with sufficient observations such that the revenue function can be estimated are included in the final sample. Table 2.6 in Appendix 2.A list the 53 2-digit NACE industries that are included in the final sample. The final sample consists of 235,892 firms for a total of 1,162,506 firm-year observations. Table 2.7 in Appendix 2.A presents a breakdown of observations by year and NACE section.

Table 2.1 reports summary statistics for key firm-level variables. All variables are positively skewed with means often substantially exceeding medians. The outliers in the right tales ensure that standard deviations are much larger than the inter-quartile range.

rary employment agencies enters unobserved revenue productivity ω_{it}, together with all other unobserved inputs, so that it is controlled for and does not affect the revenue elasticity of labor.

[18]In the Netherlands, the term "wage" is typically used to refer to gross salary.

[19]As an example: NACE section C is "manufacturing", which consists of NACE divisions 10-33. NACE division 10 is "Manufacture of food products" and includes 9 different NACE groups. NACE group 101 is "Processing and preserving of meat and production of meat products", which includes three different NACE codes. NACE code 1011 is "preserving and processing of meat".

Table 2.1: Summary statistics

variable	p(25)	p(50)	p(75)	mean	s.d.
Nominal revenue	286	812	2,207	2,626	9,996
Nominal book value of capital	21	93	429	565	3,551
Labor (FTE)	2	5	12	11.83	30.99
Nominal labor expenditure	104	240	597	619	1,596
Nominal materials expenditure	111	420	1,316	1,778	8,189
Nominal EBIT	2	45	143	155	796
Nominal net income	-2	37	128	145	1,800

Notes: Summary statistics for key variables based on the full sample of 1,162,506 observations. EBIT is earnings before interest and taxes. p(25), p(50), and p(75) refer to the 25th, 50th, and 75th percentile of the distribution, respectively. Mean and s.d. are the unweighted mean and standard deviation. Monetary values in thousands, rounded to whole numbers. Non-monetary variables rounded to two decimal points.

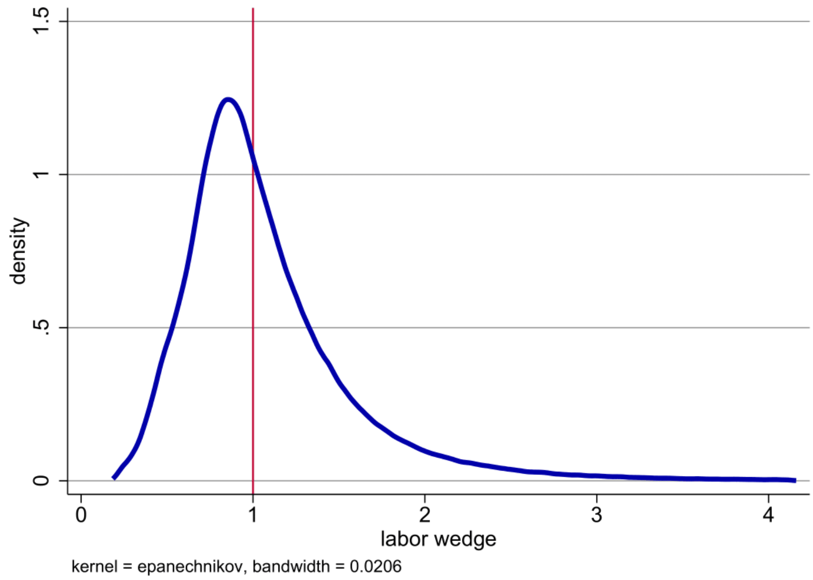
These outliers are typically large, publicly traded, firms that can be found in international datasets such as Compustat. Compared to those datasets, our sample includes many small firms. The median number of employees is 5, while the mean is 11.83. Total labor cost has a (rounded to thousands) median of 240,000 euro, and a mean of 619,000 euro. The median of book value of capital is 93,000 euro, while the mean is 565,000. euro. For revenue, the median and mean are 812,000 euro and 2,626,000 euro respectively. Earnings before interest and taxes (EBIT) are mostly positive, with a median of 45,000 euro and a mean of 155,000 euro. However, after net financial income and (corporate) taxes, net income is only 37,000 euro and at the 25th percentile a loss of 2,000 euro is recorded. As with all variables, this measure is highly skewed with mean net income of 145,000 euro and a standard deviation of 1,800,000 euro.

2.4 Results

In Section 2.4.1, we analyze the distribution of firm-level labor wedges in the Netherlands. In Section 2.4.2, we investigate how the labor wedge distribution changes over time, while Section 2.4.3 explores the relation between the labor wedge, input use, and market outcomes. In Section 2.4.4, the distribution of the materials wedge, and the relation between the materials wedge and the labor wedge, is discussed.[20]

[20] Throughout the results section the mean is omitted because the interpretation of the labor wedge is not symmetric around 1. For instance, a labor wedge of 1.5 implies that the marginal revenue product of labor is 50 percent higher than the wage, while a labor wedge of 0.5 implies

Figure 2.1: Density function of firm-level labor wedges in the Netherlands



Notes: Kernel density function of firm-level labor wedges based on the full samples of 1,162,506 firm-year observations over the years 2007 to 2018.

2.4.1 Wage markups and wage markdowns in the Netherlands

Figure 2.1 displays the distribution of the firm-level labor wedge in the full sample, and Table 2.2 gives several percentiles of this distribution. The median labor wedge is 0.96, and wage markups cover 53.86 percent of all observations, implying that in the majority of firm-year instance, firms pay a wage that exceeds the marginal revenue product of labor. However, wage markups and wage markdowns are both prevalent. These results differ markedly from Hershbein et al. (2020), who find that labor wedges in U.S. manufacturing are considerably larger than unity in the majority of all plant-year observations, and interpret these findings as evidence of widespread oligopsony power in U.S. labor markets. Figure 2.1 suggests that this is not the case in the Netherlands, as labor wedges below unity are not consistent with a model of oligopsonistic wage setting. An appealing explanation of these differences is the traditionally strong position of employees in the Netherlands due to the institutional setting of collective bargaining discussed in Section 2.3.1. Compared to the U.S., where such institutions are much less prevalent, these factors might shift the whole distribution of the labor wedge to the left.[21]

that wage is twice as high as the marginal revenue product of labor. Minima and maxima of distributions are omitted, as the CBS does not allow the disclosure of this information.

[21]Indeed, as in this chapter, Hershbein et al. (2020) find that the labor wedge distribution is spread out even in narrowly defined industries. Therefore, factors that shift the whole labor

Table 2.2: Summary statistics of the labor wedge

variable	p(5)	p(25)	p(50)	p(75)	p(95)
Labor wedge	0.49	0.76	0.96	1.26	2.02
MRPL	21,427	39,316	52,670	70,954	146,124
Wage	26,235	41,952	54,607	72,837	124,402
MRPL - Wage	-40,289	-13,854	-2,445	11,493	52,574

Notes: Summary statistics of the labor wedge γ_{it}, the marginal revenue product of labor $MRPL_{it}$, the wage W_{it}, and the difference between the marginal revenue product of labor and the wage. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the distribution, respectively. The labor wedge is rounded to two decimal points. Monetary values are in 2015 euros, rounded to whole numbers. Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

The distribution of the firm-level labor wedge is widely dispersed. The spread of wage markups and wage markdowns is comparable. That is, in terms of implications, the firm-level labor wedge is distributed quite symmetrically. For instance, the 5th and 95th percentile of the labor wedge distribution are 0.49 and 2.02 respectively. This implies that wage is at least twice as high as the marginal revenue product of labor in roughly 5 percent of all cases. Similarly, the marginal revenue product of labor is at least twice as high as the wage in roughly 5 percent of all cases. Likewise, the labor wedge is close to $\frac{4}{5}$ at the 25th percentile, and close to $\frac{5}{4}$ at the 75th percentile of the distribution. Again, note that these findings are not consistent with a model of oligopsonistic wage formation, as that would imply the existence of wage markdowns, but not wage markups.

Both elements of the labor wedge – the marginal revenue product of labor and the wage – are themselves widely dispersed. Table 2.2 shows summary statistics for the marginal revenue product of labor, the wage, and the difference between the former and the latter, all at the firm-year level. The median $MRPL_{it}$ is 52,672 euro, while the median wage is 54,577. The distributions of $MRPL_{it}$ and W_{it} are similar, especially within the inter-quartile range. However, the distribution of $MRPL_{it}$ has longer tails than the distribution of W_{it}. While the distributions of $MRPL_{it}$ and W_{it} are similar, the distribution of the labor wedge implies that a firm typically does not occupy the same spot in the distributions of $MRPL_{it}$ and W_{it}. This is confirmed by looking at the distribution of $MRPL_{it} - W_{it}$. In 50 percent of all firm-year instances, the wage is at least 2,445

wedge distribution, such as country-wide institutions, are likely key to explaining differences between the U.S. and the Netherlands.

euro above the marginal revenue product of labor. In the tails of the distributions, the differences are stark. In 5 percent of all instances, the wage is at least 40,289 euro higher than the marginal revenue product of labor. In another 5 percent, the wage is at least 52,574 euro below the marginal revenue product.

Table 2.3: Summary statistics of the labor wedge, by NACE section

NACE section	p(5)	p(25)	p(50)	p(75)	p(95)	observations
A: Agriculture, forestry and fishing	0.42	0.58	0.73	0.96	1.51	28,005
C: Manufacturing	0.49	0.72	0.87	1.04	1.42	120,335
E: Water supply and waste management	0.40	0.64	0.85	1.25	2.18	2,326
F: Construction	0.52	0.75	0.88	1.03	1.51	127,565
G: Wholesale and retail trade	0.54	0.78	0.99	1.27	1.83	323,449
H: Transportation and storage	0.59	0.73	0.84	1.04	1.63	45,868
I: Accomodation and food service activities	0.31	0.42	0.50	0.58	0.80	48,874
J: Information and communication	0.59	0.84	1.02	1.25	1.88	81,501
M: Professional scientific and technical activities	0.71	1.00	1.26	1.67	2.65	231,322
N: Administrative and support service activities	0.38	0.64	0.79	0.93	1.33	40,649
P: Education	0.53	0.79	1.03	1.40	2.30	14,984
Q: Human health and social work activities	0.60	0.89	1.13	1.47	2.19	66,527
R: Arts, entertainment and recreation	0.52	0.71	0.91	1.23	2.12	21,523
S: Other services	0.44	0.63	0.73	0.84	1.11	9,578

Notes: Summary statistics of the labor wedge, γ_{it}, across all NACE sections in the sample. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the labor wedge distribution, respectively. The labor wedge is rounded to two decimal points. Full name of section E is "Water supply, sewerage, waste management and remediation". Full name of section G is "Wholesale and retail trade, repair of motor vehicles and motorcycles". Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

The dispersion of the labor wedge is due to dispersion *within* industries, not variation *between* different industries. Table 2.3 shows selected percentiles of the labor wedge distribution for all 14 NACE sections included in the sample – broad industry classifications including several 2-digit NACE industries. The distribution of the labor wedge in most sections closely resembles the distribution in the full sample. The median labor wedge is on average 0.9 across all sections (standard deviation is 0.19), compared to a median labor wedge of 0.96 in the full sample. Both wage markups and wage markdowns are present in each NACE section. In all but one NACE section, $W_{it} > MRPL_{it}$ at the 25th percentile of the labor wedge distribution, and in all but four NACE sections, $W_{it} < MRPL_{it}$ at the 75th percentile. Table 2.9 and Table 2.10 in Appendix 2.G report selected percentiles of the distributions of $MRPL_{it}$ and W_{it}, respectively, by NACE section. Table 2.11 in Appendix 2.G report selected percentiles of the distributions of the monetary wedge $MRPL_{it} - W_{it}$, by NACE section. In all NACE sections, as in the full sample, there is substantial dispersion in the wage, the marginal revenue product of labor, and their difference, confirming that between NACE section variation can not explain the presence of both wage markups and wage markdowns in the full sample.[22]

Table 2.4: Labor wedge statistics at different levels of industry aggregation

Level	average p(50)	average p(75) - p(25)	average p(95) - p(5)	observations
Total sample	0.96 (-)	0.50 (-)	1.53 (-)	1
Section	0.90 (0.19)	0.42 (0.16)	1.24 (0.44)	14
Division (2-digit)	0.88 (0.17)	0.38 (0.14)	1.11 (0.38)	53
Group (3-digit)	0.88 (0.17)	0.38 (0.15)	1.09 (0.41)	192
Code (4-digit)	0.90 (0.18)	0.38 (0.17)	1.05 (0.41)	458

Notes: Labor wedges statistics at different levels of NACE industry classifications, more digits is a more narrowly defined industry. Averages are taken over all industries at the level, standard deviation in brackets. Number of units on which the average is based listed under "observations". p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the labor wedge distribution, respectively. The labor wedge is rounded to two decimal points.

Table 2.4 reports statistics on the labor wedge distribution at the 2-digit, 3-digit, and 4-digit industry level. Dispersion of the labor wedge exists even in narrowly defined 4-digit industries. The presence of both wage markups and wage markdowns within NACE sections is therefore not explained by differences between industries at more dis-aggregated industry levels. The average over industries of the median labor wedge is nearly identical at the 2-digit (0.88), 3-digit (0.88), and 4-digit (0.9) level. Moreover, the standard deviation of this average is also nearly identical at the 2-digit (0.17), 3-digit (0.17), and 4-digit (0.18) level, implying that between-industry differences in the median labor wedge are not increasing as industry definitions become increasingly narrow. Significant dispersion of the labor wedge also remains at lower levels of industry aggregation. The industry average of the inter-quartile range of the labor wedge is 0.38 at the 2-digit, 3-digit, and 4-digit level – again with similar standard deviations. Given that equal-sized positive and negative deviations from a labor wedge of unity are not equivalent in terms of implications, one should in general be careful to draw strong conclusions about the labor wedge based on such a dispersion comparison. However, given that the labor wedge at the 75th percentile is comparable at all levels of aggregation, the statistics in Table 2.4 are strong evidence that dispersion of the labor wedge is prevalent even in narrowly defined industries.

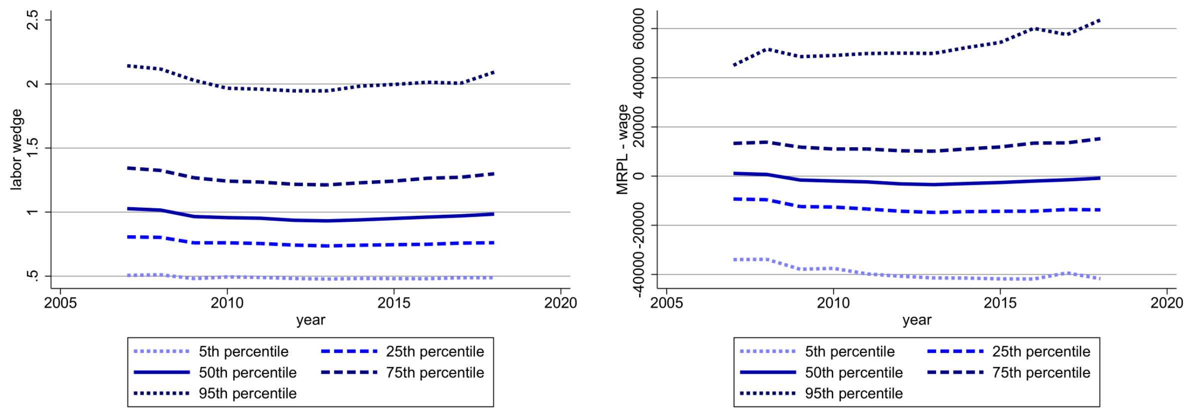
The results presented in this subsection are mostly in line with recent studies using

[22]NACE section I, characterized by wage markups, and NACE section M, characterized by wage markdowns, are outliers. These two sections are discussed in Appendix 2.E.

the cost minimization approach to identify labor wedges in Europe. Mertens (2020b) finds that the median labor wedge in his sample of German manufacturing industries is 0.93, with both wage markups and wage markdowns present in different 2-digit industries. Caselli et al. (2021) report that observed wages exceed marginal revenue contributions by 56.4 percent on average in French manufacturing, with wage markups characterizing all included 2-digit manufacturing industries. In contrast, using a representative sample of about 9000 plants in Germany over the years 1996 to 2016, Dobbelaere et al. (2020) find that wage markdowns are more prevalent than wage markups, and in addition document that the presence of labor unions is negatively correlated with the labor wedge. Taken together, these findings suggest that institutional differences between the U.S. and Europe can explain differences in the median labor wedge.

Figure 2.2: Selected percentiles of the distribution of the labor wedge distribution (panel a), and $MRPL_{it} - W_{it}$ (panel b), over time

(a) Labor wedge (b) $MRPL_{it} - W_{it}$

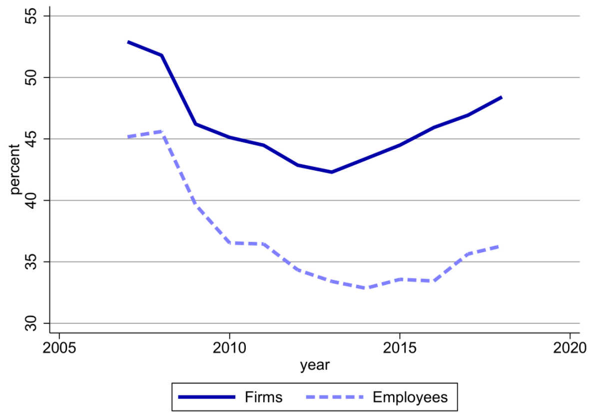


Notes: Panel a (Panel b) displays the 5th, 25th, 50th, 75th, and 95th percentile of the distribution of the labor wedge (the marginal revenue product of labor minus the wage) over the years 2007 to 2018, based on the full sample of 1,162,506 firm-year observations.

2.4.2 The labor wedge distribution over time

Figure 2.2 shows that the labor wedge distribution is stable over time. Panel a shows that the median, the 75th, and the 95th percentile of this distribution all slightly decrease after 2007, and start increasing back to initial levels around 2013. The 5th and 25th percentile barely change over time. Panel b plots selected percentiles of the $MRPL_{it} - W_{it}$ distribution over time. Within the inter-quartile range, not much has changed between

Figure 2.3: Percentage of all firms with wage markdowns (solid line), and all employees that work for firms with wage markdowns (dashed line), over time



Notes: Yearly percentage of all firms (solid line) that have wage markdowns (labor wedges exceeding 1) and the percentage of all employees working for firms with wage markdowns (dashed line), over time, based on the full sample of 1,162,506 firm-year observations.

2007 and 2018. However, at the extremes the monetary gaps between marginal revenue products and wages have increased. The 5th percentile has dropped from wage a 33,966 euro below the marginal revenue product in 2007, to wage 41,729 euro below the marginal revenue product in 2018. The 95th percentile has increased from the marginal revenue product 45,033 euro above the wage in 2007, to the marginal revenue product 63,518 above the wage in 2018. While the *ratio* of the marginal revenue product of labor to the wage has barely changed over time, the *difference* between the two has increased in the tails of the distribution. This is because the spread of the marginal revenue product of labor has increased over time compared to the spread of the wage (see Figure 2.10 in Appendix 2.F).

While Figure 2.2 shows that the cross-sectional variation of the labor wedge is much larger than the time-series variation, but this does not imply that there is no clear pattern in the time-series. Figure 2.3 displays the percentage of all firms with wage markdowns over time. This percentage drop from 52.9 in 2007 to 42.3 in 2013, only to increase again to 48.41 in 2018. A likely explanation is the aftermath of the financial crisis of 2007 and 2008 affecting revenues more severely than total labor expenditure due to market imperfections such as firing costs. Indeed, between 2007 and 2013 the median labor share increased from 0.32 to 0.35, while the median revenue elasticity of labor remained at 0.31. It is noteworthy that the time-series variation of the labor wedge over such turbulent years is very moderate compared to the cross-sectional variation in a given year. These findings suggest that adjustment frictions alone are insufficient to explain the observed dispersion of the labor wedge. To explain the cross-sectional dispersion of the labor wedge, we therefore next turn to the relation between the labor wedge and firm-level observables such as input use and profitability.

2.4.3 Non-parametric regression analysis

The results on dispersion of the labor wedge presented in Section 2.4.1 suggest that firm-level labor market imperfections are crucial to explaining our results. In this section, we therefore relate labor wedges to firms level observables. To correlate the labor wedge to a variable of interest, x, the following non-parametric regression is used

$$ln(\gamma_{it}) = \beta_0 + \sum_{d=2}^{10} \beta_d^x \mathbb{I}_{x_{it} \in X_d} + NACE_i + Year_t + \varepsilon_{it}, \quad (2.9)$$

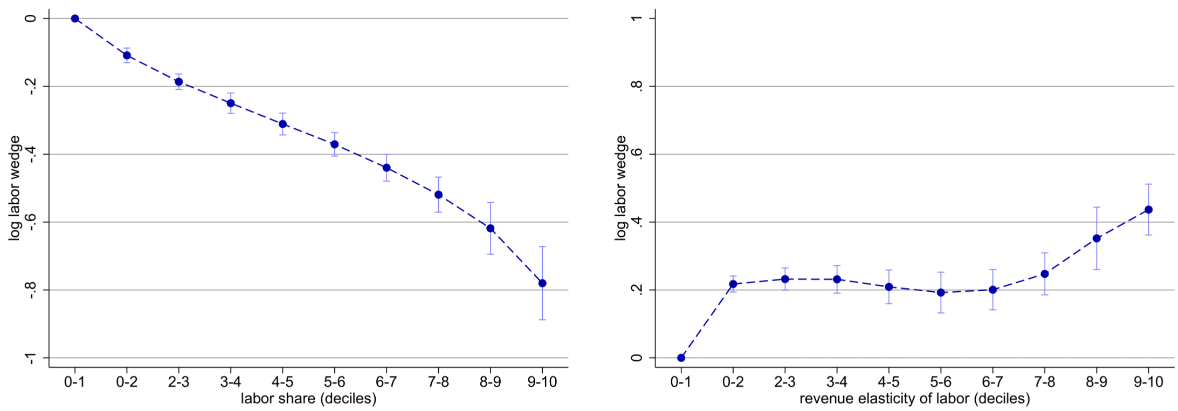
where $\mathbb{I}_{x_{it} \in X_d}$ is an indicator that equals 1 if x_{it} lies between the the d^{th} and $d-1^{th}$ decile of the distribution of x in the full sample, $NACE_i$ is a set of 4-digit industry fixed effects, and $Year_{it}$ is a set of year fixed effects. This non-parametric regression, inspired by Haltiwanger et al. (2013), is used because key variables in our sample are widely spread, which might lead to non-monotone relations between variables of interest. We begin by relating the labor wedge to it's separate components, the revenue elasticity of labor and the labor share. All regressions are run on the full sample, and standard errors are clustered at the 4-digit industry level.

Figure 2.4 plots coefficients from regressions relating the labor wedge to the labor share (panel a), and the revenue elasticity of labor (panel b). Variation in the firm-level labor wedge can be explained mostly by variation in labor shares, and only somewhat by variation in revenue elasticities of labor. There is a very strong negative relation between the labor wedge and the labor share. Nearly all of the variation in the labor wedge can be induced by moving from the bottom decile of the labor share distribution to the top decile. The revenue elasticity of labor is only weakly positively related to the labor wedge. In fact, outside of the top and bottom deciles of the revenue elasticity distribution, there seems to be no relation to the labor wedge at all. Figure 2.4 suggests that the compensation of employees is central to the labor wedge, more so than the ability of a firm to generate revenue with an additional worker. One factor that might determine both the labor share and the labor wedge is a firm's input mix, a question to which we turn next.

Figure 2.5 displays coefficients from regressions associating the labor wedge to the the book value of capital (panel a), and the capital-labor ratio (panel b). Both the

Figure 2.4: The labor wedge regressed on the labor share (panel a), and the revenue elasticity of labor (panel b)

(a) Labor share (b) Revenue elasticity of labor



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on the labor share (panel a), and the revenue elasticity of labor (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

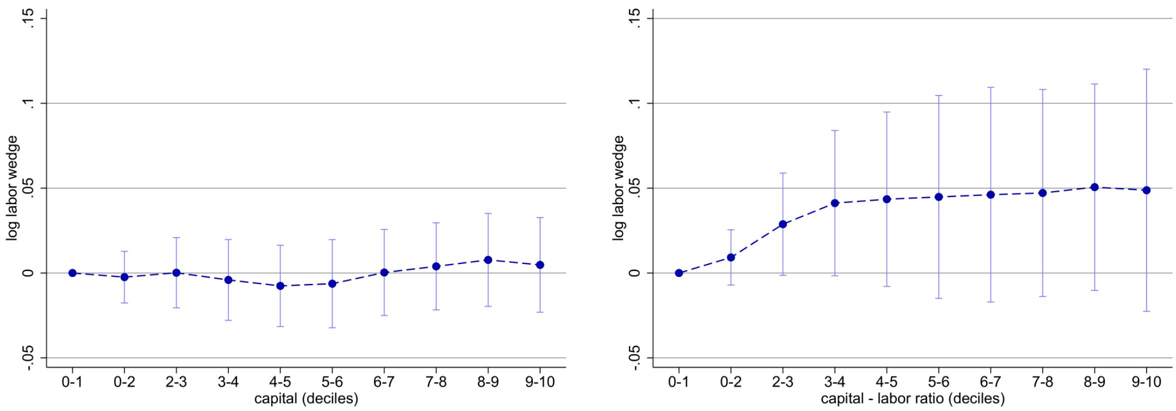
capital-labor ratio and the amount of capital that a firm possesses are unrelated to the labor wedge. The capital-labor ratio shows a very slight, but statistically insignificant, positive relationship with the labor wedge. Point estimates of the coefficients on the decile-indicators of the capital distribution are all very close to 0. The widespread phenomenon of declining labor shares has been linked to firms substituting labor for capital (Karabarbounis and Neiman, 2014).[23] Although the labor share is fundamental in explaining variation in the labor wedge in our sample, Figure 2.5 shows that input substitution is an unlikely mechanism. An alternative explanation, to which we turn next, is that differences in the compensation of labor are behind the link between the labor share and the labor wedge.

Figure 2.6 plots coefficients from regressions relating the labor wedge to firm-level employment (panel a), and the wage (panel b). Firms with high labor wedges pay significantly lower wages than firms with low labor wedges, although the labor wedge and firm-level employment are unrelated. Point estimates of the coefficients on the decile-

[23] Elsby et al. (2013) report that other forces than input substitution are likely more important to explain the fall of the labor share, as confirmed by much of the later literature (e.g. Autor et al. (2020); Kehrig and Vincent (2021)).

Figure 2.5: The labor wedge regressed on capital (panel a), and the capital-labor ratio (panel b)

(a) Capital (b) Capital-labor ratio



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on capital (panel a), and the capital-labor ratio (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

indicators of the employment distribution are all close to 0, as was the case with capital. The wage is very strongly negatively associated with the labor wedge, and can induce the vast majority of its variation. In fact, the relationship between the labor wedge and wage (Figure 2.6, panel b) is virtually identical to the relationship between the labor wedge and the labor share (Figure 2.4, panel a). This suggests that the main driver behind variation in the labor wedge is the average wage firms pay their employees.

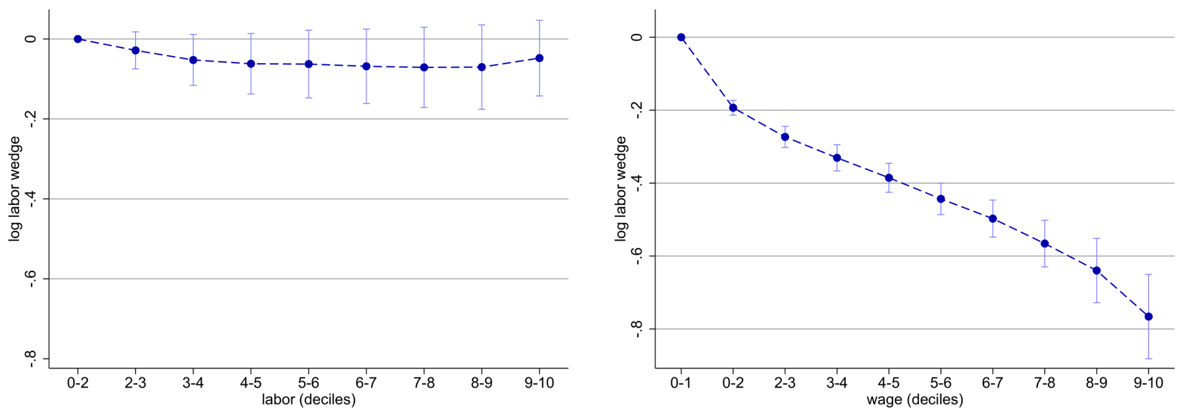
The results on input use displayed in Figure 2.5 and Figure 2.6 suggest that firm size is not an important determinant of the labor wedge. Alternative measures of (relative) firm size, such as a firm's employment share in its 4-digit industry, are also unrelated to the labor wedge (see Figure 2.11 of Appendix 2.F). In contrast, Hershbein et al. (2020) report a positive relation between firm size and the labor wedge in the U.S..[24] Our results so far suggest that firms with wage markdowns are not necessarily good at generating revenue from additional employment compared to firms with wage markups, but they do

[24]As firm size and firm age are correlated, one would typically want to control for firm age Haltiwanger et al. (2013). Unfortunately, firm age is not available in our data. Note however that the relation between size and the labor wedge is unaffected by age controls in Hershbein et al. (2020).

pay lower wages, which hints at firms with wage markdown being more profitable.

Figure 2.6: The labor wedge regressed on labor (panel a), and the wage (panel b)

(a) Labor (b) Wage



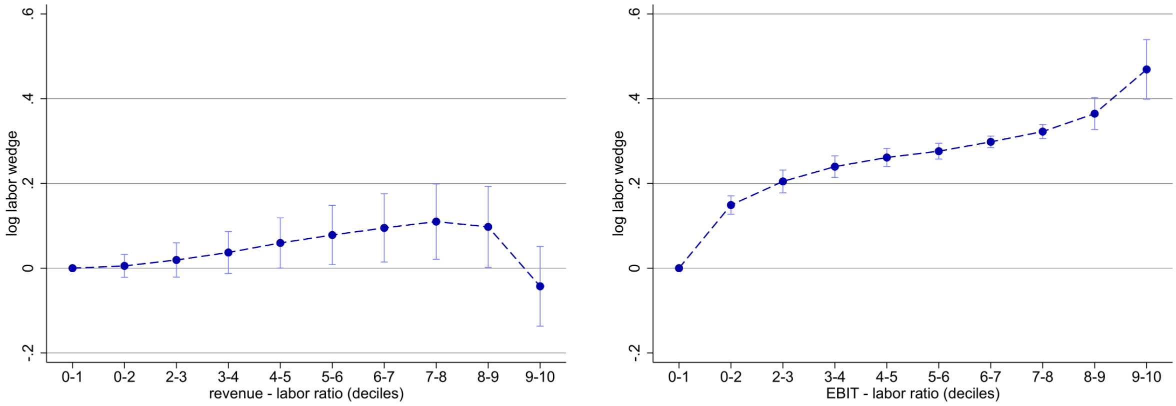
Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on labor (panel a), and the wage (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. For labor, the first two deciles are merged as variation in labor only starts occurring in the second decile. The coefficient on the indicator of the first decile(s) is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

Figure 2.7 displays coefficients from regressions relating the labor wedge to revenue per worker (panel a), and EBIT per worker (panel b). Per-employee pre-tax accounting profit is substantially higher for firms with higher labor wedges, while the labor wedge and revenue per employee are barely related. Although a weak positive relation between revenue per worker and the labor wedge appears to exist, with exception of the top deciles of the revenue per worker distribution, the majority of the estimated coefficients are statistically indistinguishable from zero. EBIT per worker, on the other hand, is strongly positively correlated with the labor wedge. Going from the bottom decile to the top decile of the distribution of EBIT per worker induces about half the variation in the labor wedge. When considering total measures, instead of per worker measures, it remains true that revenue is unrelated to the labor wedge, while EBIT is positively related to the labor wedge (see Figure 2.12 in Appendix 2.F).

Summing up, the main difference between firms with markdowns and markups in the Netherlands is the average wage those firms pay their employees. While variation in the labor wedge is strongly related to the labor share, this link does not appear to be due to differences in revenue productivity across firms. In contrast, Kehrig and Vincent

Figure 2.7: The labor wedge regressed on the revenue-labor ratio (panel a), and EBIT-labor ratio (panel b)

(a) Revenue-labor ratio (b) EBIT-labor ratio



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on the revenue-labor ratio (panel a), and the ratio of earnings before interest and taxes to labor (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

(2021) point to revenue labor productivity as an important determinant of the labor share decline in the U.S.. Our results on revenue and revenue productivity of labor also imply that “superstar firms” are not behind the variation of the labor wedge in the Netherlands (see Autor et al. (2020)). In line with this, Figure 2.11 in Appendix 2.F shows that the labor wedge is unrelated to the revenue share of firms in their 4-digit industry.

Given that the majority of all firm-year cases in the Netherlands consists of wage markups, our results point to employees having significant bargaining power resulting in high wages relative to their marginal revenue contribution. This begs the questions: where is the money coming from to subsidize the wages? One answer suggested by Figure 2.7, is that profits are lower for firms with lower labor wedges, but variation in accounting profitability can only induce part of the variation in the labor wedge. In the next section we point to one additional possible explanation: firms subsidize wages using rents earned in the market for materials.

2.4.4 The materials wedge and its relation to the labor wedge

In order to relate the labor wedge to market imperfections in the market for materials, we estimate the materials wedge. The materials wedge is given by

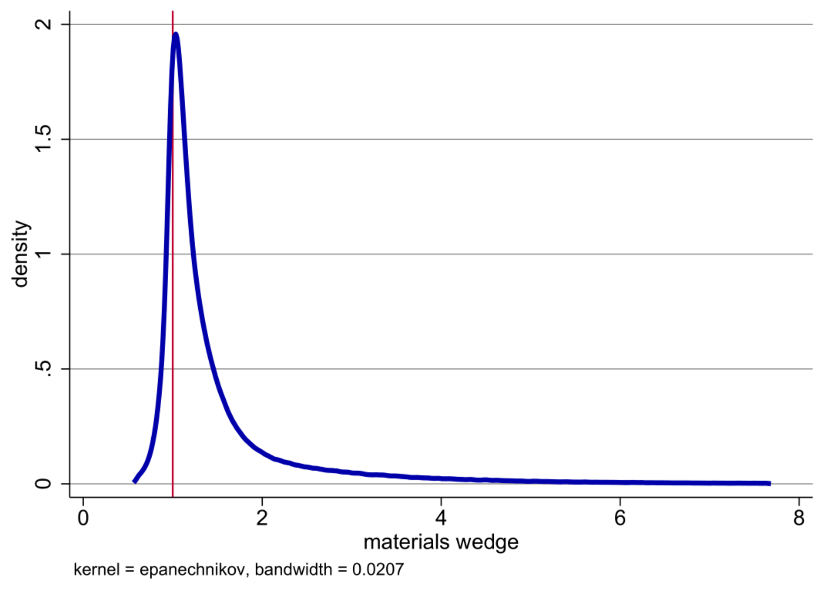
$$\iota_{it} = \frac{MRPM_{it}}{P^M_{it}}, \tag{2.10}$$

where $MRPM_{it} = \frac{\partial R_{it}}{\partial M_{it}}$ and P^M_{it} is the price of materials that firm i pays at time t. In a perfectly competitive materials market the materials wedge is equal to one, as is the case with the labor wedge, and market imperfections in the materials market can cause the materials wedge to differ from unity. Identification of the materials wedge proceeds along the same lines as identification of the labor wedge. Multiplying equation (2.10) by $\frac{M_{it}R_{it}}{M_{it}R_{it}}$ gives

$$\iota_{it} = \frac{\theta^M_{it}}{MS_{it}}, \tag{2.11}$$

where θ^M_{it} is the revenue elasticity of materials, $\frac{\partial R_{it}}{\partial M_{it}}\frac{M_{it}}{R_{it}}$, and MS_{it} is materials expenditure as a fraction of revenue – the materials share. The materials share is observed in the data, and to obtain the revenue elasticity of materials a revenue function is estimated – as discussed in Section 2.2.2.

Figure 2.8: Density function of firm-level materials wedges in the Netherlands



Notes: Kernel density function of firm-level materials wedges based on the full samples of 1,162,506 firm-year observations over the years 2007 to 2018.

Table 2.5: Percentiles of the materials wedge distribution

variable	p(5)	p(25)	p(50)	p(75)	p(95)
Materials wedge	0.88	1.03	1.18	1.54	3.35

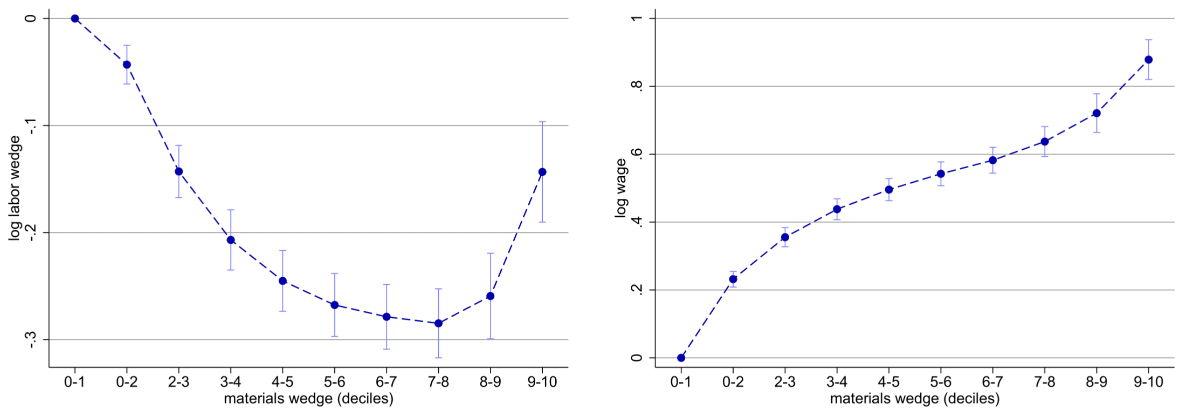
Notes: Selected percentiles of the distribution of the materials wedge – the ratio of the marginal revenue product of materials and the price of materials. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the materials wedge distribution, respectively. The materials wedge is rounded to two decimal points. Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

Figure 2.8 plots the distribution of the firm-level materials wedge in the full sample, and Table 2.5 gives several percentiles of this distribution. Materials wedges are typically larger than unity in the Netherlands, implying that most firms pay a price for their material inputs that is *lower* than the marginal revenue generated by materials. The median materials wedge is 1.18, and in 80.92 percent of all cases the materials wedge exceeds one. The right tail of the distribution of the materials wedge is long: at the 95th percentile, materials yield a marginal revenue that is 3.35 times as high as the price of materials. As our results point to substantial imperfections in the materials market, it is questionable whether the prevalent cost minimization approach to estimating the labor wedge can be applied to the Netherlands, as this approach tends to assume that firms are price-takers in the materials market and that materials can be frictionlessly adjusted. Figure 2.1 and Figure 2.8 show that most firms in the Netherlands pay *more* for their labor than it generates in marginal revenue, while most firms pay *less* for their materials than they generate in marginal revenue. These aggregate statistics suggest a firm-level relationship between the labor wedge and the materials wedge, to which we turn next.

Panel a of Figure 2.9 plots coefficients from a regression of the labor wedge on deciles of the materials wedge, as specified in equation (2.9). Firms with high labor wedges have low materials wedges. With exception of the highest decile(s) of the materials wedge, there is a clear negative relation between the labor wedge and the materials wedge. The relationship between the labor wedge and the separate elements of the materials wedge, the revenue elasticity of materials and the materials share, is non-monotone and difficult to distinguish from zero, as shown by Figure 2.13 in Appendix 2.F. This shows that the relationship between the materials market and the labor wedge is driven by how much a firm pays for its materials *relative* to how much they add in terms of revenue.

Figure 2.9: The labor wedge (panel a), and the wage (panel b), regressed on the materials wedge

(a) Labor wedge regressed on materials wedge (b) Wage regressed on materials wedge



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on the materials wedge (panel a), and from a non-parametric regression of log wage on the materials wedge (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

Panel b of Figure 2.9 displays coefficients from a regression of wage on the materials wedge. Firms that pay higher wages, pay little for their materials compared to the marginal revenue that materials generate. This positive relation between the wage and the materials wedge is precisely estimated, and very strong. Going from the bottom decile to the top decile of the distribution of the materials wedge can induce all variation in the wage. This indicates a channel through which the labor wedge and the materials wedge are related: firms that obtain a good deal in the materials market pay their employees a higher wage. Wage differences in turn are the main channel that can explain within-industry dispersion of the labor wedge.

One potential explanation of dispersion in the materials wedge is dispersion of the price of materials. This hypothesis can not be investigated for the Netherlands as data on quantity or price of materials is unavailable. In the U.S., Atalay (2014) documents substantial dispersion of materials prices in narrowly defined manufacturing industries with relatively homogeneous product, and attributes part of this dispersion to within-supplier markup differences. Dobbelaere and Wiersma (2020) provide evidence that trade liberalization, by decreasing the price of intermediate inputs, increased price-cost margins in product markets and decreased labor wedges in China. While Dobbelaere and Wiersma

(2020) assume that firms can frictionlessly adjust intermediate inputs, an input for which they are price takers, their results provide insight in a potential mechanism that could explain high materials wedges and low labor wedges in the Netherlands. The fact that materials wedges typically exceed unity in our sample might therefore also be explained by materials prices. This is consistent with findings of buyer power in the market for imported intermediate inputs in France (Morlacco, 2020).[25]

2.5 Concluding remarks

A large and expanding literature finds that oligopsony power is prevalent in the U.S., suggesting that wage markdowns are common (e.g. Ashenfelter et al. (2010); Azar et al. (2020); Hershbein et al. (2020)). However, several literatures, including work on rent-sharing (e.g. Kline et al. (2019)) and labor unions (e.g. Breda (2015)), point to mechanisms that could lead to wage markups instead. To assess the net effect of all underlying market imperfections on wage markups and wage markdowns, this chapter introduces a method to directly estimate the labor wedge, and documents the labor wedge in the Netherlands over the years 2007 to 2018. The main advantage of this method, compared to the prevalent cost minimization approach to identifying the labor wedge, is that no assumptions are needed on any input market imperfections, or on firm conduct.

We show that most firms pay a wage that *exceeds* their marginal revenue product of labor, and that both wage markups and wage markdowns are commonly observed even in narrowly defined industries. These results suggest that U.S.-based oligoposony results do not transfer to the European context. A potential explanation is the institutional setting in the Netherlands, where – in line with much of Europe – measures such as collective bargaining agreements are prevalent compared to the U.S. (OECD, 2020).

The labor wedge is strongly negatively related to the labor share, while a clear correlation with the revenue elasticity of labor is not observed. Variation in the labor share, and the labor wedge, is in turn primarily due to variation in the wage. Wages, and the labor wedge, are related to imperfections in the materials market. Firms that have a high marginal revenue product of materials relative to the price of materials they pay, pay higher wages. In general, firms in the Netherlands tend to pay less for their materials than the marginal revenue generated by those materials.

The results presented in this chapter suggest that on the margin employees benefit at

[25] Elsby et al. (2013) identify offshoring as a leading explanation for declining labor shares in the U.S., suggesting that the ability of firms to switch to cheap imported inputs might be behind the labor share dispersion, and hence the labor wedge dispersion, in the Netherlands.

the expense of employers in the Netherlands, while employers benefit on the margin at the expense of suppliers of materials. Possible mechanisms underlying these findings should be studied in further work. One potential explanation in line with the literature, and discussed in more detail in Section 2.4.4, is that firms generate rents from cheap imported inputs, and share those rents with their employees. Another possible explanation, so far not discussed, is that wage dispersion can be explained by high skilled labor and changing modes of production. For instance, skilled employees in innovative industries, characterized by investments in information technology (IT), are known to command high wages and contribute to wage dispersion (e.g. Dunne et al. (2004); Andersson et al. (2009)). As IT intensive firms experience decreases in marginal costs, this might also explain the high materials wedges by increasing the marginal revenue productivity of materials (Bartel et al., 2007). Such mechanisms are beyond the scope of this chapter and left for future work.

2.A Data

2.A.1 Data sources

We construct a yearly firm-level dataset covering the majority of all non-financial Dutch firms over the period 2007-2018, using non-public data obtained from Statistics Netherlands (CBS).

The "General Firm Registry" (ABR) is a yearly firm-level dataset that aims to document all firms located in the Netherlands. The ABR uses registry data of the Dutch Chamber of Commerce and the Dutch tax authority as primary sources.[26] Organizations that are not required to register at the Chamber of Commerce are omitted from the ABR, primarily ecclesiastical organizations, embassies, and consulates. The CBS uses daily updates from the Chamber of Commerce, and monthly updates from the tax authority, to construct anonymized firm identifiers. From the ABR, we take data on the total employment in full-time equivalent units (FTE) rounded to whole numbers, and each firm's 4-digit NACE Rev. 2 industry.

The "Financial Statistics of Non-financial Firms" (NFO) is a yearly firm-level dataset containing anonymized balance sheets and income statements of all identifiable firms active outside the financial sector. The NFO uses two primary data sources, depending on whether the firm in question is classified as "small" or "large".[27] For small firms, data is obtained on a yearly basis from the Dutch Ministry of Finance which documents balance sheet and income statement data observed primarily on tax returns. For large firms, data is obtained on a yearly basis using surveys. Each firm receives a survey that is extensively checked for consistency with the data previously obtained by CBS. In case a reporting error is suspected, the firm is contacted again to verify the information. The cleaning procedure documented further in this appendix is intended to eliminate any reporting errors that might have survived this process, in particular for the small firms. From the NFO, we take data on revenue, expenditure on labor and materials, the book value of capital, and various measures of accounting profit.

In the process of anonymization, the CBS creates new firm identifiers at different

[26] In particular, the "Nieuwe Handelsregister" (NHR) from the Chamber of Commerce, and the "Beheer van Relaties" (BvR) from the Dutch tax authority are used. In addition, prior to April 1st, 2014, the "Basis Bedrijvenregister" (BBR) was employed, a partnership between the Chamber of Commerce, the tax authority, and the CBS.

[27] Prior to 2011, all firms with a balance sheet total of less than 23 million euros were classified as small. As of 2011, all firms with a balance sheet total of less than 40 million euros are classified as small.

levels of aggregation. The balance sheet and income statement data in the NFO comes at the "organization group" (OG) level, which is considered to be the "actual agent in financial processes" (CBS, 2020b). The ABR is at the "firm-unit" (BE) level, which is characterized by an "autonomous actor in the production process" (CBS, 2020c). For the vast majority of firms, there is a one-to-one mapping from BEs to OGs, but for the largest firms (the so-called TOPX, containing roughly 2000 firms each year) one OG can hold more than one BE. For these OGs, we aggregate employment and 4-digit NACE Rev.2 codes to the OG level of the balance sheets and income statements.[28] Firm identifiers at the OG level allow us to merge the NFO and the ABR.

Eurostat's NACE Rev. 2 industry classification is used throughout this chapter. The most aggregated industry classification is the NACE section (one or more 2-digit NACE codes), while NACE divisions (2-digit), groups (3-digit) and codes (4-digit) are increasingly dis-aggregated industry classifications. Eurostat (2008) provides a complete description of all NACE classifications and the conversion to other international industry classification codes. The ABR provides data on a firm's SBI08 code, the first four digits of which correspond to the firm's NACE Rev. 2 code. The NFO contains data on the first two digits of a firm's SBI08 code, and is used as a consistency check for industry classification. Prior to 2008, the CBS only provided the SBI93 industry classification, which are therefore first converted to SBI08 codes. All NACE divisions (2-digit NACE industries) with sufficient observations such that the revenue function can be estimated are included in the final sample. Table 2.6 in Appendix 2.A list the 53 NACE division that are included.

When estimating the revenue function, all monetary variables are deflated to make them comparable across time using the appropriate deflators at the 2-digit NACE Rev. 2 industry level obtained from the OECD STAN database (Horvát and Webb, 2020).

2.A.2 Variable Definitions

The following list explains how all variables used in this article are constructed.

- Revenue (R_{it}): Total revenue net of value added taxes (VAT), in euros.
- Capital (K_{it}): Total book value of fixed assets, in euros.
- Labor (L_{it}): Full-time equivalent employment rounded to the nearest integer.

[28] We aggregate categorical variables by selecting the mode of the separate BE-level observations as the value for the OG. Our results are not sensitive to how the NACE industries are aggregated.

- Total labor expenditure ($W_{it}L_{it}$): Total labor expenditure consisting of gross wages and all other labor expenses such as employers' mandatory social contributions, in euros.
- Materials (M_{it}): Deflated total expenditure on intermediate goods, energy, and other intermediate expenses, in euros.
- Total materials expenditure ($P_{it}^{M}M_{it}$): Total expenditure on intermediate goods, energy, and other intermediate expenses, in euros.
- Earnings before interest and taxes ($EBIT_{it}$): Revenue minus cost of goods sold and all operating expenses, plus non-operating income.
- Net income (NI_{it}): $EBIT_{it}$ minus taxes and plus net financial income.
- Wage (W_{it}): Average labor expenditure per worker $\frac{W_{it}L_{it}}{L_{it}}$, in euros.
- Marginal revenue product of labor ($MRPL_{it}$): Labor wedge times wage $\gamma_{it}W_{it}$, in euros.
- Labor share (LS_{it}): Total labor expenditure $W_{it}L_{it}$ divided by total revenue R_{it}.
- Materials share (MS_{it}): Total materials expenditure $P_{it}^{M}M_{it}$ divided by total revenue R_{it}.

2.A.3 Data cleaning

We clean the data in four steps, closely following the cleaning procedure that Gopinath et al. (2017) use on Bureau van Dijk's AMADEUS balance sheet and income statement data. The raw data for non-financial, non-government, for-profit firms contains 2,707,659 firm-year observations.

2.A.3.1 Necessary variables

We implement the following steps

1. We drop observations for which revenue, total assets, (in)tangible assets, employment, wages, materials, or depreciation are missing.
2. We drop observations for which revenue, capital, employment, wages, or materials are incorrectly signed or zero.

3. We drop observations with missing NACE Rev.2 codes, and for which the NACE Rev.2 division from the ABR is not consistent with the first two digits of the NACE Rev.2 code from the NFO.

In total 1,826,781 firm-year observations are left after these steps. This is primarily due to step 2, where 763,443 observations are dropped. The majority of these observations are small firms that report both zero capital and zero employment.

2.A.3.2 Internal consistency of balance sheets and income statements

We check the internal consistency of balance sheets and income statements by comparing the sum of variables in some aggregate to the variable holding the aggregate. We construct the following ratios

1. The sum of tangible and intangible assets, total shareholdings, long and short receivables, inventories, debtors, and liquid assets, as a ratio of total assets.
2. The sum of domestic and foreign shareholdings, as a ratio of total shareholdings.
3. Revenue minus the sum of wages, materials, and depreciation, as a ratio of earnings before interest and taxes (EBIT).
4. EBIT net of total shareholdings, interest income and charges, extraordinary income and charges, and other financial results, as a ratio of pre-tax income.
5. Pre-tax income net of corporate taxes and third party equity as a ratio of after tax income.

Due to small rounding errors these ratios are not always equal to one even if the individual components are otherwise correct. Therefore, we drop all observations for which the above ratios are smaller than 0.95 or larger than 1.05. This reduces our sample to 1,826,754 firm-year observations, confirming that the CBS internal consistency checks do a very good job of eliminating inconsistent reports.

2.A.3.3 Further quality checks

As final quality checks we implement the following steps

1. We drop firms for that at some point report negative capital, employment or tangible assets.
2. We drop observations with incorrectly signed or zero total liabilities.

3. We drop observations with incorrectly signed total shareholdings, long and short receivables, debtors, liquid assets, third party equity, equilization reserves, provisions, long and short debt, or depreciation.

4. We drop observations with negative value added, where value added is constructed as revenue net of materials.

5. We drop the top and bottom percent of the capital to wage ratio, the total assets to total funds ratio, and the wages to value added ratio.

These steps reduce our sample to 1,659,537 firm-year observations.

2.A.3.4 Winsorization

Within each NACE Rev.2 code-year cell, we winsorize the top and bottom percent of the distributions of revenue, capital, total labor expenditure, and total materials expenditure. After these steps the sample consists of 1,566,102 firm-year observations. For several 2-digit NACE Rev. 2 codes, insufficient firms exist to estimate a revenue function. These NACE divisions are omitted from the final sample. Finally, upon estimating the revenue function, observations with a negative labor wedge or materials wedge are dropped. In addition, the top and bottom percent of the distributions of all variables based on estimates are winsorized. That is, the labor wedge, the revenue elasticity of labor, the labor share, the marginal revenue product of labor, the wage, the difference between the marginal revenue product of labor and the wage, and the materials wedge are winsorized. These steps are taken to remove outliers that are very likely to be the result of underlying data-imperfections. In all our non-parametric regressions, the winsorization only (marginally) affects coefficients on the first and last decile indicators, leaving coefficients on all other deciles virtually unchanged. The final sample consists of 1,162,506 firm-year observations. Table 2.7 reports the distribution of all observations in the final sample over years and NACE sections.

Table 2.6: NACE Rev. 2 sections and divisions covered in the final sample

Section	Description	Divisions
A	Agriculture, forestry, and fishing	01
C	Manufacturing	10,13-18,20,22-33
E	Water supply, sewerage, waste management and remediation	38
F	Construction	41-43
G	Wholesale and retail trade, repair of motor vehicles and motorcycles	45-47
H	Transportation and storage	49,52-53
I	Accommodation and food service activities	55-56
J	Information and communication	59,61-63
M	Professional, scientific, and technical activities	70-74
N	Administrative and support service activities	78,80-82
P	Education	85
Q	Human health and social work activities	86-88
R	Arts, entertainment and recreation	90,93
S	Other services	96

Notes: NACE Rev. 2 sections and divisions (2-digit NACE industries) that are covered by the final sample.

Table 2.7: Observation count, by year and NACE section

	2007	2008	2009	2010	2011	2012	2013
A	1,950	2,098	2,124	2,264	2,388	2,397	2,388
C	8,287	9,118	9,350	9,808	10,355	10,446	10,523
E	119	141	163	181	210	212	214
F	9,238	10,139	10,943	11,048	11,455	11,251	10,968
G	23,191	25,296	26,047	26,500	27,716	27,897	28,069
H	3,256	3,564	3,677	3,717	3,901	3,912	3,963
I	2,927	3,195	3,351	3,505	3,867	4,044	4,211
J	4,816	5,584	5,924	5,879	6,427	6,782	7,061
M	16,171	18,401	19,255	18,157	19,225	19,550	19,516
N	2,243	2,824	3,085	3,124	3,431	3,493	3,567
P	918	1,072	1,099	1,111	1,225	1,279	1,304
Q	3,726	3,941	4,213	4,415	4,811	4,948	5,019
R	1,291	1,533	1,655	1,650	1,785	1,817	1,861
S	637	704	733	759	799	802	837
	78,770	87,610	91,619	92,118	97,595	98,830	99,501
	2014	**2015**	**2016**	**2017**	**2018**		**total**
A	2,448	2,461	2,586	2,324	2,577		28,005
C	10,602	10,668	10,836	9,857	10,485		120,335
E	221	218	228	203	216		2,326
F	10,804	10,716	10,865	9,382	10,756		127,565
G	28,332	28,287	28,701	25,398	28,015		323,449
H	4,014	3,987	4,137	3,793	3,947		45,868
I	4,405	4,635	4,937	4,692	5,105		48,874
J	7,325	7,772	8,321	7,029	8,581		81,501
M	20,040	20,395	21,420	17,772	21,420		231,322
N	3,739	3,767	3,883	3,539	3,954		40,649
P	1,319	1,389	1,462	1,269	1,537		14,984
Q	5,186	5,456	8,347	8,038	8,427		66,527
R	1,932	1,960	2,060	1,845	2,134		21,523
S	835	867	893	841	871		9,578
	101,202	102,578	108,676	95,982	108,025		1,162,506

Notes: Observation count in the full sample, by year and NACE section. NACE sections are broad industry classifications corresponding to one or more 2-digit NACE industries.

2.B Models of wage formation

In this appendix, we show that equation (2.1) can be derived in two different models of wage formation, a monopsony model where firms have labor market power so that $MRPL_{it} > W_{it}$, and a model of efficient bargaining where employees have bargaining power so that $W_{it} > MRPL_{it}$. This exposition is meant to provide two very basic examples, not an exhaustive overview. As mentioned in the main text, γ_{it} can be derived in a much broader class of models. See Lu et al. (2019) and Mertens (2020c) for derivations of the labor wedge in these, and other, models. This appendix draws on Dobbelaere and Mairesse (2013).

2.B.1 Monopsonistic labor market

Consider n firms, each monopsonists on their respective labor markets, implying that each firm faces an imperfectly elastic labor supply curve $W_{it}(L_{it})$. Competition on the output market remains unspecified, and summarized by the revenue function $R_{it}(\cdot)$. Assume that each firm selects capital and labor to maximize static profit given by

$$\Pi_{it}(K_{it}, L_{it}) = R_{it}(K_{it}, L_{it}) - P_{it}^K K_{it} - W_{it}(L_{it})L_{it}, \tag{2.12}$$

where P_{it}^K is the price of capital, and the other firms' choice variables have been suppressed. The first-order condition with respect to labor is

$$\frac{\partial R_{it}(K_{it}, L_{it})}{\partial L_{it}} = W_{it}(L_{it}) + \frac{\partial W_{it}}{\partial L_{it}} L_{it}, \tag{2.13}$$

which can be rewritten as

$$\frac{MRPL_{it}}{W_{it}} = \frac{1 + \varepsilon_{it}^L}{\varepsilon_{it}^L} > 1, \tag{2.14}$$

where ε_{it}^L is firm i's labor supply elasticity ($0 < \varepsilon_{it}^L < \infty$). Note that γ_{it} is higher the less elastic is the labor supply, ε_{it}^L.

2.B.2 Efficient bargaining

Consider n firms that individually bargain with a single risk-neutral labor union to determine W_{it} and L_{it}. The labor union acts as a cartel, and firms can only hire workers through the union. The union maximizes the following utility function

$$U(L_{it}, W_{it}) = W_{it}L_{it} + (\bar{L}_{it} - L_{it})\bar{W}_{it}, \tag{2.15}$$

where $\bar{L}_{it}$ is the employment level that would emerge if labor market were perfectly competitive and $\bar{W}_{it}$ is the reservation wage of the union's workers ($W_{it} > \bar{W}_{it}$). Output markets are not perfectly competitive, and each firm obtains a positive rent that can potentially be (partially) obtained by its workers. Each firm bargains over L_{it} and W_{it} and selects K_{it} to maximize static profit given by

$$\Pi_{it}(K_{it}, L_{it}) = R_{it}(K_{it}, L_{it}) - P^K_{it}K_{it} - W_{it}L_{it}. \tag{2.16}$$

The generalized Nash-bargaining solution to the Nash-bargaining process between the firm and the union solves

$$\max_{K_{it},L_{it},W_{it}} (W_{it}L_{it} + (\bar{L}_{it} - L_{it})\bar{W}_{it})^{\phi_{it}}(R_{it}(K_{it}, L_{it}) - P^K_{it}K_{it} - W_{it}L_{it})^{1-\phi_{it}}, \tag{2.17}$$

where ϕ_{it} denotes the bargaining power of the union ($0 < \phi_{it}$¡1). The first-order condition with respect to W_{it} is

$$W_{it} = \bar{W}_{it} + \frac{\phi_{it}}{1-\phi_{it}}\left(\frac{R_{it} - P^K_{it}K_{it} - W_{it}L_{it}}{L_{it}}\right), \tag{2.18}$$

and the first-order condition with respect to L_{it} is

$$W_{it} = MRPL_{it} + \phi_{it}\left(\frac{R_{it} - P^K_{it}K_{it} - MRPL_{it}L_{it}}{L_{it}}\right), \tag{2.19}$$

where equation (2.18) and (2.19) together imply that $MRPL_{it} = \bar{W}_{it}$ so that $\frac{MRPL_{it}}{W_{it}} < 1$. Note that γ_{it} is lower the higher is the bargaining power of the union, ϕ_{it}.

2.C The cost minimization approach

In this appendix, we explain how the labor wedge is identified in papers using cost minimization assumptions. We refer to papers that either directly estimate the labor wedge (e.g. Lu et al. (2019); Mertens (2020b,c); Hershbein et al. (2020); Caselli et al. (2021); Brooks et al. (2021)), or closely related measures based on the marginal revenue product of labor and the wage (e.g. Dobbelaere and Mairesse (2013); Nesta and Schiavo (2019); Mertens (2020a); Dobbelaere et al. (2020); Dobbelaere and Wiersma (2020)), using a cost minimization framework.

The literature has approached identification of γ_{it} using a cost minimization approach closely following the cost minimization approach to obtaining firm-level markups in output markets put forward by De Loecker and Warzynski (2012) and based on Hall (1988). This method requires the existence of a frictionlessly adjustable input for which firms are price-takers. Denote such an input by V_{it}. Under the assumption that firm i selects V_{it} in period t to minimize its conditional cost function, De Loecker and Warzynski (2012) show that the markup of price over marginal cost, $\mu_{it} = \frac{P_{it}}{\lambda_{it}}$, can be expressed as the ratio of the output elasticity of input V_{it}, $\tilde{\theta}^V_{it}$, to the revenue-share of expenditure on input V_{it}, $\frac{P^V_{it} V_{it}}{P_{it} Q_{it}}$,

$$\mu_{it}(V_{it}) = \frac{\tilde{\theta}^V_{it}}{P^V_{it} V_{it} / P_{it} Q_{it}}, \tag{2.20}$$

where $\mu_{it}(V_{it})$ is used to stress that the markup is expressed as a function of input V_{it}.[29] The choice of V_{it} is crucial in recovering the true markup μ_{it}. If V_{it} is not frictionlessly adjustable, or the firm is not a price taker for V_{it}, then $\mu_{it}(V_{it})$ is a joint measure of the markup, and imperfection in the input market for V_{it}. This insight has led the the cost minimization literature to estimate the labor wedge by comparing markup estimates obtained using different inputs as V_{it}. Most recent work uses intermediate inputs, often referred to as "material" M_{it}, as frictionlessly adjustable input. A comparison of $\mu_{it}(M_{it})$ with markups estimated using labor as the frictionless input, $\mu_{it}(L_{it})$, can then be used to infer the labor wedge. In particular, we can write γ_{it} as the ratio of the two markups

$$\gamma_{it} = \frac{\mu_{it}(L_{it})}{\mu_{it}(M_{it})} = \frac{\tilde{\theta}^L_{it} P^M_{it} M_{it}}{\tilde{\theta}^M_{it} W_{it} L_{it}}, \tag{2.21}$$

where P^M_{it} is the price of materials. As γ_{it} nests many different models potentially leading

[29] The conditional cost function refers to the static cost function conditional on other choice variables of the firm, which are potentially determined by a much more complicated dynamic maximization problem.

to labor market power on either side of the market, it depends on the paper how equation (2.21) is exactly derived. However, three key requirements need to be met in order to identify the labor wedge. First, as mentioned, firms should be able to frictionlessly adjust materials, for which they are price takers. Second, firms should select M_{it} such that their conditional cost function is minimized. Third, the output elasticities of labor and materials need to be identified. For a discussion of how these three requirements relate to the method used in the chapter, see Section 2.2.

Note that equation (2.21) only identifies the labor wedge if $\mu_{it}(M_{it})$ is equal to the the actual markup μ_{it}, that is, if the three requirements are satisfied. The cost minimization approach uses the markup in the output market as a benchmark from which to infer labor market imperfections. Any imperfections in the market for materials will affect the markup estimate, and therefore also enter the estimate of the labor wedge. Likewise, failure to identify the output elasticities of materials and labor will lead to the labor wedge estimate being biased. Most papers in the cost minimization literature use the control function approach to production function estimation pioneered in Olley and Pakes (1996) and Levinsohn and Petrin (2003). Using the control function approach to obtain markups is particularly challenging because one needs to control for price variation stemming from market power. In essence, to obtain an estimate related to market power, μ_{it}, one needs to control for market power, which makes identification using control functions challenging in most settings (see Doraszelski and Jaumandreu (2019) and Bond et al. (2021)).

2.D Revenue function estimation

This appendix provides additional information on the estimation of the revenue elasticities, and lists means, medians, and standard deviations of revenue elasticities and revenue returns to scale by NACE section in Table 2.8.

Substituting the law of motion of revenue productivity, equation (2.7), and the translog revenue function, equation (2.6), into the logged revenue function given in equation (2.4) yields

$$r_{it} = \sum_{x \in \mathcal{I}} \beta_x x_{it} + \sum_{x \in \mathcal{I}} \beta_{xx} x_{it}^2 + \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} + g_s(\omega_{it-1}) + \xi_{it} + \varepsilon_{it}, \quad (2.22)$$

where $\mathcal{I} = \{k, l, m\}$. Inverting materials demand from equation (2.5) gives

$$\omega_{it} = h_s(k_{it}, l_{it}, m_{it}), \quad (2.23)$$

where $h_s(\cdot) = m_s^{-1}(\cdot)$. Substituting this expression for revenue productivity, lagged one year, into equation (2.22) results in

$$r_{it} = \sum_{x \in \mathcal{I}} \beta_x x_{it} + \sum_{x \in \mathcal{I}} \beta_{xx} x_{it}^2 + \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{lm} l_{it} m_{it} + g_s(h_s(k_{it-1}, l_{it-1}, m_{it-1})) + \xi_{it} + \varepsilon_{it}, \quad (2.24)$$

which is the equation to be estimated separately for each of the 53 2-digit NACE industries in the sample.

The Wooldridge (2009) one-step estimator is used, so that moments are formed on the sum of the idiosyncratic revenue productivity innovation and the idiosyncratic measurement error in the revenue function, $\xi_{it} + \epsilon_{it}$. Recall that we follow the literature in assuming $\mathbb{E}(k_{it}, (\xi_{it} + \epsilon_{it})) = 0$, as capital adjusts slowly due to adjustment frictions. We allow for, but do not impose, the possibility that l_{it} and m_{it} can be adjusted in response to the realization of $(\xi_{it} + \epsilon_{it})$, so that $\mathbb{E}(l_{it}, (\xi_{it} + \epsilon_{it})) \neq 0$ and $\mathbb{E}(m_{it}, (\xi_{it} + \epsilon_{it})) \neq 0$, potentially. Therefore, we instrument contemporaneous labor and materials with their lags. Together, the following moments result

$$\mathbb{E}((\xi_{it} + \epsilon_{it})\mathbf{Z}_{it}) = 0, \quad (2.25)$$

where $\mathbf{Z}_{it}$ includes all terms in $g_s(\cdot)$, which is approximated by a third order polynomial in all arguments of $h_s(\cdot)$, contemporaneous capital as a level and squared, and interactions of contemporaneous capital with lagged inputs. That is, $\mathbf{Z}_{it}$ contains k_{it}, k_{it}^2, $k_{it}k_{it-1}$,

$k_{it}l_{it-1}$, $k_{it}m_{it-1}$, k_{it-1}, k^2_{it-1}, k^3_{it-1}, $l_{it}k_{it-1}$, $l_{it}l_{it-1}$, $l_{it}m_{it-1}$, $m_{it}k_{it-1}$, $m_{it}l_{it-1}$, $m_{it}m_{it-1}$, l_{it-1}, l^2_{it-1}, l^3_{it-1}, m_{it-1}, m^2_{it-1}, m^3_{it-1}, $k_{it-1}l_{it-1}$, $k^2_{it-1}l_{it-1}$, $k_{it-1}l^2_{it-1}$, $k_{it-1}m_{it-1}$, $k^2_{it-1}m_{it-1}$, $k_{it-1}m^2_{it-1}$, $l_{it-1}m_{it-1}$, $l^2_{it-1}m_{it-1}$, $l_{it-1}m^2_{it-1}$, and $k_{it-1}l_{it-1}m_{it-1}$.

Table 2.8: Revenue elasticities and returns to scale: median *mean* (standard deviation), by NACE section

NACE section	labor	materials	capital	RTS	observations
A: Agriculture, forestry and fishing	0.17	0.69	0.08	0.94	28,005
	0.18 (0.07)	*0.69* (0.10)	*0.07* (0.04)	*0.94* (0.02)	
C: Manufacturing	0.28	0.68	0.04	1.00	120,335
	0.28 (0.12)	*0.68* (0.12)	*0.04* (0.02)	*1.00* (0.03)	
E: Water supply and waste management	0.20	0.73	0.05	0.99	2,326
	0.20 (0.07)	*0.74* (0.08)	*0.05* (0.06)	*0.99* (0.04)	
F: Construction	0.30	0.66	0.04	1.00	127,565
	0.31 (0.14)	*0.65* (0.14)	*0.04* (0.02)	*1.00* (0.01)	
G: Wholesale and retail trade	0.19	0.78	0.03	1.00	323,449
	0.21 (0.10)	*0.77* (0.10)	*0.03* (0.02)	*1.00* (0.03)	
H: Transportation and storage	0.31	0.61	0.07	0.99	45,868
	0.30 (0.12)	*0.62* (0.14)	*0.07* (0.03)	*0.99* (0.02)	
I: Accomodation and food service activities	0.18	0.78	0.03	1.00	48,874
	0.17 (0.04)	*0.78* (0.06)	*0.04* (0.04)	*1.00* (0.03)	
J: Information and communication	0.50	0.50	0.05	1.05	81,501
	0.49 (0.18)	*0.51* (0.17)	*0.05* (0.02)	*1.05* (0.05)	
M: Professional scientific and technical activities	0.69	0.49	0.05	1.20	231,322
	0.66 (0.23)	*0.50* (0.14)	*0.05* (0.04)	*1.22* (0.17)	
N: Administrative and support service activities	0.40	0.48	0.06	0.95	40,649
	0.40 (0.17)	*0.47* (0.18)	*0.06* (0.03)	*0.93* (0.08)	
P: Education	0.46	0.61	0.00	1.10	14,984
	0.47 (0.17)	*0.61* (0.14)	*0.00* (0.04)	*1.08* (0.10)	
Q: Human health and social work activities	0.57	0.33	0.04	0.94	66,527
	0.56 (0.13)	*0.34* (0.14)	*0.04* (0.02)	*0.94* (0.06)	
R: Arts, entertainment and recreation	0.33	0.58	0.05	0.98	21,523
	0.33 (0.10)	*0.59* (0.14)	*0.05* (0.03)	*0.98* (0.06)	
S: Other services	0.33	0.57	0.08	0.99	9,578
	0.32 (0.12)	*0.59* (0.12)	*0.08* (0.04)	*0.99* (0.02)	
Full sample	0.31	0.65	0.04	1.00	1,162,506
	0.37 (0.23)	*0.63* (0.18)	*0.04* (0.03)	*1.04* (0.12)	

Notes: Summary statistics for firm-level revenue elasticities of labor, materials, and capital, and the revenue returns to scale (RTS). For each NACE sections, the median, mean (in italics), and standard deviation (in brackets) are displayed. Medians, means, and standard deviations are rounded to 2 decimal points. Full name of section E is "Water supply, sewerage, waste management and remediation". Full name of section G is "Wholesale and retail trade, repair of motor vehicles and motorcycles". Based on the full sample of 1,162,506 observations.

2.E Additional results on NACE sections I and M

Table 2.3 shows that two NACE sections are outliers. In section I, "Accommodation and food service activity", the median labor wedge is only 0.5. This implies that firms pay a wage that is at least twice as high as the marginal revenue product of labor in 50 percent of all cases. In 98.29 percent of all cases, wage markups are present. Section I contains 8 4-digit NACE industries with the bulk of the observations coming from hotels, restaurants, and bars. Wage markups characterize all these 4-digit industries: the median labor wedge in these industries is on average 0.56 (with a standard deviation of 0.1). These wage markups are not caused by high wages. The median wage in section I (34,969 euro) is substantially lower than the median wage in the full sample (54,607 euro).[30] However, the median marginal revenue product in section I is even lower at only 17,693 euro.[31] A possible explanation is that Dutch minimum wage laws prevent wages from falling to the level of the marginal revenue product.[32] In addition, recall that the labor wedge is estimated only for employees that are on a firm's pay roll. Hotels, restaurants, and bars make frequent use of detachment agencies to meet their demand for low-skilled workers and it is possible that firms mark down wages for such workers.

In section M, "Professional, scientific and technical activities", the median labor wedge is 1.26. In 74.98 percent of all cases, the marginal revenue product of labor exceeds the wage. Section M is a broad section containing five different 2-digit industries, but the main driver of high markdowns is 2-digit industry 70, "Activities of head offices and management consultancy activities", with a median labor wedge of 1.43. This division consists of three 4-digit industries with the bulk of the observations coming from head offices and consultancy firms.[33] The substantial wage markdowns set by firms in these industries is

[30]The 25th and 75th percentile of the wage distribution in section I are 26,539 euro and 43,000 euro, respectively. Low wages characterize all 4-digit industries contained in section I – on average, the median wage is 34,973 euro (with a standard deviation of 4,428 euro).

[31]The 25th and 75th percentile of the marginal revenue product of labor distribution in section I are 14,263 euro and 19,179 euro, respectively. Low marginal revenue products typify all 4-digit industries contained in section I – on average, the median marginal revenue product of labor is 19,010 euro (with a standard deviation of 3,228 euro).

[32]Dutch minimum wage laws vary by age of the employee and change (at least) yearly. The 2015 gross minimum wage for an employee of at least 23 years of age holding a full-time job is 1,501.80 euro per month (Dutch Ministry of Social Affairs and Employment, 2015).

[33]NACE industry 7010 "Activities of head offices" and NACE industry 7022 "Business and other management consultancy activities" both exhibit high labor wedges with medians of 1.39 and 1.44, respectively. NACE industry 7021 "Public relations and communication activities" displays substantially lower labor wedges, the median is 1.26, but as this 4-digit industry accounts for only 2,704 of all 131,086 observation (2.06 percent), the effect on the 2-digit results presented

not due to low wages: median wage in division 70 (67,000 euro) is substantially higher than median wage in the full sample (54,607 euro).[34] However, the marginal revenue product of labor is even higher – the median is 98,803 euro.[35] Note that executives could receive additional compensation not recorded as labor expenses, such as stock options. Such compensation is not observable in my sample, and could affect employees in the far-right tail of the distribution of the marginal revenue product of labor – exactly the type of employees in section M.

in the main text of this appendix is negligible.

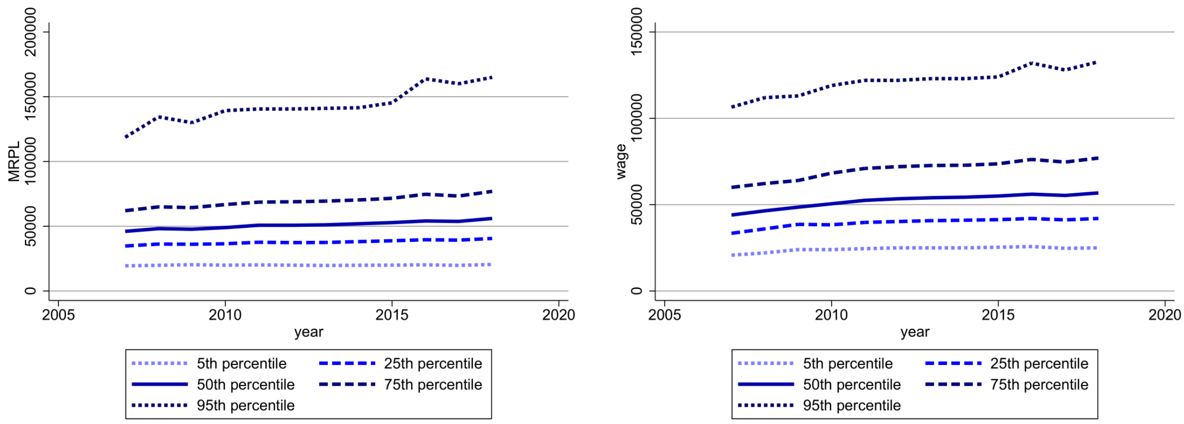
[34]The 25th and 75th percentile of the wage distribution in division 70 are 46,579 euro and 93,000 euro, respectively (compared to 41,952 euro and 72,837 euro in the full sample).

[35]The 25th and 75th percentile of the marginal revenue product of labor distribution in division 70 are 64,443 euro and 143,819 euro, respectively (compared to 39,316 euro and 70,954 euro in the full sample).

2.F Additional figures

Figure 2.10: Selected percentiles of the distribution of $MRPL_{it}$ (panel a), and W_{it} (panel b), over time

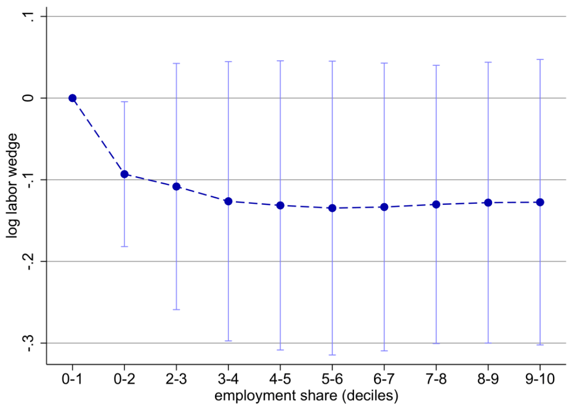
(a) $MRPL_{it}$ (b) W_{it}



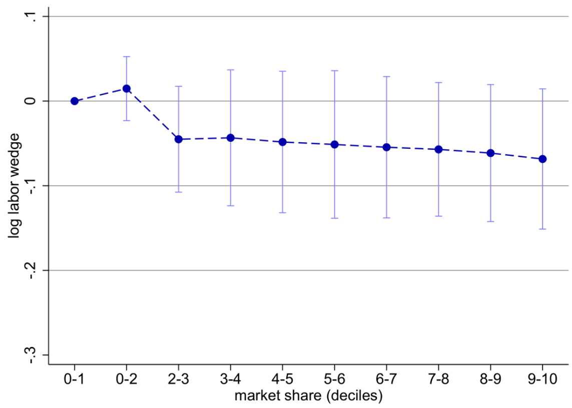
Notes: Panel a (Panel b) displays the 5th, 25th, 50th, 75th, and 95th percentile of the distribution of the marginal revenue product of labor (the wage) over the years 2007 to 2018, based on the full sample of 1,162,506 firm-year observations.

Figure 2.11: The labor wedge regressed on the firm's employment share (panel a), and market share (panel b)

(a) Employment share



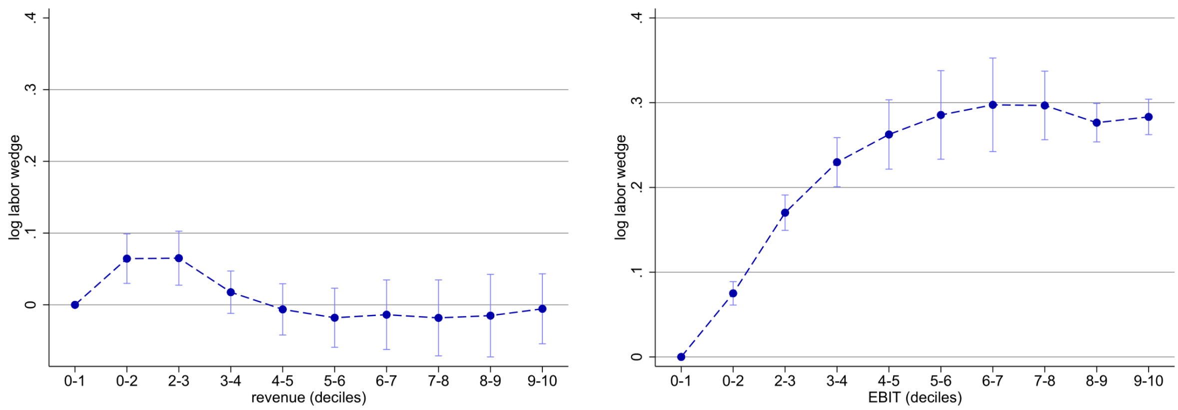
(b) Market share



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on the firm's employment as a fraction of total employment in its 4-digit industry (panel a), and on the firm's revenue as a fraction of total revenue in the its 4-digit industry (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

Figure 2.12: The labor wedge regressed on revenue (panel a), and EBIT (panel b)

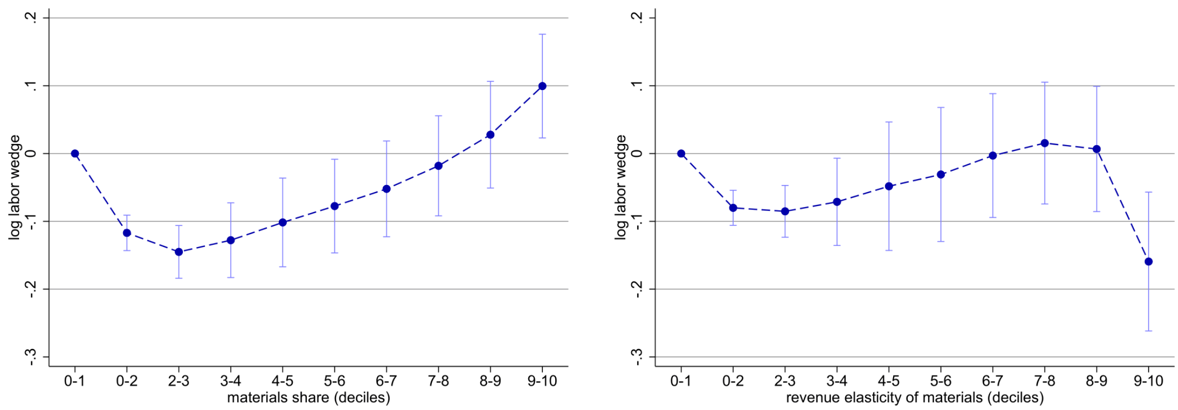
(a) Revenue (b) EBIT



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge the revenue (panel a), and earnings before interest and taxes (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

Figure 2.13: The labor wedge regressed on the materials share (panel a), and the revenue elasticity of materials (panel b)

(a) Materials share (b) Revenue elasticity of materials



Notes: Regression coefficients and 95 percent confidence intervals from a non-parametric regression of log labor wedge on the materials share (panel a), and the revenue elasticity of materials (panel b). Explanatory variables are divided into 10 categories based on the deciles of their distribution. The coefficient on the indicator of the first decile is normalized to 0. Year fixed effects and 4-digit NACE industry fixed effects included. Standard errors are clustered at the 4-digit industry level. Based on the full sample of 1,162,506 firm-year observations for the years 2007 to 2018.

2.G Additional tables

Table 2.9: Summary statistics of the marginal revenue product of labor, by NACE section

NACE section	p(5)	p(25)	p(50)	p(75)	p(95)	observations
A: Agriculture, forestry and fishing	19,961	30,491	39,664	50,997	71,385	28,005
C: Manufacturing	26,507	39,119	47,189	55,361	70,720	120,335
E: Water supply and waste management	19,796	35,187	49,508	78,504	153,025	2,326
F: Construction	33,013	43,401	48,835	54,371	69,952	127,565
G: Wholesale and retail trade	26,241	38,144	52,885	65,868	84,787	323,449
H: Transportation and storage	28,170	40,885	49,880	61,968	85,181	45,868
I: Accomodation and food service activities	10,370	14,584	17,693	21,472	31,343	48,874
J: Information and communication	32,504	49,145	62,870	80,475	124,220	81,501
M: Professional scientific and technical activities	35,617	56,862	78,988	119,264	200,655	231,322
N: Administrative and support service activities	17,873	28,745	36,162	46,297	77,580	40,649
P: Education	23,490	39,496	58,016	87,067	148,991	14,984
Q: Human health and social work activities	27,573	48,033	84,603	153,269	229,358	66,527
R: Arts, entertainment and recreation	19,076	29,253	41,512	62,167	122,125	21,523
S: Other services	17,252	23,570	29,047	35,959	47,959	9,578

Notes: Summary statistics for the marginal revenue product of labor across all NACE sections in the sample. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the marginal revenue product of labor distribution, respectively. Marginal revenue products are in 2015 euros and rounded to whole numbers. Full name of section E is "Water supply, sewerage, waste management and remediation". Full name of section G is "Wholesale and retail trade, repair of motor vehicles and motorcycles". Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

Table 2.10: Summary statistics of the wage, by NACE section

NACE section	p(5)	p(25)	p(50)	p(75)	p(95)	observations
A: Agriculture, forestry and fishing	24,924	38,964	50,558	68,224	121,798	28,005
C: Manufacturing	30,626	44,584	54,000	65,959	97,089	120,335
E: Water supply and waste management	30,013	47,471	59,220	74,393	112,571	2,326
F: Construction	29,150	45,769	55,730	68,121	104,513	127,565
G: Wholesale and retail trade	25,902	39,482	50,498	65,680	106,230	323,449
H: Transportation and storage	30,063	46,321	57,182	69,000	107,013	45,868
I: Accomodation and food service activities	19,652	27,774	34,969	45,298	72,970	48,874
J: Information and communication	28,688	46,397	62,200	83,626	133,607	81,501
M: Professional scientific and technical activities	28,898	47,230	64,000	87,969	140,746	231,322
N: Administrative and support service activities	22,298	37,013	48,069	64,452	108,402	40,649
P: Education	24,667	41,273	55,741	76,727	131,607	14,984
Q: Human health and social work activities	32,964	49,385	71,500	118,626	170,898	66,527
R: Arts, entertainment and recreation	21,402	33,000	44,798	62,694	118,837	21,523
S: Other services	21,061	30,426	39,369	53,626	84,727	9,578

Notes: Summary statistics for the wage across all NACE sections in the sample. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the wage distribution, respectively. Wages are in 2015 euros and rounded to whole numbers. Full name of section E is "Water supply, sewerage, waste management and remediation". Full name of section G is "Wholesale and retail trade, repair of motor vehicles and motorcycles". Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

Table 2.11: Summary statistics of the marginal revenue product of labor minus the wage, by NACE section

NACE section	p(5)	p(25)	p(50)	p(75)	p(95)	observations
A: Agriculture, forestry and fishing	-63,669	-25,392	-12,869	-2,096	16,088	28,005
C: Manufacturing	-43,790	-16,718	-7,257	878	14,172	120,335
E: Water supply and waste management	-43,278	-21,548	-8,483	14,020	70,567	2,326
F: Construction	-45,260	-16,450	-6,878	677	15,067	127,565
G: Wholesale and retail trade	-41,078	-12,349	-1,078	10,648	28,144	323,449
H: Transportation and storage	-37,265	-16,609	-8,739	1,294	23,854	45,868
I: Accomodation and food service activities	-47,141	-24,628	-17,060	-11,678	-4,703	48,874
J: Information and communication	-43,516	-11,783	325	11,542	37,251	81,501
M: Professional scientific and technical activities	-25,132	-754	14,130	38,761	98,147	231,322
N: Administrative and support service activities	-51,230	-21,636	-10,089	-3,354	9,443	40,649
P: Education	-36,594	-11,983	992	18,643	60,338	14,984
Q: Human health and social work activities	-30,061	-7,219	8,796	38,761	98,888	66,527
R: Arts, entertainment and recreation	-39,780	-13,728	-4,293	7,977	45,325	21,523
S: Other services	-44,451	-18,583	-10,209	-5,119	1,999	9,578

Notes: Summary statistics for the marginal revenue product of labor minus the wage across all NACE sections in the sample. p(5), p(25), p(50), p(75) and p(95) refer to the 5th, 25th, 50th, 75th and 95th percentile of the marginal revenue product of labor minus wage distribution, respectively. Marginal revenue products minus wage is in 2015 euros and rounded to whole numbers. Full name of section E is "Water supply, sewerage, waste management and remediation". Full name of section G is "Wholesale and retail trade, repair of motor vehicles and motorcycles". Statistics based on the full sample of 1,162,506 firm-year observations over the years 2007 to 2018.

Chapter 3

Cartel stability in experimental first-price sealed-bid and English auctions*

3.1 Introduction

On December 9, 2016, a member of the british nobility sold the painting 'Portrait of a Young Gentleman' for £137,000 in an auction at Christie's in London. Some 18 months later, the buyer, Dutch art dealer Jan Six, announced that he had recognized the portrait as the work of Rembrandt and that he had found an investor that was prepared to pay millions for it. Later, colleague Dutch art dealer Sander Bijl revealed that he had also identified the painting as a genuine Rembrandt and that he had struck a deal with Six that Bijl would abstain from bidding in the auction so that Six would be able to buy the painting at a price far below its actual value (Ribbens, 2018).[1]

Such collusion among bidders is a serious concern for auctioneers. The consensus view in the literature is that in settings where bidders are likely to form a bidding ring, auctioneers are well-advised to use the first-price sealed-bid auction rather than the English auction (e.g. Klemperer (2002), Kovacic et al. (2006), and OECD (2006)).[2] The under-

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[1]Presently, Bijl and Six are in a dispute over the spoils of the deal. Six even publicly denies that he and Bijl made the deal in the first place.

[2]Both the English auction and the first-price sealed-bid auction are commonly used in practice (McAfee and McMillan, 1987). The first-price sealed-bid auction featured, for instance, in cartels for school milk tenders (Porter and Zona, 1999) and infrastructure procurement (Bajari and Ye (2003); Clark et al. (2018)); the English auction was used, for example, in cartels

lying intuition, formalized by Robinson (1985), is that stable collusion is an equilibrium in the English auction and not in the first-price sealed-bid auction because only in the former, the designated winner can retaliate defection by overbidding a defecting bidder in the auction itself.[3] However, this equilibrium is not unique. In fact, the English auction has a multitude of equilibria in which collusion is unstable.

In this chapter, we compare the stability of bidding rings in the English auction and the first-price sealed-bid auction using a laboratory experiment. The experiment allows us to address the question which equilibria are most likely to be observed. An additional reason for using laboratory experiments is that it is difficult to study the collusive properties of auctions on the basis of field data. First of all, in the field, the auction format is typically not varied exogenously so that an apples-to-apples comparison between auctions is not feasible. Second, even if the researcher could observe whether bidders in the field formed a bidding ring, it would be difficult to measure if it was stable or unstable, in contrast to the lab, where such measures are readily available. Third, in the lab, the researcher can impose cartel formation to obtain a direct comparison between auction formats in terms of cartel stability. This is arguably much harder to implement in the field.

The received experimental literature finds little support for the claim that the English auction is more conductive to collusion than the first-price sealed-bid auction. *Tacit* collusion is rarely observed in either auction type in the laboratory: if subjects deviate systematically from the one-shot Nash prediction, they bid more aggressively instead of less (Kagel, 1995).[4] Bidders sometimes manage to collude explicitly when they get the opportunity to communicate with each other before the auction.[5][6]

Several recent experimental studies compare the collusive properties of the English auction and the first-price sealed-bid auction in independent private value settings where

involving tobacco (Phillips et al., 2003) and stamps (Asker, 2010).

[3]Marshall and Marx (2007) generalize Robinson's result allowing for partial cartels and side-payments. Marshall and Marx (2009) study how procedural details of the English auction affect its collusive properties.

[4]Tacit collusion is sometimes observed in multi-unit auctions in the lab, in particular in setting where bidders can find ways to "divide the market". See Kwasnica and Sherstyuk (2013) for an overview. Burtraw et al. (2009) find that bidders are better able to sustain collusive agreements in ascending than in sealed-bid multi-unit auctions when interacting repeatedly.

[5]See, e.g. Isaac and Walker (1985), Phillips et al. (2003), Sherstyuk and Dulatre (2008), Burtraw et al. (2009), Noussair and Seres (2020), and Agranov and Yariv (2018). Kagel and Levin (2016) and Kwasnica and Sherstyuk (2013) survey this literature.

[6]This finding fits well with the abundant experimental evidence that decision makers tend to benefit from pre-play communication in dilemma games, including the prisoner's dilemma (e.g. Dawes et al. (1977)), public good games (e.g. Isaac et al. (1985)), oligopoly games (e.g. Isaac et al. (1984); Hinloopen and Soetevent (2008); Fonseca and Normann (2012); Gomez-Martinez et al. (2016)), and rent-seeking games (Kimbrough and Sheremeta, 2013).

bidders can communicate. In the framework of Hu et al. (2011), bidders can decide to form a cartel before the auction at a cost. If a cartel forms, the bidders in the cartel bid in a pre-auction knockout to determine who becomes the provisional auction winner and to establish the side-payments from the provisional winner to the other cartel members. The experimental protocol enforces the agreement that (1) the designated bidder unconditionally divides her winning bid in the knockout among the other cartel members, and (2) the designated winner is the only bidder in the cartel entering the auction. Hu et al. (2011) find that at least as many cartels form in the first-price sealed-bid auction as in the English auction.

Llorente-Saguer and Zultan (2017) study collusion in the first-price and the second-price sealed-bid auctions. The second-price sealed bid auction is closely related to the English auction in that in both auctions, the winning bidder pays the second highest bid and that both auctions have an equilibrium in which bidding own value is a weakly dominant strategy in an independent private value setting. Llorente-Saguer and Zultan (2017) examine a two-bidder setting where before the auction, one of the bidders can offer a bribe to the other bidder to stay out of the auction. On the basis of results by Eső and Schummer (2004) and Rachmilevitch (2013), the authors hypothesize that the second-price auction supports collusion in equilibrium, in contrast to the first-price auction. Their data provide strong evidence against this hypothesis in that they do not show any systematic differences in collusive outcomes between the first-price and the second-price auction.

Agranov and Yariv (2018) study the effect of communication and post-auction transfers opportunities on collusion in first-price and second-price sealed-bid auctions. They observe that communication alone depresses bids only to a limited extent. When bidders can transfer money among each other after the auction, very low prices commonly emerge under both auction formats. The authors do not find the auctions to differ significantly in terms of collusive outcomes.

It is not clear why the experimental literature to date has offered little support for the proposition that the English auction is more conductive to collusion than the first-price sealed-bid auction. Several factors might explain this discrepancy: Cartels are stable by construction in Hu et al. (2011) and Llorente-Saguer and Zultan (2017); Llorente-Saguer and Zultan (2017) and Agranov and Yariv (2018) use a strategically equivalent sealed-bid variant of the English auction;[7] In Agranov and Yariv (2018), communication between

[7]One important insight from the experimental literature is that strategic equivalence does not imply behavioral equivalence. For instance, it is commonly observed that in private value settings, subjects play the dominant strategy of bidding their own value significantly more

bidders is non-binding and side payments are not enforceable. In this chapter, we aim to improve our understanding of the conditions under which the English auction is more prone to collusion than the first-price sealed-bid auction. We do so closely following the framework of Robinson (1985), where by construction, bidders have formed a cartel before the start of the auction. In two experimental studies, we let groups of three bidders make auction entry decisions in a setting where bidders are commonly informed about each other's values. The bidder with the highest value is the designated winner. All bidders are informed about a non-binding agreement that only the designated winner enters the auction. In Study 1, we compare the two auctions in a setting where participants are re-matched after every auction. In Study 2, we let the participants interact within the same group of bidders for a number of rounds. We consider a cartel to be stable if, and only if, only the designated winner enters the auction. In both studies, we find support for the hypothesis that more cartels are stable in the English auction than in the first-price sealed-bid auction.[8] We conclude that the intuition of Robinson (1985) applies in simple settings, which serves as a starting point in gaining further insight as to why it fails to work in the more complex settings such as those studied by Hu et al. (2011), Llorente-Saguer and Zultan (2017), and Agranov and Yariv (2018).

The set-up of the remainder of this chapter is as follows. We first review the theoretical predictions of Robinson (1985) in Section 3.2. In Section 3.3, we present our experimental procedures and experimental design for the re-matching case (Study 1). We report our experimental findings in Section 3.4. Section 3.5 contains our findings for the fixed-matching condition (Study 2). Section 3.6 concludes.

3.2 Theoretical model

We use a discrete version of the model in Robinson (1985) to examine the collusive properties of the English auction (EN) and the first-price sealed-bid auction (FP). The framework used for the experiment is a special case of this model. A seller auctions one indivisible object to one bidder out of a set of $n \geq 2$ risk-neutral bidders labelled $i = 1, \ldots, n$. Bidder i attaches value v_i to the object, where $v_1 \geq v_2 \geq \ldots \geq v_n \geq 0$. Assume that $v_2 \geq R + 2\varepsilon$, where R represents the seller's reserve price and $\varepsilon > 0$ is the minimum bid increment. For

frequently in the English auction than in the second-price sealed-bid auction (see Li (2017), and the references cited therein). Li (2017) argues that the observed differences across auctions are explained by the fact that the English auction is obviously strategy proof, in contrast to the second-price sealed-bid auction.

[8] Hinloopen and Onderstal (2010) find similar results in a common-value setting where cartel formation is endogenous.

analytical convenience, we assume that bidders' values and R are multiples of ε and that bids are restricted to the set $\{R, R+\varepsilon, R+2\varepsilon, \ldots, M\}$, where $M \geq v_1$ is a multiple of ε.

Both auctions consist of two stages. In the first stage, bidders simultaneously decide whether or not to submit a bid. If no bidder submits a bid, the seller retains the good. otherwise the second stage starts in which bidders who decide to submit a bid, participate in the auction. In EN, the price is raised successively in steps of size ε, starting at R and up to M. Bidders can indicate at any price whether they leave the auction at that price. The auction stops when one or zero bidders remain. If one bidder remains, this bidder wins the object for the price at which the second highest bidder left the auction. If zero bidders remain, a winner is drawn randomly among the last bidders leaving the auction; the winner obtains the object and pays the price at which she left the auction. When, at a price of M, more than one bidder remains, chance determined which of the remaining bidders wins the auction (for a price of M). In FP, bidders independently submit sealed bids. The highest bidder wins the object and pays her own bid. In the case of a tie at the highest bid, a winner is selected randomly using a uniform distribution among the highest bidders; the winner obtains the object and pays her bid.

A bidder's utility equals zero if she does not win the auction, and equals the difference between her value for the object and the winning bid if she wins. Before the auction, the bidders have formed an all-inclusive cartel in which they have credibly revealed their private information about their values for the object to each other. The model does not specify how the bidders reveal their private information in a credible way.[9] We start by characterizing the set of pure-strategy equilibria for both auctions.[10]

Proposition 3.1.
In any subgame perfect Nash equilibrium of EN, at least one bidder i for whom $v_i = v_1$ leaves the auction at price $v_1 + \varepsilon$ and the other bidders either do not submit a bid or leave the auction at a price in the set $\{R, R+\varepsilon, \ldots, v_1\}$.

Proposition 3.2.
(i) If $v_1 \geq v_2 + 3\varepsilon$, in any subgame perfect Nash equilibrium of FP, bidder 1 submits a bid b_1 in the set $\{R, R+\varepsilon, \ldots, v_1 - 2\varepsilon\}$.

[9] Generally, side-payments are required for bidders to reveal their private values truthfully in a pre-auction knockout (see, e.g. McAfee and McMillan (1992)). An alternative interpretation of the model is that values are common knowledge among bidders from the onset, which may be relevant in cases where bidders know each other intimately and/or where the values depend solely on characteristics that are commonly observed by the bidders.

[10] Proofs of all propositions are in Appendix 3.A.

(ii) If $v_1 = v_2 + 2\varepsilon$, in any subgame perfect Nash equilibrium of FP, bidder 1 submits a bid b_1 in the set $\{v_2, v_2 + \varepsilon\}$. If bidder 1 bids v_2, either at least one bidder bids $v_2 - \varepsilon$ or exactly one of the bidders having value v_2 bids v_2. If bidder 1 bids $v_2 + \varepsilon$, at least one of the other bidders bids v_2. The remaining bidders either do not submit a bid or submit a bid in the set $\{R, R + \varepsilon, \ldots, b_1 - \varepsilon\}$.
(iii) If $v_1 = v_2 + \epsilon$, in any subgame perfect Nash-equilibrium of FP, bidder 1 submits a bid $b_1 \in \{v_2 - \varepsilon, v_2\}$; if $b_1 = v_2$, either at least one bidder bids $v_2 - \varepsilon$ or at least one bidder having value v_2 bids v_2; if $b_1 = v_2 - \varepsilon$, all bidders having value v_2 bid $v_2 - \varepsilon$ and the other bidders either do not submit a bid or submit a bid in the set $\{R, R + \varepsilon, \ldots, v_2 - \varepsilon\}$.
(iv) If $v_1 = v_2$, in any subgame perfect Nash equilibrium, either (1) all bidders having value v_1 bid $v_1 - \varepsilon$, all bidders having value $v_1 - \varepsilon$ either do not submit a bid or submit a bid in the set $\{R, R + \varepsilon, \ldots, v_1 - \varepsilon\}$, and all other bidders either do not submit a bid or submit a bid in the set $\{R, R + \varepsilon, \ldots, v_1 - 2\varepsilon\}$, or (2) at least two bidders having value v_1 bid v_1, and all other bidders either do not submit a bid or submit a bid in the set $\{R, R + \varepsilon, \ldots, v_1 - \varepsilon\}$.

Now, assume that the bidders make the following cartel agreement before the auction. Among the bidders who have the highest value v_1, a designated winner is appointed. The bidders agree that only the designated winner submits a bid in the auction. In what follows, we sometimes refer to the remaining bidders as the designated losers. We consider a cartel agreement to be stable if, and only if, it constitutes a subgame perfect Nash-equilibrium. Propositions 3.1 and 3.2 imply immediately that stable cartel agreements only exist in EN.

Corollary 3.1.
In EN, the cartel agreement is part of a subgame perfect Nash equilibrium; in FP the cartel agreement is not part of a subgame perfect Nash equilibrium.

The intuition behind this result is the following. In EN, the designated winner can ensure that entry into the auction by other bidders is not profitable by remaining in the auction until the price reaches her value. Of course, such a collusive equilibrium requires the designated losers to play a weakly dominated strategy: irrespective of the bidding strategies of others, a designated loser is always weakly better off by overbidding others up to a price equal to her value. While the play of weakly dominated strategies may make the collusive equilibrium less plausible, note that these strategies can survive iterated elimination of weakly dominated strategies. For the designated winner, bidding below values of the designated losers does not survive iterated elimination of weakly dominated strategies. As a result, abstaining from bidding is no longer dominated for the designated losers once the weakly dominated strategies of the designated winner are sequentially deleted.[11] Whether designated losers play weakly dominated strategies is an empirical question, which we explore in the experiment.

In FP, the designated winner best responds to the cartel agreement by bidding R. However, this cannot be part of an equilibrium because then at least one other bidder is better off by deviating from the cartel agreement and bidding $R + \varepsilon$. Indeed, in FP, the best a cartel can achieve in equilibrium is obtaining the good at a price $v_2 - \varepsilon > R$ as the following corollary shows.

Corollary 3.2.
If $v_1 \geq v_2 + 2\varepsilon$, FP has no equilibrium in which the designated winner obtains the object for a price strictly lower than v_2. If $v_1 \in \{v_2, v_2 + \varepsilon\}$, FP has no equilibrium in which the designated bidder obtains the object for a price strictly lower than $v_2 - \varepsilon$.

Notice that both EN and FP are plagued by a multitude of equilibria. We formulate our hypotheses assuming that bidders coordinate on the "least competitive" equilibrium, i.e. the Nash equilibrium that yields the lowest revenue for the auctioneer. In other words, we base our hypotheses on the assumption that in EN, only the designated winner submits a bid and that in FP, the designated winner bids at most the second highest value minus one bid increment. This yields the following hypotheses that we will test using our experiments:[12]

H1: Stable cartels emerge more frequently in EN than in FP.
H2: Revenue in FP is higher than in EN.
H3: EN is at least as efficient as FP.

H1 follows directly from the fact that the least competitive equilibrium of EN is a stable cartel and the least competitive equilibrium of FP is not a stable cartel. H2 follows from the observation that in the least competitive equilibrium, revenue equals R in EN and it equals at least $v_2 - \varepsilon$ in FP. As to H3, an auction is efficient if, and only if, it allocates the object to the bidder with the highest valuation. H3 then follows from the fact that the designated winner always wins the object in the least competitive equilibrium in EN

[11] We thank an anonymous referee for pointing this out.
[12] Notice that risk aversion does not affect our hypotheses.

and not necessarily in FP.[13]

3.3 Study 1: Experimental procedures and design

The computerized experiment was conducted at the Center for Research in Experimental Economics and political Decision making (CREED) of the University of Amsterdam. Students were recruited by public announcement. In total 144 students from the University's entire undergraduate population participated in one of six sessions. The points that subjects earned were converted to euros according to an exchange rate of 50 points equals 1 euro. A show-up fee of 7 euros was converted to 350 points for those subjects that participated in the experiment. To ensure that all subjects understood the experiment, they had to correctly answer several questions before the experiment started.[14] Average earnings were 12.07 euros per subject while sessions took 60 to 90 minutes to complete.

At the start of each session, matching groups of nine subject were formed randomly. These groups did not change during the sessions and communication between subjects (other than through their play) was not possible. All subjects consisted of at least 35 rounds. From round 35 onward, each next round was the final round with 20% probability.[15] Only after the last round was played, the participants learned that the experiment was over. At the start of each round subjects were randomly matched with two other subjects from the same matching group.[16] We used a between-subject design in which 72 participants participated in FP while the remaining 72 participated in EN, yielding in total 16 statistically independent observations.

Recall that our theoretical analysis relies on the assumption that bidders share their private information before the auction. To be able to isolate the effect of the auction format on cartel stability, we impose this condition in our experiment. In the experiment bidders drew their values from a uniform distribution on the set $\{20, 12, \ldots, 70\}$. These

[13]In fact, this result holds true regardless of the equilibrium played in either auction.

[14]Appendix 3.B contains an English translation of the instructions.

[15]We are not the first to use a fixed number of rounds followed by a random stopping rule. See Holt (1985) for an early example. The procedure has the advantage that each group has a minimum of 35 rounds of interactions, which facilitates learning and the statistical comparison across groups. The procedure also softens potential end-game effects.

[16]Subjects were re-matched in such a way that they would not face the same opponent in two consecutive rounds. Subjects were informed about this conditional re-matching. Although (tacit) collusion is quite unlikely to be observed in groups with four or more subjects (see e.g. Huck et al. (2004)), we introduced this conditional re-matching to eliminate any tendency towards (tacit) collusion due to repeated play that might affect a proper comparison between treatments. In Section 3.5, we discuss our second study, were subjects were not re-matched.

draws were independent across rounds and bidders. To improve the comparison between the treatments, bidder values were drawn before the start of the experiment and the same set of realizations was used for all treatments. Bidders were commonly informed about each other's values. The designated winner is the bidder with the highest value. In case of a tie the designated winner was selected randomly among the bidders with the highest value. Losses, which could occur when a bidder would bid more than her value and win, were subtracted from the participants' starting capital.

After bidders learned their values, they were informed about the cartel agreement, according to which only the designated winner submits a bid. Designated losers received the message that "[a]ccording to the agreement you are not supposed to submit a bid", while designated winners were informed that "[a]ccording to the agreement you are the only bidder who is supposed to submit a bid". The cartel agreement was not binding. This design feature corresponds exactly to the set-up of Robinson (1985) whereby the cartel is assumed to select from among its members a designated winner (who should be the member with the highest valuation if they differ) and to recommend that she follows a particular bidding strategy while requesting other cartel members to be inactive in the bidding (p.143). At the end of each round, we informed the participants about which bidders entered the auction, the bids they submitted, and the own payoffs.

We implemented the following auction rules. In FP, each subject could submit a bid from the set $\{0, 1, \ldots, 70\}$ or could decide not to submit a bid. The highest bidder won the auction of that round. Ties were resolved randomly (nobody won the object when all group members decided not to submit a bid). The auction winner earned the difference between her value and her bid. In EN, a thermometer showed a price that started at 0 and increased by 1 every half-second. Bidders could indicate to leave the auction at any price by pressing a virtual button. When a bidder pressed that button, the thermometer would briefly pause at the current price, informing the remaining bidders at what price the bidder left the auction (but not about his or her value). When all but one bidder had left the auction, the remaining bidder bought the item at the price at which the runner-up left the auction. When a bidder was the only one submitting a bid, she immediately obtained the object for a price of 0. When, at a price of 70, less than two bidders had left the auction, chance determined which of the remaining bidders won the auction (for a price of 70). We always let the thermometer run up to 70 to prevent participants from learning abut the auction outcomes in other groups.[17]

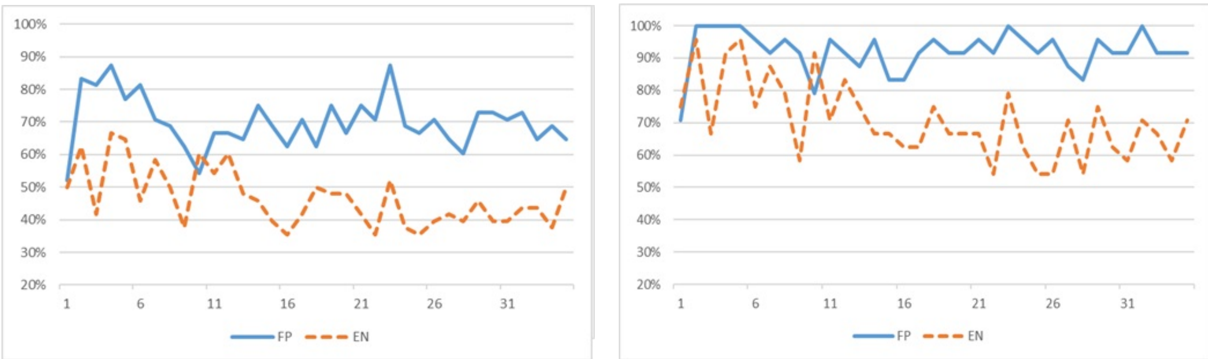
[17]The software was programmed in such a way that in each round, the thermometer started running simultaneously in all groups. If we had stopped the thermometer after all groups in the session had finished, all subjects in the session would have learned about the highest price at

3.4 Study 1: Experimental results

In this section we analyze the experimental data of Study 1. In Section 3.4.1 we compare FP and EN in terms of cartel stability, the key outcome variable in this chapter. Section 3.4.2 presents the relative performance of the two auctions in terms of revenue and efficiency, to examine if a trade-off exists between cartel instability on the one hand, and revenue and efficiency on the other. In Section 3.4.3, we zoom in on the bidding behavior.[18]

Figure 3.1: Propensity to defect (panel a) and cartel breakdown (panel b), over time across auctions

(a) Panel a (b) Panel b



3.4.1 Cartel stability

We mark a bidder as defecting from the cartel agreement if, and only if, she submits a bid while being a designated loser. We say that a cartel breaks down if at least one bidder defects. As a result, cartels that do not break down are stable.[19] Table 3.1 presents the aggregate results of cartel stability across auctions, and Figure 3.1 shows subjects' propensities to defect (panel a) and cartel breakdown (panel b) over time. Cartels in EN

which any auction finished in each round, which may have affected behavior across groups.

[18]Unless otherwise noted, the Wilcoxon rank-sum test is employed for comparisons between different treatments, and the Wilcoxon signed-rank-sum test is used for within-treatment comparisons. All tests are two-sided, with each re-matching group taken as one independent observation in the non-parametric tests. All reported statistics that correspond to out non-parametric tests are based on matching group averages over rounds 6 to 35. We find quantitatively the same results when we take all rounds into account.

[19]Our definition of cartel stability is arguably conservative. Our results do not change qualitatively when relaxing the definition to instances where the designated winner wins (see Sections 3.4.2 and 3.5.2 where we discuss efficiency).

are substantially more likely to be stable than cartels in FP. Subjects defect in 69% of the cases in FP and in 45% of the cases in EN. As a result, in FP 92% of the cartels break down, as opposed to 68% in EN. In other words, cartels are about 4 times more likely to be stable in EN than in FP, a difference that is statistically significant ($p = 0.018$). These results are consistent with hypothesis **H1**. As we will discuss in Section 3.4.3, the fact that many cartels break down in EN as well is in line with equilibrium.

Table 3.1: Cartel instability and efficiency measures, across auctions

	Propensity to defect (by subject)	Cartel breakdown	Probability that a cartel is efficient	Fraction of maximum efficiency
EN	0.45 (0.20)	0.68 (0.19)	0.93 (0.04)	0.98 (0.02)
	$\wedge^{**}$	$\wedge^{**}$	$\vee^{***}$	$\vee^{***}$
FP	0.69 (0.11)	0.92 (0.08)	0.78 (0.05)	0.93 (0.02)

Notes: Propensity to defect (by subject) = probability that a designated loser submits a bid; Cartel breakdown = probability that at least one designated loser submits a bid; Probability that a cartel is efficient = probability that the designated winner wins the auction; Fraction of maximum efficiency = the ratio of the difference between the winner's value and the lowest value, and the difference between the highest and the lowest value in the cartel; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3.2: Cartel instability and bidders' valuations, across auctions

	Average value unstable cartels		Average value stable cartels	SD of values unstable cartels		SD of values stable cartels
EN	45.75 (0.90)	$>$	45.17 (3.44)	12.45 (0.38)	$<$	14.32 (4.90)
FP	45.59 (0.28)	$>$	41.79 (5.85)	12.46 (0.36)	$<$	12.48 (2.39)
	$v_1 - v_2$ in unstable cartels		$v_1 - v_2$ in stable cartels	Probability that bidder with 2^{nd} value defects		Probability that bidder with 3^{rd} value defects
EN	9.60 (0.71)	$<$	10.56 (4.04)	0.53 (0.18)	$>^{**}$	0.36 (0.22)
FP	9.90 (0.55)	$<$	13.98 (5.63)	0.86 (0.09)	$>^{**}$	0.51 (0.15)

Notes: v_1 and v_2 are the highest and second-highest values in a cartel, respectively; Unstable cartel = at least one designated loser submits a bid; Stable cartel = no designated loser submits a bid; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Taking a closer look at the data, we observe that cartel stability is unaffected by the value draws. Table 3.2 presents our tests relating bidders' valuations to cartel stability, and Figure 3.2 shows the probability that a cartel breaks down as a function of the two highest values in the cartel. In FP, the average value draw for stable cartels is 41.79, and 45.59 for unstable cartels (no significant difference, $p = 0.124$), the concomitant standard deviations are 12.48 and 12.46 ($p = 1.000$) respectively, and the difference between the two highest values is, respectively, 13.98 and 9.90 ($p = 0.484$), and 10.56 and 9.60 ($p = 0.208$).[20] In FP (EN), 635 (390) of all 993 (646) defections were committed by the cartel member with the second highest value in the cartel. In FP, the probability that the cartel member with the second highest value in the cartel defects from the agreement, 0.86, is higher than the probability that the cartel member with the lowest value in the cartel defects, 0.51 ($p = 0.012$). For EN, these respective numbers are 0.53 and 0.36 ($p = 0.012$).[21]

Result 3.1: Cartel stability
The fraction of stable cartels is significantly greater in EN than in FP. In FP, 92% of all cartels break down, while in EN 68% of all cartels break down. In both auctions, cartel stability is not related to the average value in a cartel, value variance, or the difference between the highest and second highest value. The cartel member with the second highest value is significantly more likely to defect than the cartel member with the lowest value.

3.4.2 Revenue and efficiency

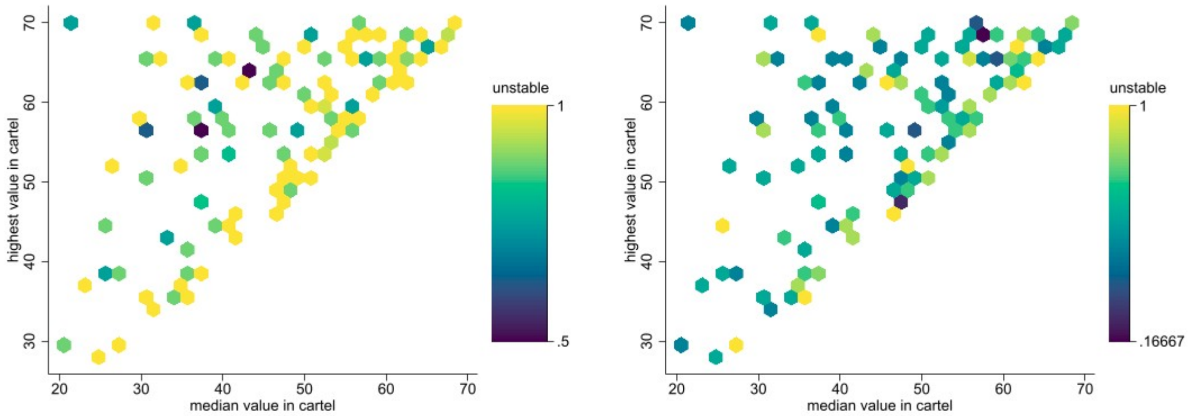
For the sake of comparability across rounds, we normalize revenue by reporting it as a fraction of the second highest value among the three bidders in a cartel. Table 3.3 contains the aggregate results and Figure 3.3 displays revenue for both stable and unstable cartels over time. In line with **H2**, normalized revenue is significantly lower in EN (0.58) than in FP (0.98). This is also true if we distinguish between stable and unstable cartels. In

[20]Comparing the highest, median, and lowest values between stable and unstable cartels yields similar results. For EN, the highest (median) [lowest] value in stable cartels, 57.57 (47.01) [30.93], does not differ from the concomitant value in unstable cartels, 56.74 (47.14) [33.38] (respective p-values: $p = 0.889$, $p = 0.327$, $p = 0.124$). For FP, the highest (lowest) value in stable, 54.36 (30.36), and unstable cartels, 56.70 (33.27), do not differ (respective p-values: $p = 0.327$, $p = 0.124$). For FP, the median value in stable cartels (40.38) is smaller than the median value in unstable cartels, 46.80 ($p = 0.093$).

[21]In 16 auctions, both the designated losers were assigned the same value, but a strictly lower value than the designated winner. In this case, both designated losers are counted as having the second highest value in the auction.

Figure 3.2: Cartel breakdown probability as a function of the two highest values in FP (panel a) and EN (panel b)

(a) Panel a (b) Panel b



EN, revenue for stable cartels (which is zero by construction) is significantly lower than revenue for unstable cartels. In FP, there is no significant difference in terms of revenue between stable and unstable cartels. Revenue of unstable cartels in EN is significantly lower than revenue of stable cartels in FP ($p = 0.009$).[22]

Table 3.3: Revenue of stable and unstable cartels, across auctions

	FP		EN
Stable Cartels	0.97 (0.10)	$>^{***}$	0.00 (0.00)
	$\wedge$		$\wedge^{**}$
Unstable Cartels	0.99 (0.02)	$>^{***}$	0.85 (0.10)
All Cartels	0.98 (0.03)	$>^{***}$	0.58 (0.16)

Notes: Stable cartel = no designated loser submits a bid; Unstable cartel = at least one designated loser submits a bid; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

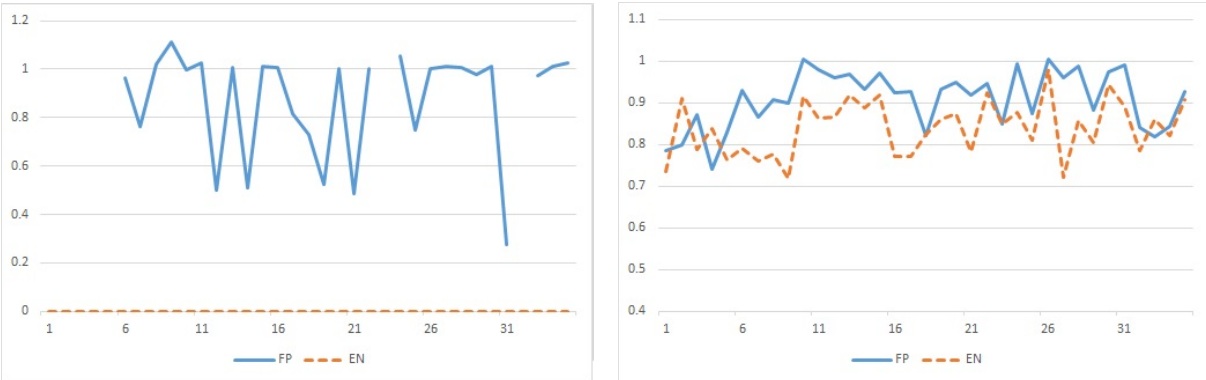
The variance in revenue in EN is 0.198, which is significantly higher than the variance of 0.012 in FP ($p = 0.001$). As Figure 3.4 shows, fundamentally different revenue distributions underlie this observed difference. For both auctions, a large fraction of revenue is

[22]The observation that winning bids in a stable cartel in FP are almost 100% of the second highest value is explained by the facts that (1) before the auction, the designated winner was not informed whether designated losers entered the auction and (2) the fraction of stable cartels (in which the other two bidders did not enter the auction) among all auctions is very low (8%).

concentrated around the second highest value. In addition, in EN a spike in the distribution of revenue arises at 0 due to stable cartels, that yield no revenue by construction. Such a spike is not visible in FP. As a result, the variance in revenue is much lower in FP than in EN. We discuss individual bidding behavior underlying the revenue distributions in the next subsection.

Figure 3.3: Revenue as a fraction of the second highest value for stable cartel (panel a), and unstable cartels (panel b), over time

(a) Panel a (b) Panel b



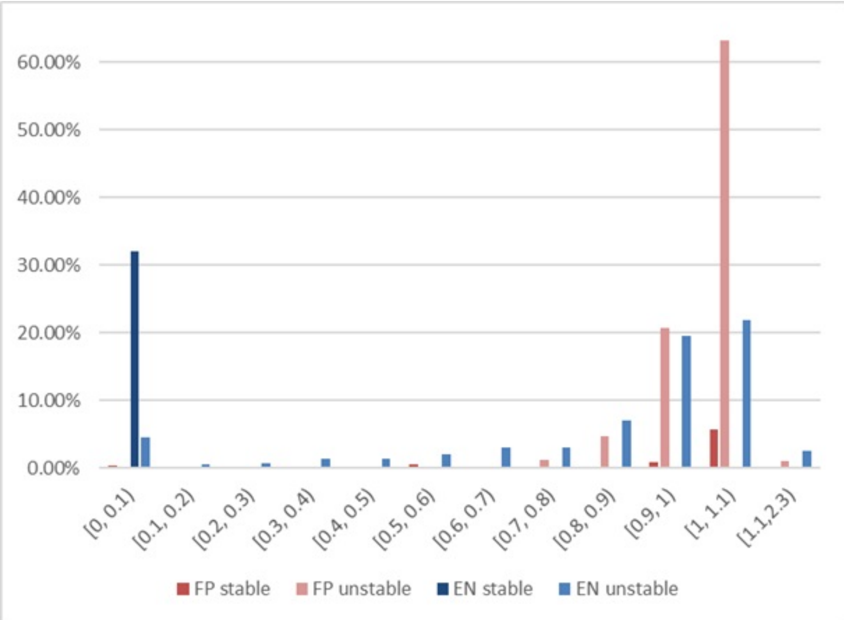
Result 3.2: Revenue
EN raises significantly less revenue than FP. The variance of revenue as a fraction of the second highest value is significantly higher in EN than in FP.

How do the auctions perform in terms of efficiency? Table 3.1 also reports our concomitant results. An auction is efficient if, and only if, the bidder with the highest value wins the auction. In other words, efficiency dictates that the designated winner secures the object. This happens in 78% of the cases in FP and 93% of the cases in EN. This difference is significant ($p = 0.001$). An alternative measure of efficiency is the ratio of realized to maximum efficiency $\frac{w-v}{V-v}$, where w is the winner's value, and v [V] refers to the lowest [highest] value in the cartel (see e.g. Hu et al. (2011)). Using this measure, efficiency in EN is 98%, which is significantly higher than the efficiency of 0.93 in FP ($p = 0.005$).

Result 3.3: Efficiency
EN is more efficient than FP.

Result 3.3 is in line with **H3**. The relative inefficiency of FP is rooted in off-equilibrium behavior in that designated winners frequently bid lower than the second highest value minus one bid increment, as we will discuss in the next subsection. As a result, they are sometimes outbid by a designated loser so that the object does not end up in the hands of the bidder having the highest value.

Figure 3.4: Relative frequencies of revenue as a fraction of the second highest value

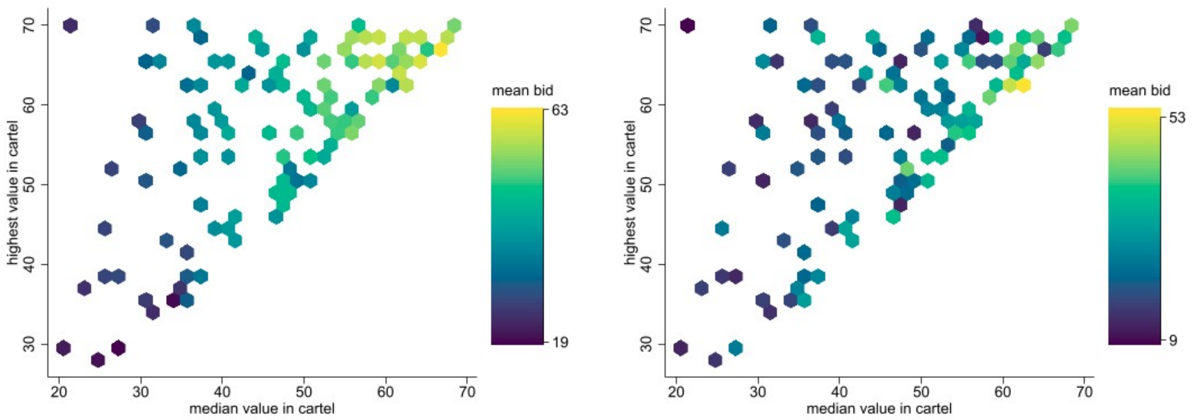


3.4.3 Bidding behavior

To what extent is bidding behavior consistent with equilibrium play? Figure 3.5 shows average bids of designated winners as a function of the two highest values in the auction. For FP, the designated winner bids at least the second highest value in equilibrium according to Corollary 3.2. As Proposition 3.2 shows, a large range of Nash equilibria produces such an outcome. Such equilibria have in common that (1) the designated winner surely wins if her value differs more than two bid increments with the second highest value, (2) she bids an amount at least equal to the second highest value minus one bid increment, and (3) at least one of the designated losers submits a bid of at least the second highest value minus one bid increment, such that the designated winner could not reduce her bid and still win. The observed bidding behavior deviates from this pattern in that we observe that (1) the designated winner secures the object in only 78% rather than at least 85.56% of the cases, (2) the bid of designated winners (0.92) is significantly below the second highest value ($p = 0.012$), and (3) bids of designated losers (0.76) are significantly below the second highest value ($p = 0.012$).[23]

Figure 3.5: Average bids by designated winners as a function of the two highest values in the auction in FP (panel a) and EN (panel b)

(a) Panel a (b) Panel b



To get a more refined picture of deviations from equilibrium play in FP, we compare actual bidder behavior with the bidders' best responses to the empirically observed bidding behavior by the bidders in their matching group. We separately analyze the bidding behavior of designated winners and designated losers.[24] We predict the bids of all bidders using a linear bid function with the three values in the auction as predictors, and apply a two-step procedure to correct for the fact that not all designated losers submit a bid. These estimates are used to predict the bid distributions for each auction, one for each subject. The risk-neutral best response of subject i having value V is then estimated as

$$\arg\max_{b \in \{0,1,\ldots,70\}} (V - b)\hat{G}(b), \tag{3.1}$$

where $\hat{G}(b)$ is the distribution of the maximum bid that subject i is expected to face.[25] We compute the difference between the estimated best response and the actual bid at subject-auction level, and then obtain matching group averages of this difference which we subsequently test against zero using a Wilcoxon rank sum test. Bids, as a fraction of the second highest value, (0.91 on average) and estimated best responses (0.92) of designated winners do not differ significantly ($p = 1.000$). Designated losers with the highest value in an auction who submit a bid, bid significantly lower (0.85) than the estimated best

[23] In only seven cases did the designated loser bid above value, resulting in winning the auction on four occasions.

[24] Details are in Appendix 3.C.

[25] $\hat{G}(b)$ is the product of the other two subjects in the auction.

response (0.92) ($p = 0.000$). Likewise, designated losers with the lowest value in an auction who submit a bid, bid significantly less (0.59) than the estimated best response (0.74) ($p = 0.000$). However, bidding the best response always yields positive profits in expectation: sticking to the cartel agreement is not *ex ante* optimal for designated losers.[26] In sum, designated winners best-respond on average to the bidding behavior of designated losers, whereas designated losers could do better by always defecting from the cartel agreement, and submitting higher bids than they did on average.

While the observed behavior could point to collusion,[27] it is miles away from the collusive outcome in which both designated losers abstain from bidding. It is not obvious what drives these results. Cognitive limitations of designated losers is an unlikely explanation as designated winners do best respond, and all subjects randomly alternate between being designated winners and designated losers throughout the experiment. A possible explanation is that subjects view the cartel agreement as a promise, and have a preference for sticking to promises.[28]

In EN, an even larger range of outcomes can be supported in equilibrium than in FP. In any equilibrium, (1) designated losers, when submitting a bid, leave the auction at a price between 0 and the highest value, (2) the designated winner stays in the auction until the price reaches her value, and (3) the designated winner wins the auction. Observed behavior is reasonably in line with this prediction. The designated winner typically does not exit the auction at a price below her value: only in 44 instances (6% of all auctions), the designated winner leaves the auction at a price below her value allowing a designated loser to win.[29] As said, in 32% of the cases, the bidders reach the collusive equilibrium outcome in which both designated losers abstain from bidding and the designated winner obtains the object for a price of zero. There are two typical scenarios when a designated

[26]Risk aversion does not offer an explanation either because the designated loser always earns at least zero when winning with a bid below value.

[27]We find no evidence of an end-game effect whereby designated losers start bidding their best response in the final rounds of the experiment. Restricting our analysis to all rounds past the 30^{th} round, we find that designated losers with the highest value in the auction bid (0.87) significantly less than their best response (0.92) ($p = 0.007$). The concomitant values for designated losers with the lowest value in the auction are 0.60 and 0.67 ($p = 0.007$). See Appendix 3.C for more details.

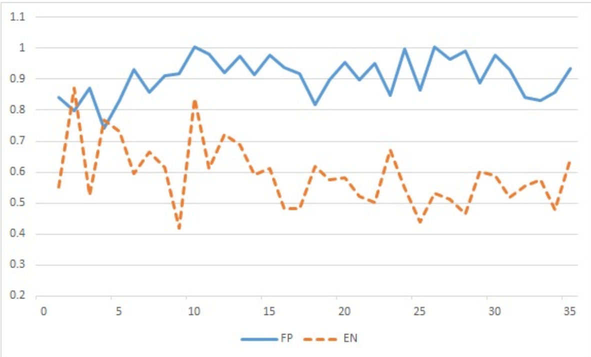
[28]Vanberg (2008) documents a preference for promise keeping per se.

[29]In 27 of those cases, the winning bid of the designated loser was below her value. Across rounds, designated winners tend to learn avoiding losing the auction by dropping out at a price below their value. Considering all rounds, disproportional 55% of all such cases occur in the first 10 rounds. The size of the mistake also tends to decline: in the first 10 rounds, 84% of the designated winners losing the auction drops out at a price more than 10 below value, while after round 10, only 42% does so.

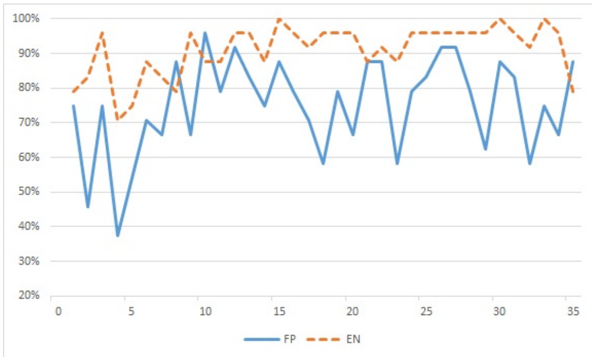
loser submits a bid: either the designated loser leaves the auction almost immediately, or she exits the auction at a price close to her value. More specifically, 7.89% bid 0, 4.64% bid in the interval $[1, 5]$, and 63.16% bid in the interval $[\text{value} - 5, \text{value}]$.[30] In line with equilibrium, deviating from the agreement is hardly profitable. The price paid by a designated loser winning the auction does not differ significantly from the second highest value ($p = 0.484$).[31] As we observed in the previous section, the designated winner wins in 93% of the cases.

Figure 3.6: Designated winners' bids as a fraction of the second highest value (panel a) and the likelihood of winning the auction (panel b), over time

(a) Panel a



(b) Panel b



Does behavior converge towards equilibrium play over time? Figure 3.6 suggests it does. The figure shows the bids of the designated winners over time (panel a), and the probability that the designated winner wins the auction (panel b).[32] In EN, after round 10, designated winners are almost certain to win the auction, which is in line with equilibrium. In FP, bids by the designated winner exhibit a non-significant upward trend towards the second highest value, with a concomitant increase of the likelihood that the designated winner wins the auction.[33]

Result 3.4: Bidding behavior

In FP, designated winners and deviating designated losers submit a bid close to, but statistically significantly below, the second highest value. In EN, designated

[30]In 86 auctions (13.31% of all defections) a designated loser left the auction at a price exceeding her value, which resulted in winning the auction 21 times.

[31]Over all rounds, the designated loser pays significantly less than the second highest value ($p = 0.017$).

[32]For EN, the "bids" refer to the price paid by the designated winner when winning the auction, and to the dropout price otherwise.

[33]Appendix 3.D provides regressions investigating the trend of bids and convergence point of FP.

winners hardly ever leave the auction at a price below their value while designated losers that submit a bid either step out of the auction almost immediately or exit the auction at a price close to their value.

3.5 Study 2: Fixed matching

In the previous section, we observed that cartels are more likely to be stable in EN than in FP, although also in EN the majority of the cartels break down. The purpose of this second study is to test the robustness of this result in the case of repeated interaction.[34] The experimental procedures are the same as in Study 1 with the only exception that the three subjects that where matched at the beginning of the session remained in the same group over the course of the experiment. In both FP and EN, 27 subjects participated yielding nine independent observations per auction. Subjects earned 12.67 euros on average in sessions that lasted, again, between 60 and 90 minutes. As we explain in more detail below, the results are qualitatively very similar across Studies 1 and 2.

In line with Result 1, under fixed matching, the fraction of stable cartels is significantly greater in EN than in FP. In FP, 92% of all cartels break down, while in EN 68% of all cartels break down. For cartels in both FP and EN, the designated loser with the highest value defects significantly more often than the designated loser with the lowest value.[35] How do the value draws affect cartel stability? In EN, the average value is 46.06 for unstable cartels and 43.21 for stable cartels ($p = 0.345$), and the concomitant standard deviations are 11.66 and 13.13 ($p = 0.116$). For FP the corresponding numbers are 46.28 and 38.78 ($p = 0.018$), and 12.27 and 13.75 ($p = 0.237$). In other words, in FP, cartels are more likely to break down when bidders draw larger values. Also, in FP, the difference between the highest and second highest value is 18.96 for stable cartels and 11.08 for unstable cartels. The latter is significantly below the former ($p = 0.018$). In EN, these differences are, respectively, 13.86 and 8.58 ($p = 0.028$). That is, cartel defection is more likely to occur the smaller is the difference between the highest and second highest value. So, in contrast to the re-matching condition, we observe that value-draws affect cartel stability in the fixed-matching condition, at least to some extent.

As with re-matching, revenue is lower in EN than in FP. This also holds (again)

[34] In practice, cartels often center around a set of bidders that interact repeatedly (Phillips et al., 2003).

[35] For auctions in FP, the designated loser with the highest value defected in 77.66% of all cases, while the designated loser with the lowest value defected in 51.04% of the cases ($p = 0.008$). In EN, these numbers are, respectively, 39.76% and 26.04% ($p = 0.042$). See Table 3.8 in Appendix 3.E for further details.

if we consider stable and unstable cartels separately, although there is no statistically significant difference anymore between the revenue of unstable cartels. Moreover, the variance of revenue is significantly lower in FP than in EN, as with re-matching. Again, efficiency is higher in EN than in FP. More details are in Tables 3.9 and 3.10 in Appendix 3.E. All in all, Results 3.2 and 3.3 are robust with respect to the matching protocol.

The similar results across matching protocols for cartel stability, revenue, and efficiency suggests that the underlying bidding behavior is also similar. This indeed turns out to be the case. In FP, (1) the designated winner secures the object in 73% of the cases, (2) the bid of designated winners (0.87) is significantly below the second highest value ($p = 0.011$), and (3) the bid of designated losers that submit a bid (0.74) is significantly below the second highest value ($p = 0.008$).[36] These bidding patterns suggest that also with fixed matching the designated winner weighs the possibility that no designated loser submits a bid against the likelihood of defection. In contrast to the re-matching case, observed deviation is profitable: If designated losers win the auction, their winning bid is significantly below the second highest value ($p = 0.015$).

In EN, as with the re-matching case, the designated winner typically does not exit the auction at a price below her value, and wins the auction in 93% of the cases. Only in 7.41% of all auctions, a designated loser secures the object at a price below the designated winner's value. The collusive equilibrium outcome, in which both designated losers do not submit a bid, emerges in 55% of all cases. Designated losers that submit a bid tent to step out of the auction at a price close to their value. More specifically, only 1.16% bid in the interval $[0, 5]$, while 50.87% bid in the interval $[\text{value} - 5, \text{value}]$.[37]

How do the auction outcomes differ between the re-matching condition (Study 1) and the fixed matching condition (Study 2)? Repeated interaction, as with the fixed matching case, does not affect the collusive properties of EN; cartels remain stable in equilibrium. However, from the theory of supergames (Friedman, 1971), it follows that stable cartels may form in FP too if the auction is repeated an indefinite number of rounds and if bidders are "patient enough" (Aoyagi, 2007). A stable cartel emerges in equilibrium if bidders play a grim strategy that tells the designated losers to abstain from bidding and the designated winner to bid zero in all rounds up to the point that some bidder deviates. From then on, all bidders bid according to a one-shot Nash equilibrium in all subsequent rounds.

[36] In 19 cases did a designated loser bid above value, resulting in winning the auction on 12 occasions.

[37] The bids of designated losers are significantly below the second highest value in the cartel ($p = 0.018$). In 62 of all 173 defections, the designated losers bids above her value. In 7 of those cases, the designated loser won the auction.

While the theory suggest that the matching protocol may affect auction outcomes, we do not find substantive differences between the two studies, at least not in the sense of statistical significance.[38] For both auctions, defection and cartel breakdown is not significantly less likely in the case of fixed matching than in the case of re-matching. Moreover, revenue and revenue variance do not differ statistically between the two matching protocols. The matching protocol does not significantly affect efficiency for E; for FP, efficiency is (marginally) significantly lower under re-matching than under fixed matching, but only in terms of potential value realization.[39] Finally, for both auctions, designated winners' and designated losers' bidding strategies do not differ significantly between the fixed-matching and re-matching protocols. However, given the small sample sizes, one should be cautious in interpreting the insignificant differences, also because non parametric tests tend to be more conservative than parametric tests.

Result 3.5: Fixed matching vs. re-matching
For both FP and EN, the two matching protocols do not differ statistically significantly in terms of cartel stability, revenue, efficiency, and bidding behavior.

3.6 Conclusion

Bidding rings are commonly observed in antitrust cases. In the 1980s, about 75% of the U.S. cartel cases were related to auctions (Krishna, 2009). Based on more recent data, Agranov and Yariv (2018) report that since 1994, around 30% of the antitrust cases filed by the U.S. Department of Justice involve collusion in auctions.[40] This begs the question as to what is the best way to fight bidding rings.[41] The theoretical result of Robinson (1985) that cartels are more stable in the English auction than in the first-price sealed auction would suggest that auction designers should follow the advice of the OECD (2006)

[38]More details regarding the comparison across matching protocols are in Table 3.8, 3.9, 3.10 and 3.11 in Appendix 3.E.

[39]For all rounds, the difference is statistically significant at the 5% level ($p = 0.021$).

[40]The set of bidding rings discovered by antitrust authorities may only be the tip of the iceberg. Kawai and Nakabayashi (2018) estimate that almost 40% of 15,000 Japanese construction projects is inconsistent with competitive behavior, suggesting that the number of bidding rings is substantially greater than the four cartel cases that were initiated in connection with the projects in their sample. McMillan (1991) presents anecdotal (and amusing) evidence about how bidders for Japanese public-works contracts organize and enforce cartel agreements. Based on simulations, he estimates that the excess profits from collusion amount to 16% to 33% of the price.

[41]Hinloopen and Onderstal (2014) observe antitrust policies to be ineffective in the English auction and only partially effective in the first-price sealed-bid auction.

to use the first-price sealed-bid auction rather than the English auction in environments where collusion is a significant threat (p.36). However, Hu et al. (2011), Llorente-Saguer and Zultan (2017), and Agranov and Yariv (2018) fail to provide empirical support to the OECD's advice in that they do not find the auctions to differ in terms of collusion. Indeed, why does Robinson's (1985) insight not hold true experimentally? Our experiment is a first step in addressing this question by studying the collusive properties of the two auctions in a simple setting. In contrast to the earlier experimental evidence, our results are in line with the theory in that in our experiments, cartels are more stable and average revenue is lower in the English auction than in the first-price sealed-bid auction.

We conclude that Robinson's (1985) intuition works in simple settings, which serves as a starting point in gaining insight as to why it fails to work in the more complex settings studied by Hu et al. (2011), Llorente-Saguer and Zultan (2017), and Agranov and Yariv (2018). Two potential reasons why our results are differ from theirs come to mind. First of all, in our set-up (and in line with Robinson (1985)) cartels are exogenously imposed. While this is instrumental in identifying the effect of auction format on cartel stability, in practice, cartel formation may be endogenous. Second, we impose common knowledge of values among bidders. Indeed, by doing so, our experimental design mimics Robinson's (1985) framework on which we build our hypotheses. The experiments to date differ in too many dimensions to identify the key conditions under which the advice of the OECD applies. Further experimental research should create a more detailed map of how the relative performance of the two auctions in terms of collusion depends on the endogeneity of cartel formation, whether or not the values are common knowledge, the precise auction rules, the way bidders can communicate, the possibility of side payments, the number of bidders, the value structure, and so forth.

3.A Proofs of propositions

This appendix contains the proofs of Propositions 3.1 and 3.2. To avoid tedious case distinctions, we prove the propositions for $v_1 \geq v_2 + 3\varepsilon$ and $M \geq v_1 + 2\varepsilon$. The proofs proceed analogously for other parameter constellations.

Proof of Proposition 3.1

When reached, in any final subgame, i.e., at price $M - \varepsilon$, leaving the auction is a dominant strategy for all remaining bidders. As a result, each bidder's equilibrium payoffs when reaching the final subgame are strictly negative. Reasoning backwards, all bidders leave the auction in equilibrium when reaching any price $p > v_1$. At price $p = v_1$, for all bidders apart from bidder 1, it is a strict best response to leave the auction. Bidder 1, in turn, best responds by remaining (and paying $v_1 - \varepsilon$). At any price $p < v_1$, when reached, remaining in the auction is a strict best response for bidder 1. On the equilibrium path, the other bidders are indifferent between not entering the auction and entering and leaving at any price $p \leq v_1$.

Proof of Proposition 3.2

Let, for $i = 1, \dots, n$, b_i denote the bid submitted by bidder i, where, by convention, $b_i = -1$ if bidder i does not enter the auction. Define $b_{-1} \equiv \max\{b_2, b_3, \dots, b_n\}$ as the highest bid submitted by the bidders other than bidder 1. We distinguish 4 cases.
Case 1: $b_{-1} \leq v_2 - 2\varepsilon$. Bidder 1's unique best response is to bid $b_1 = b_{-1} + \varepsilon$. However, bidder 2's bid cannot be part of the equilibrium because bidder 2 is strictly better of by bidding b_1 instead of b_2.
Case 2: $v_2 - \varepsilon \leq b_{-1} \leq v_1 - 3\varepsilon$. Bidder 1's unique best response is to bid $b_1 = b_{-1} + \varepsilon$. An equilibrium is established as b_i is a best response for bidders $i = 2, 3, \dots, n$.
Case 3: $b_{-1} = v_1 - 2\varepsilon$. If $b_1 = b_{-1} + \varepsilon$, an equilibrium is established. If $b_1 = b_{-1}$, bidder $k > 1$ for whom $b_k = b_{-1}$ is strictly better off by biding $b_{-1} - \varepsilon$, so that bidder k's bid cannot be part of an equilibrium.
Case 4: $b_{-1} \geq v_1 - \varepsilon$. For bidder 1's best response bid b_1 it holds true that $b_1 \leq b_{-1}$. However, bidder $k > 1$ for whom $b_k = b_{-1}$ is strictly better off by bidding $b_{-1} - \varepsilon$, so that bidder k's bid cannot be part of an equilibrium.
So, any equilibrium belongs to either case 2 or case 3, resulting in the equilibrium set described in the proposition.

3.B Instructions

The instructions are computerized. Subjects could read through the html-pages at their own pace. Below is a translation of the Dutch instructions for the English auction with fixed groups. The instructions for the other treatments are available from the authors upon request.

Welcome!

You are about to participate in an auction experiment. The experiment consists of at least **35 rounds** and each round consists of **2 steps**. Those steps are the same in each round and will be explained later in more detail.

In every round of the experiment, all participants will be randomly divided in **groups of 3** members. This will be done in such a way that participants will never be in the same group in two subsequent rounds; at the beginning of every round, you will be matched with two other participants than in the previous round.

Group members remain anonymous; you will not know with whom you are matched. Moreover, there will not be contact between separate groups during any round.

From round 35 onwards, a next round starts with 80% probability. In other words, from round 35 onwards, the experiment stops with 20% probability.

Earnings

In every round of the experiment, you can earn points. At the end of the experiment, points will be exchanged for Euros. The exchange rate will be **50 points = 1 euro**.

At the beginning of the experiment, you will receive a **starting capital of 350 points**. At the end of every round, the points you will earn in this round will be added to your capital. If you earn a negative number of points in a round, these points will be subtracted from your capital.

In the remainder of these instructions, we will present an overview of the experiment followed by a further explanation of the two steps that are played in each round. We will conclude with examples and test questions.

Overview of the experiment

In every round, a product can be bought. Only 1 item of the product is available in each round. The product is sold in an **auction**.

Every round consists of two steps.

In **step 1**, all groups members learn their value for the product in the current round. The bidders also learn about an agreement as to who of the three group members will participate in the auction (and who will not). This agreement is made on your behalf; you only learn the outcome of the agreement as far as it concerns you. The agreement is not binding. Subsequently, you indicate whether or not you want to participate in the auction. The other group members have to decide as well at the same moment. Group members only know their own choice regarding auction entry.

In **step 2**, the product is auctioned. Only group members who indicated to be willing to participate in the auction can submit a bid. You only earn points if you win the auction. If you win, the number of points that you earn in the auction will be equal to **your value – the winning bid**.

Now, an explanation of both steps follows.

Step 1: Agreement

At the start of each round, you will be informed about your value for the auctioned product. This value differs from one round to the next. You are also informed about the other group members' value for the product. Values are always in between 20 and 70 points and are drawn at the start of every round. This happens randomly: Every value between 20 and 70 is equally likely. The value for each group member is independent of the values of the other two group members. The values are also independent of the round that is being played.

At the start of each round, you will also be informed about the agreement between all group members. According to this agreement, the group member with the highest value is the only one submitting a bid in the auction. This is the designated winner. The agreement is not binding though.

Finally, you have to decide in step 1 of each round whether or not you want to submit a bid in the auction. To answer the question "Would you like to submit a bid?" you must press "yes" or "no". The two other group members simultaneously answer the same question.

Step 2: The auction

The auction is an increasing "thermometer": the price starts at 0 and is raised in steps of 1 point. While the thermometer increases, all participating bidders can click on the Stop button. A bidder who presses the Stop button leaves the auction. All bidders observe the price at which a bidder presses the Stop button (but not which bidder it is). The auction stops when only one bidder remains who has not pressed the Stop button.

The bidder who has not pressed the Stop button, wins the auction. He or she pays the price at which the auction stopped. This is the price at which the second-last remaining bidder pressed the Stop button.

If only one bidder participates in the auction, the auction stops directly at a price of 0.

Step 2: The auction (continued)

If the remaining two (or three) bidders happen to press the Stop button at the same price, chance determines which bidders buys the product. Also in this case, the auction winner pays the price at which the thermometer stops.

The thermometer always stops at a price of 70. If at this price, two or three bidders have not pressed the Stop button, chance determines which of those bidders buys the product (for a price of 70). Invisibly to the bidders, the thermometer always runs up to 70, even if the auction stops at a lower price. The next round only starts when the thermometer has reached 70.
The auction winner obtains **the winner's value – the winning bid** The other group members obtain zero points.

If in step 1 all group members choose not to participate in the auction, the product will not be auction and all group members (including the designated winner) obtain zero points.

3.C Out of equilibrium bidding behavior for the first-price sealed-bid auction

This appendix outlines our analysis of out-of-equilibrium bidding behavior in FP. We estimate bidding functions to generate empirical best responses for designated winners and designated losers, and compare best responses to actual bids. We find that designated winners best respond to designated losers' bidding behavior, while designated losers should always defect and bid more conditional on defection. We first turn to the analysis of designated winners' bidding behavior.

To generate an empirical best response of designated winner i in auction c, we need to predict the bid of each designated loser in auction c conditional on the values of all subjects in the auction. We need to take into account that designated winner i does not observe the identity of the designated losers she faces in auction c, but can predict their bids from observed behavior of designated losers in all auctions of i's matching group. In the main text, we show that designated losers with the highest value are significantly more likely to submit a bid than designated losers with the lowest value. We therefore estimate two separate bidding functions for each designated winner i: one to predict bids of the designated loser with the highest value, and one to predict bids of designated losers with the lowest value. The sample used to predict bids of the designated loser with the highest value contains all auctions in i's matching group where subject i was not the designated loser with the highest value. Likewise, the sample used to predict the bid of the designated loser with the lowest value contains all auctions in i's matching group where subject i was not the designated loser with the lowest value. We therefore assume that designated winner i only takes into account behavior of subjects she actually encounters in the experiment, and the values in an auction. We Heckman's two-step procedure to correct for selection effects: not all designated losers submit a bid. This procedure is run separately for each subject i.

As an example, consider designated winner i in auction c. We now outline the estimation of the predicted bid for the designated loser with the highest value in auction c. Recall that the sample consists of all auctions j in subject i's matching group provided subject i is not the designated loser with the highest value in auction j. This implies that we will obtain subject-specific estimates, and, as a consequence, subject-specific best-responses to a value draw. Let $\tilde{b}_j$ be a binary variable that equals one when the designated loser with the highest value in auction j submits a bit, and b_j be the bid that is submitted if that designated loser does indeed defect. The selection equation is:

$$Pr(\tilde{b}_j = 1) = \Phi(\alpha_0 + \alpha_1 v_j^1 + \alpha_2 v_j^2 + \alpha_3 v_j^3 + \alpha_4 X_t), \tag{3.2}$$

where v_j^k indicates the k^{th} highest value in auction j, and X_t consists of variables relating to the round auction j occurred in. We report results for X_t consisting of round fixed effects, and X_t consisting of one dummy for the first five rounds (the early-dummy), and one dummy for all rounds after the 35^{th} round (the late dummy).[42] The bid equation is:

$$b_j = \beta_0 + \beta_1 v_j^1 + \beta_2 v_j^2 + \beta_3 v_j^3 + \beta_4 \hat{\lambda}_j + \epsilon_j, \tag{3.3}$$

where $\hat{\lambda}_j$ is the inverse Mills ratio (Wooldridge, 2010). The estimates of (3.3) allow us to construct the predicted bid of the designated loser with the highest value in auction c, conditional on the three values in auction c. Denote the estimated bid of the designated loser with the highest value in auction c by $\hat{b}_c^H$. Repeating estimation of (3.2) and (3.3) on the sample of all auctions j in subject i's matching group provided subject i is not the designated loser with the lowest value in auction j gives and estimated bid of the designated loser with the lowest value in auction c: $\hat{b}_c^L$. Denote the concomitant bid distributions by $F_H^{v_c^1, v_c^2, v_c^3}$ and $F_L^{v_c^1, v_c^2, v_c^3}$. Under (3.2), and the additional assumption that errors in (3.2) and (3.3) satisfy conditional mean independence, the estimated bids are asymptotically normal. As an approximation, we therefore have:

$$F_H^{v_c^1, v_c^2, v_c^3} \sim N(\hat{b}_c^H, se(\hat{b}_c^H)); \qquad F_L^{v_c^1, v_c^2, v_c^3} \sim N(\hat{b}_c^L, se(\hat{b}_c^L)). \tag{3.4}$$

Equation (3.4) allows us to construct the empirical best response of designated winner i in auction c. The best response of the designated winner i in auction c is:

$$b_i^{br} = \arg\max_{b \in \{0,1,\ldots,70\}} (v_i - b) G_i(b), \tag{3.5}$$

where $G_i(b) = F_H^{v_c^1, v_c^2, v_c^3} F_L^{v_c^1, v_c^2, v_c^3}$, and G is indexed by i to indicate that the estimated distributions differ by subject, and v_c^k is the k^{th} highest value in auction c. For each auction c, (3.5) gives the best response of the designated winner based on the bidding behavior of designated losers in her matching group, conditional on the values in auction

[42]Including a variable in the selection equation that is not present in the bid equation is necessary to prevent collinearity issues in the bid equation: the so-called exclusion restriction. Using variables related to rounds amounts to assuming that the designated winner in an auction anticipates round- (for round fixed effects) or begin- and end-game effects (for the early- and late-dummy specification) on defection.

c.

To determine the best response of the designated loser with the highest value in auction c, subject l, the above procedure is repeated twice with some slight alterations. To estimate the bid of the designated loser with the lowest value in the auction, the sample of all auctions in l's matching group such that subject l is not the designated loser with the lowest values is used. To estimate the bid of the designated winner, equation (3.3) is estimated by OLS, and equation (3.2) is omitted.[43] With both estimates in hand, equation (3.5) gives the best response of the designated loser with the highest value in auction c. The best response of the designated loser with the lowest value in auction c is determined similarly.

Table C1 shows comparisons of the estimated best responses from equation (3.5) to the actual bids.[44] Bids and estimated best responses of designated winners do not differ significantly, indicating that designated winners are best responding to the bidding behavior of designated losers in their matching group.[45] In all auctions the expected profit of submitting a bid equal to the best response is positive for all designated losers, suggesting that the 31% of designated losers that abstain from bidding are not best responding. In addition, designated losers who do submit a bid, bid less than the best response. Bids by designated losers with the highest value (0.85) are significantly below best responses (0.92).[46] Likewise, designated losers with the lowest value bid (0.57) significantly less than the estimate best response (0.70).[47] In sum, designated winners best respond to the bidding behavior of designated losers, whereas designated losers could do better by always defecting and bidding more conditional on defection. Table 3.4 shows that these results are robust to varying the exclusion restriction.

Table 3.5 shows comparisons of best responses to actual bids for all rounds past the 30^{th} round. We find no evidence for an end-game effect whereby designated losers start best responding. Bids by designated losers with the highest value (0.87) are significantly below best responses (0.92).[48] Likewise, designated losers with the lowest value bid (0.60)

[43]Selection is unimportant for designated winners as in all but 6 auctions, the designated winner submits a bid.

[44]As in the main text, we use non parametric tests that take each matching group average as one independent observation. We first compute the difference between the best response and the bid for individual bidders, and then compute matching group averages of these differences that we test against a difference of 0. Our results are robust to first generating matching group averages of bids and best responses, and then testing whether these averages are different.

[45]P-values: $p = 1.000$ for the round fixed effect specification, and $p = 0.370$ for the early- and late-dummy specification.

[46]P-values: $p = 0.000$ for both specifications.

[47]P-values: $p = 0.000$ for both specifications.

[48]P-values: $p = 0.007$ for the round fixed effects specification, and $p = 0.073$ for the early-

significantly less than the estimated best response (0.67).[49] Time-series of the difference between estimated best responses and actual bids are provided in Figures 3.7-3.9. Plotted are the mean +/- two standard deviations. If anything, designated losers bid below their best response in the latter rounds.[50] However, these end-game results should be interpreted with caution due to the small sample sizes underlying the matching group averages, and the ordinal nature of our non parametric tests.

Table 3.4: Comparison best responses to bids, first-price sealed-bid auction

	Designated winners	Designated losers (highest value)	Designated losers (lowest value)	Exclusion restriction
Best response	0.92 (0.02)	0.92 (0.05)	0.70 (0.01)	Round FE
	$\vee$	$\vee^{***}$	$\vee^{***}$	
Bids	0.91 (0.02)	0.85 (0.05)	0.57 (0.08)	
Best response	0.93 (0.02)	0.92 (0.04)	0.70 (0.01)	Early- and late-dummies
	$\vee$	$\vee^{***}$	$\vee^{***}$	
Bids	0.91 (0.02)	0.85 (0.05)	0.57 (0.08)	

Notes: Exclusion restriction = variables that are included in the selection equation, but not in the second stage; Early-dummy = dummy variable indicating an observation from the first 5 rounds; Late-dummy = dummy variable indicating an observation from rounds after the 35^{th} round; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

and late-dummy specification.

[49] P-values: $p = 0.007$ for the round fixed effects specification, and $p = 0.073$ for the early- and late-dummy specification.

[50] P-values: $p = 0.073$ for both specifications.

Table 3.5: Comparison best responses to bids for rounds 31 and onward, first-price sealed-bid auction

	Designated winners	Designated losers (highest value)	Designated losers (lowest value)	Exclusion restriction
Best response	0.92 (0.04)	0.92 (0.05)	0.67 (0.02)	Round FE
	$\vee^{*}$	$\vee^{***}$	$\vee^{***}$	
Bids	0.89 (0.14)	0.87 (0.07)	0.60 (0.09)	
Best response	0.90 (0.04)	0.92 (0.05)	0.67 (0.02)	Early- and late-dummies
	$\vee^{*}$	$\vee^{*}$	$\vee^{*}$	
Bids	0.89 (0.14)	0.87 (0.07)	0.60 (0.09)	

Notes: Exclusion restriction = variables that are included in the selection equation, but not in the second stage; Early-dummy = dummy variable indicating an observation from the first 5 rounds; Late-dummy = dummy variable indicating an observation from rounds after the 35^{th} round; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Figure 3.7: Difference between best responses and actual bids, designated winners

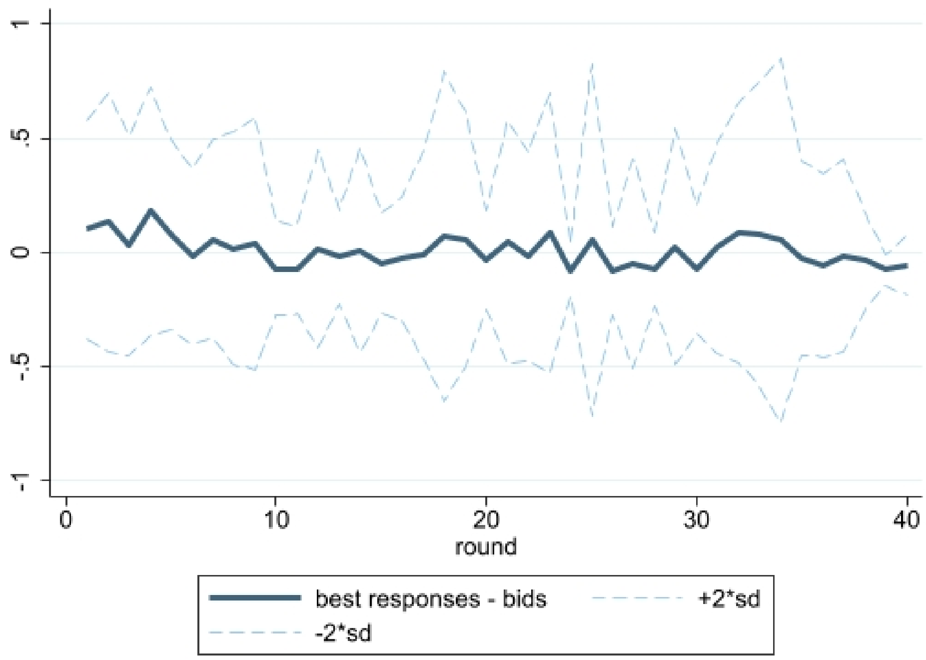


Figure 3.8: Difference between best responses and actual bids, designated losers with the highest value

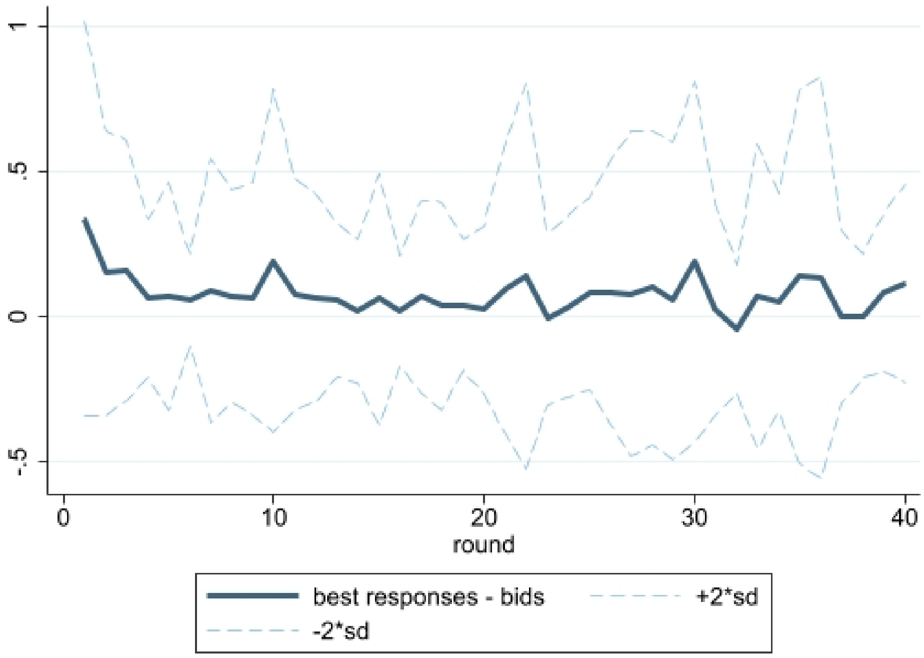
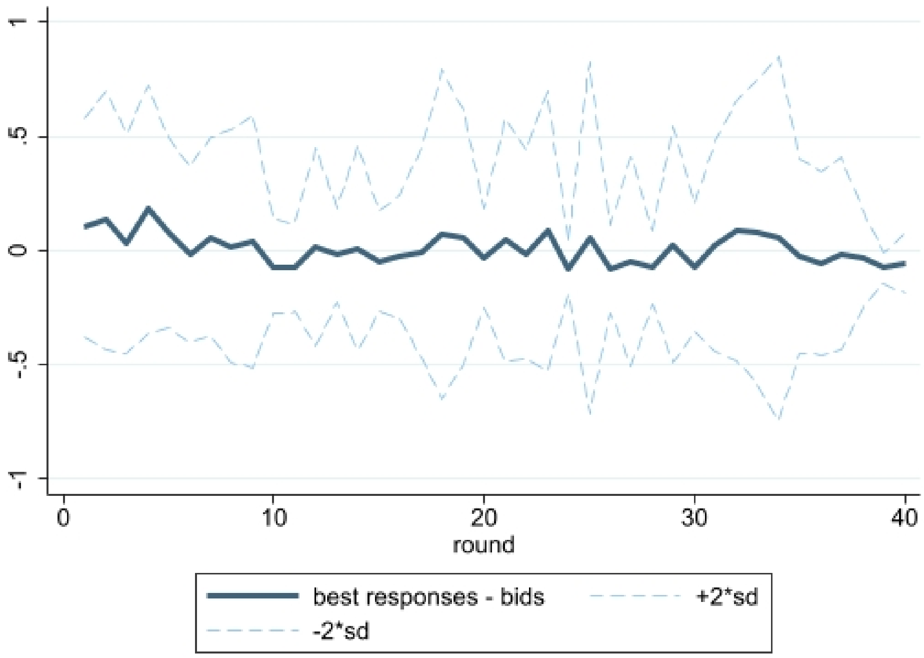


Figure 3.9: Difference between best responses and actual bids, designated losers with the lowest value



3.D Convergence of bidding behavior for the first-price sealed-bid auction

We estimate two fixed effects models to investigate possible convergence to Nash-equilibrium bidding behavior in first-price sealed-bid auctions, whereby we explicitly control for possible within-matching group correlations. For the first regression, we run the following specification separately for designated winners that submitted a bid, and designated losers with the highest value in the auction that submitted a bid:

$$\text{bid}_{it} = \beta_1 t + \alpha_i + u_{it}, \tag{3.6}$$

$i = 1, 2, \ldots, n$, $t = 1, \ldots, 40$, where n is the number of subjects, and bid_{it} is the submitted bid as a fraction of the second-highest value in the auction.[51] Standard errors are clustered at the matching group level. The regression results are in Table 3.6.

Table 3.6: Fixed effects estimates of bid-trend in first-price auctions

	Re-matching		Fixed Matching	
	Designated winners (1)	Designated losers (2)	Designated winners (3)	Designated losers (4)
Time trend	0.0015	0.0015	0.0073***	0.0083***
	(0.0012)	(0.0008)	(0.0012)	(0.0012)
Average FE	0.8881***	0.8196***	0.7075***	0.6564***
	(0.2428)	(0.1672)	(0.0236)	(0.0244)
Observations	906	798	347	287

Notes: Standard errors clustered at the matching group level in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

The second specification we estimate is a fixed effects model that examines convergence over time of the winning bids in first-price auctions. Again, we run this specification separately for designated winners that submit a bid, and designated losers with the highest valu in the auction that submit a bid:

$$\text{bid}_{it} = \beta_1 T1_t + \beta_2 T2_t + \alpha_i + u_{it}, \tag{3.7}$$

[51]Due to the random stopping rule, sessions need not have an equal number of rounds. No session had more than 40 rounds.

$i = 1, 2, \ldots, n$, $t = 1, \ldots, 40$, where n and bid_{it} are defined as before, $T1_t = \max\{0, 35-t\}$ and $T2_t = \max\{0, t-35\}$. Note that the inclusion of the two time trends implies that the average of the estimated value of α_i corresponds to the value of the scaled bid to which the bidding behavior converges in round 35. Standard errors are clustered at the matching group level. The regression results are in Table 3.7.

Table 3.7: Fixed effects estimates of bid convergence-point in first-price auctions

	Re-matching		Fixed Matching	
	Designated winners (1)	Designated losers (2)	Designated winners (3)	Designated losers (4)
Time trend 1-35	-0.0014	-0.0014	-0.0084^{***}	-0.0082^{***}
	(0.0015)	(0.0010)	(0.0012)	(0.0014)
Time trend 36-40	0.0037	0.0060	-0.0193	0.0099
	(0.0109)	(0.0065)	(0.0193)	(0.0113)
Average FE	0.9388^{***}	0.8694^{***}	0.9871^{***}	0.9457^{***}
	(0.0258)	(0.0156)	(0.0209)	(0.0222)
Observations	906	798	347	287

Notes: Standard errors clustered at the matching group level in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

3.E Additional tables

Table 3.8: Cartel instability, across auctions and matching schemes

	Propensity to defect (by subject)			Cartel breakdown		
	Re-matching		Fixed Matching	Re-matching		Fixed Matching
EN	0.45 (0.20)	>	0.32 (0.35)	0.68 (0.19)	>	0.45 (0.45)
	$\wedge^{**}$		$\wedge^{*}$	$\wedge^{**}$		$\wedge^{*}$
FP	0.69 (0.11)	>	0.64 (0.13)	0.92 (0.08)	>	0.88 (0.13)

Notes: Propensity to defect (by subject) = probability that a designated loser submits a bid; Cartel breakdown = probability that at least one designated loser submits a bid; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3.9: Revenue, across auctions and matching schemes

	FP		EN
Fixed matching			
Stable cartels	0.94 (0.22)	$>^{***}$	0.00 (0.00)
	$\vee$		$\wedge^{**}$
Unstable cartels	0.93 (0.12)	>	0.83 (0.22)
All cartels	0.93 (0.12)	$>^{***}$	0.42 (0.45)
	$\wedge$		$\wedge$
Re-matching	0.98 (0.03)	$>^{***}$	0.58 (0.16)

Notes: Stable cartel = no designated loser submits a bid; Unstable cartels = at least one designated loser submits a bid; standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3.10: Variance of revenue, across auctions and matching schemes

	FP		EN
Re-matching	0.012 (0.018)	$<^{***}$	0.198 (0.031)
	$\wedge$		$\vee^{***}$
Fixed Matching	0.018 (0.023)	$<^{*}$	0.070 (0.060)

Notes: Standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 3.11: Efficiency, across auctions and matching schemes

	Designated winner wins			Value realization		
	FP		EN	FP		EN
Re-matching	0.78 (0.05)	$<^{***}$	0.93 (0.04)	0.93 (0.02)	$<^{***}$	0.98 (0.02)
	$\vee$		$\vee$	$\vee^{*}$		$\vee$
Fixed matching	0.73 (0.08)	$<^{***}$	0.93 (0.09)	0.87 (0.07)	$<^{**}$	0.96 (0.05)

Notes: Standard deviation based on matching group averages in brackets; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Chapter 4

Corporate social responsibility by joint agreement*

4.1 Introduction

There is a growing realization that certain social objectives, such as diverting climate change, assuring fair trade that respects human rights, and promoting public health, urgently require drastic measures that governments often fail to take. With this realization have come appeals that corporations should take more social responsibility and serve wider stakeholder interests beyond mere shareholder value. A prominent recent call is that competitors best do this jointly, by coordinating their corporate social responsibility (CSR) activities. Nidumolu et al. (2014) claim that business collaboration is imperative to advancing sustainability. Kotchen and Segerson (2019) advocate voluntary collective agreements to solve commons problems in natural resource sectors such as forestry and fishery. Henderson (2020) calls for such "industry-wide cooperation" to stop environmental degradation and economic inequality. Permitting industry-wide CSR agreements is expected by these proponents to induce impactful corporate social responsibility efforts.

There have been several initiatives in recent years of companies joining together for good causes such as guarding against child labor and deforestation, or reducing the waste-

*This chapter is joint work with Maarten Pieter Schinkel and based on Schinkel and Treuren (2021a). We thank Robert Dur, Sander Onderstal, Yossi Spiegel, Jan Tuinstra, and Jeroen van de Ven for helpful discussions and suggestions. We also appreciate comments made by participants of various conferences and seminars in which we presented preliminary and partial findings from the research here reported on in full, including the 2018 IIOC in Indianapolis, the 2018 EARIE conference in Athens, 2019 BECCLE, 2019 SMYE, 2021 CLEEN, OECD conferences on *Sustainability and Competition* in 2020 and 2021, and the European Commission's conference, 4th February 2021, on *Competition Policy Contributing to the Green Deal.* Opinions and errors remain ours.

ful use of water and plastics. The Business Roundtable in 2019 united close to two hundred companies to “share a fundamental commitment to all of our stakeholders”, including the environment.[1] Examples include chocolate producers wanting to agree together to improve the livelihoods of cocoa farmer under the tutelage of the Fair Trade Advocacy Office, fashion labels joining to ban garment production involving sweatshops with the Fair Wear Foundation, and a recent joint pledge by truck manufacturers to phase out diesel engines by 2040 under the umbrella of automaker association ACEA.[2] Earlier examples of collaboration to induce CSR efforts are given in Lyon and Maxwell (2004) and Peloza and Falkenberg (2009).

In this chapter, we study what type(s) of joint CSR agreements amongst competitors can be expected to indeed advance CSR activities. The public interests to which CSR aims to contribute can require central coordination. Where governments fail to provide such coordination – for lack of legal instruments, information or political power – private coordination may be a solution. On the other hand, growing consumer appreciation and willingness to pay for products that are produced and sold more responsibly have elevated CSR as a dimension of product and corporate image differentiation. Companies increasingly recognize that consumers turn away from products that are seen as unjust, unfair and unsustainably manufactured.[3] This allows firms to monetize a comparative advantage in CSR on their rivals. Bansal and Roth (2000) and Porter and Kramer (2006) identified the strategic CSR business model, on which a large literature has developed since. Consumers wanting to buy from firms that are serious about their CSR is a fast growing force that compels corporations to take more responsibility for environmental and social objectives.[4]

If CSR allows firms to differentiate themselves, then joint agreements on CSR efforts amongst firms in the same industry eliminate one aspect of competition amongst them. For this reason, cooperative CSR initiatives raise antitrust concerns, which have been noted to discourage or block such initiatives.[5] Competition law scholars have pointed at

[1]Statement on the Purpose of a Corporation, 19 August, 2019. Obtained from https://www.businessroundtable.org/business-roundtable-redefines-the-purpose-of-a-corporation-to-promote-an-economy-that-serves-all-americans

[2]See respectively www.fairtrade-advocacy.org, www.fairwear.org and www.acea.be.

[3]See, for example, Iannuzzi (2017).

[4]Servaes and Tamayo (2013) stress the role of customer awareness, and in particular reputation, as a responsible company. Delmas and Colgan (2018) point out that while consumers' willingness to pay for CSR out of pure altruism may be small, it is boosted by perceived features such as improved performance, health attributes, savings, status and peer pressure.

[5]Henderson (2020), making a case in Chapter 6 for sustainable palm oil in which all firms agree “pre-competitive” to buy sustainable oil and push for sanctions against those of their competitors who do not behave accordingly, notes that there may be antitrust issues (page 169,

possibilities to exempt agreements that promote CSR benefits from cartel law.[6] Under the U.S. statutes on competition, the pursuit of wider public interests has little traction as an antitrust defense. Indeed, car manufacturers that agreed with the State of California to increase standards above the Federal standards for tailpipe emissions were promptly investigated for collusion.[7] In Europe there may be more legal leeway, but there are few precedents to date beyond washing machines and powders.[8] Proponents of deploying market power in the fight against climate change are calling for more guidance on when sustainability agreements may be permitted.[9]

The central premise of advocates of allowing joint agreements to promote CSR, is that corporations will take *more* social responsibility when they face *less* competition. It resonates with a literature that attributes erosion of social responsibility to market competition. Shleifer (2004) gives some examples of ethical behavior that can be undermined by competitive pressures and the need to cut cost. Falk and Szech (2013) and Bartling et al. (2015) find experimental evidence suggesting that intrinsic CSR behavior may be eroded in market settings – even though the number of competing subjects has no significant effect on that erosion.[10]

Yet empirical studies on the relationship between market competition and CSR efforts suggests predominantly the opposite. Delmas and Montes-Sancho (2010) critically assess a voluntary agreement in the U.S. on climate. Du et al. (2011) identify CSR as a challenger's competitive weapon against a market leader. Fernández-Kranz and Santalo (2010) and Flammer (2015b) establish with variations in import duties and market concentration that stronger competition increases CSR efforts at the firm level. Simon and Prince (2016) find that a reduction in industrial concentration in the U.S. is associated with lower toxic

footnote 16). For more examples see Schinkel and Treuren (2021b).

[6]See Scott (2016) for cartel exemption possibilities under U.S. antitrust law, and Holmes (2020) under European competition law.

[7]See Hovenkamp (2019).

[8]In *CECED* (1999), the European Commission allowed washing machine producers to agree to take their least energy-efficient models collectively off the market. Yet the avoided emissions, though substantial, were not pivotal to the decision. Instead, the Commission concluded that a typical consumer would be compensated for the increased purchase costs of a more energy-efficient washing machines by the savings on his electricity bills. See *CECED* (1999), recital 56 and Ahmed and Segerson (2011). Some years later, in the complementary market for household laundry detergents, an accredited industry initiative to promote more sustainable washing powders became a cover for price collusion in *Consumer Detergents* (2011).

[9]See most of the contributions in Holmes et al. (2021).

[10]Ziegler et al. (2020) show that subversion of morals in lab experiments is larger in multi-unit markets than in single-unit markets. In contrast to this literature, Gomez-Martinez et al. (2019) find that consumer and managerial values are more important drivers of socially responsible behaviour in the lab than coordination.

releases at the factory level. Aghion et al. (2020) report that firms more frequently engage in green innovation if consumers prefer sustainability, and increasingly so in more competitive markets. Ding et al. (2020) directly link antitrust policy to sustainability by showing that stricter competition law regimes are associated with higher CSR, and that this link is stronger in countries with higher scores on a social norms index that weighs several factors including consumers' attitudes towards the environment and human rights.

Theoretical work also finds little evidence for a negative relation between CSR efforts and competition. Schinkel and Spiegel (2017) show that when consumers have a willingness to pay for more sustainable products, firms have stronger incentives to promote sustainability in competition than when they can make sustainability agreements. Dewatripont and Tirole (2020) study a variety of market models to conclude that whether competition is green or grey depends on the effect of "cutting ethical corners" on demand. But when prices are determined by an unconstrained market mechanism, they find that the intensity of competition has no effect on ethical behavior.

We study different types of joint CSR agreements in a model of oligopolistic competition with goods that are differentiated, including by the CSR efforts of their manufacturer. Consumers prefer to buy from companies that are committed to CSR and have a higher willingness to pay for their products. Numerous studies support this assumption. Casadesus-Masanell et al. (2009) report that people pay more for T-shirts made with organic cotton. Eichholtz et al. (2010) document a higher willingness to pay for office buildings with sustainability labels. In a survey of the literature, Kitzmueller and Shimshack (2012) conclude that willingness to pay in general positively depends on the degree of CSR a firm engages in. Flammer (2015a) finds sales growth after the companies adopt CSR proposals by shareholders. Delmas and Colgan (2018) give many examples of this, in particular with eco-labels.

Reasons why firms may act responsibly range from purely profit motivation to purely intrinsic motivation.[11] We assume that firms base their business decisions, including their CSR efforts, first and foremost on profit. A pronounced CSR profile allows a company to attract more customers and charge higher prices. Early contribution on strategic CSR as a for-profit product differentiation strategy are Baron (2001) and McWilliams and Siegel (2001) For-profit CSR comprises a substantial part of the literature.[12] Fernández-Kranz and Santalo (2010) and Flammer (2015b) interpret their findings that CSR increases with

[11]Bénabou and Tirole (2010). The debate on whether companies should pursue CSR objectives is old and polarized, see Friedman (1970). Magill et al. (2015) show that instructing firms to maximize stakeholder value can reduce negative externalities on their workers and consumers.

[12]See Kitzmueller and Shimshack (2012) for an overview.

more product market competition as consistent with CSR being strategic, since lower profit in competition leaves less scope for intrinsic CSR investments. Calveras and Ganuza (2018) find that CSR can serve as a tool for a firm's product differentiation strategy.[13]

In addition to these immediate for-profit objectives, companies can also have more sophisticated intrinsic reasons to invest in CSR. In surveys, executives indeed report both financial and intrinsic motives for engaging in CSR.[14] Baron (2007) studies social entrepreneurship out of "warm-glow" preferences. Hart and Zingales (2017a,b) point out that firms are right to pursue CSR objectives that contribute negatively to monetary profit when their shareholders are prosocial. Forward looking corporations may be of the view that contributing to society builds goodwill and a reputation that will pay-off in the long-run even when immediate demand is small. For example, Unilever CEO Paul Polman was convinced that a company can only be successful when in pace with society.[15] He explained how a socially driven mission aligns with core business in a *Harvard Business Review* interview titled "Captain Planet":

> "For proper long-term planning, you've got to take your externalities into account, in order to be close to society. It's clear that if companies build this thinking into their business models and plan carefully, it will accelerate growth." (*op. cit.* p.114)

A similar view may motivate large investment funds, such as Blackrock and Vanguard, to make public commitments to reduce emissions.[16] Such reasons for companies to put weight on social issues beyond their explicit profit motive, we capture in our model by a direct "intrinsic" motivation for CSR efforts. This can also include leadership by CEOs who are personally passionate about CSR and powerful enough to influence their company's decision making. Chatterji and Toffel (2019) refer to such efforts as "CEO activism".

CSR efforts have implications for a company's costs. Many of the motivating calls for collaborative CSR concern the need for firms to make a transition, for example by implementing known alternative methods of production, such as installing CO2 filters in factories, improving workplace safety, setting up a sustainable forest cycle, or building

[13]Bagnoli and Watts (2003), Kotchen (2006), and Besley and Ghatak (2007) show how for-profit companies investing in CSR can be a form of private public goods provision. See also Schinkel and Tóth (2019).

[14]See Graafland and Mazereeuw-Van der Duijn Schouten (2012).

[15]See Henderson (2020), in which Polman's corporate sustainability plans feature extensively, and Smith (2019).

[16]See Azar et al. (2021) and Kerber (2021).

more spacious housing for their livestock. Such transitions come at a fixed cost that increases with the level of CSR efforts. The cost of attracting capital for such investments can be lower for firms with a stronger CSR profile, which can have fixed and variable cost implications. Firms with better CSR scores are found to have better access to capital and cheaper equity financing, due to growing reluctance of consumers and investors to fund gray production.[17] CSR efforts may also affect the marginal costs of production. Typically, concrete steps such as paying fairer wages and applying biological pesticides will increase per unit production costs. CSR efforts can also decrease marginal costs of production. Sustainable sourcing can giving higher yields, for example in agriculture and forestry, and employees are found willing to accept lower wages working for a company that has a socially driven mission.[18]

In our model, each firm first commits to a CSR level, and subsequently decides how much to produce. We analyze the effects of joint agreements on CSR efforts, production and prices when firms make these agreements about their CSR efforts, about their production volumes, or about both. A robust finding is that joint agreements that involve CSR levels directly – either agreements on CSR efforts alone or together with coordinated production – *reduce* CSR efforts compared to competition. This is true for any positive willingness to pay for CSR, no matter how little. The reason is that CSR coordination eliminates CSR as a dimension of competition, which allows firms to jointly profit from lower CSR investment costs. If CSR is to be increased by collaboration, only permitting coordination of output volumes (or prices) delivers. It increases the total rents from CSR investments, while maintaining competition for a larger share of those rents by each firm investing more in CSR.

These findings hold irrespective of the strength of companies' intrinsic motivation for CSR. In fact, intrinsic motivation magnifies our polar results. CSR coordination reduces the additional CSR due to intrinsic motivation because the loss of profit from increasing CSR effort beyond the profit maximizing level is larger for firms who jointly decide on CSR. Joint agreements on CSR throttle both for-profit and intrinsic motivation for corporate social responsibility. Therefore, if the social objective is to promote CSR by joint agreements, only coordination of output (or price) should be permitted.

Output (and price) agreements, however, are particularly problematic under the antitrust laws. Moreover, whenever firms have an incentive to form such agreements, we

[17]See Sharfman and Fernando (2008), El Ghoul et al. (2011), and Cheng et al. (2014).

[18]Additionally, Flammer (2015a) reports higher labor productivity. See Polman's HBR interview (2012, p.114) on increased yields, and de Bettignies et al. (2020) on green human resource management.

find that they necessarily reduce welfare. The current requirement under European competition law for obtaining a cartel exemption for an anticompetitive horizontal agreement is full compensation of the consumers of the products concerned. Yet compensation of consumers is not possible, as no joint agreement exists that simultaneously increases CSR levels, consumer welfare ánd profit over the competitive situation. Our findings on welfare imply that the compensation requirement must be relaxed if CSR is to be promoted by joint (output or price) agreement.

One possibility is to also take benefits outside the relevant market, such as externalities, into account.[19] When production causes negative externalities to non-consumers, and CSR efforts reduce those externalities, another reason arises to favor production agreements over agreements on CSR directly. Production agreements decrease negative productions externalities, while CSR agreements, resulting in lower output and less CSR, do not. Allowing consumers to be harmed while valuing non-consumer benefits is not standard practice in competition policy, however. Such out-of-market-benefits are also very complex to assess. We show that government regulation is likely the better alternative. For any level of CSR, welfare is higher when that level is simply required by government regulation from companies remaining in competition, than when it is provided by exempting a production agreement from cartel law.

Our analysis of CSR agreements is in line with the literature on Research Joint Ventures (RJVs), where firms coordinate investments in cost-reducing R&D and subsequently compete in the output market. Seminal contributions are d'Aspremont and Jacquemin (1988), Suzumura (1992), and Kamien et al. (1992). RJV's can increase R&D investments above competitive levels if spillovers of one firm's innovation benefits the other firms, so that unilateral investments are discouraged. For this reason, there is a broad exemption clause available for RJVs, that extends also to cooperative research into more socially responsible and environmentally friendly production methods. However, with limited spillovers, competition is found to be the stronger driver of R&D. Importantly, CSR initiatives of the kind discussed in this chapter have little or no spillovers from one company to another. Instead, they are primarily about firms transitioning to higher CSR levels by implementing existing technologies or more responsible ways of doing business.

Our model extends in various directions on Schinkel and Spiegel (2017), who study the effects of collaboration on sustainability efforts in a duopoly semi-collusion model. The semi-collusion literature allows for analyses of markets in which competitors cooperate in one dimension of competition, while competing in the other. Fershtman and Gandal

[19]This has been proposed recently by the Dutch competition authority (ACM, 2021). See Schinkel and Treuren (2021b) for a critical review.

(1994) and Brod and Shivakumar (1999) analyze the effects of cost-reducing R&D in RJVs between two firms in this setting. Cooperation in the output market and competition in the investment stage increase R&D but not necessarily profit. In more complex extended models, including to n-firms, Matsui (1989) studies investments in capacity, Fershtman and Pakes (2000) in product quality, and Symeonidis (2000) in advertising. Our application is to CSR efforts, allowing for any number of firms, with varying consumer willingness to pay for the improved product brand image, and additional firm intrinsic motivation to invest in CSR. We also consider partial agreements – by a subset of competitors, both on CSR and quantities – with findings that are in line with recent work on mergers where firms select both prices and R&D, as in Federico et al. (2018), Motta and Tarantino (2017), and Bourreau et al. (2021).

The remainder of the chapter is organized as follows. In the next section we introduce our model of competition in CSR efforts and quantities. In Section 4.3, we analyze what level of CSR results under different types of joint agreement. In Section 4.4, we study welfare effects. In Section 4.5, we discuss how production agreements that advance CSR efforts may qualify for an antitrust exemption, despite harming consumers, by taking wider, out-of-market-efficiencies into account. Section 4.6 concludes. Proofs of all propositions are in Appendix 4.A. Robustness analyses in case of price-setting instead of quantity-setting, alternate preferences and associated demand in which price and CSR increases trade off differently in consumer welfare, and partial CSR agreements that do not involve all competitors, are discussed in Appendices 4.B to 4.D.

4.2 A model of strategic CSR investments

Consider a market in which n firms, labeled $i = 1, ..., n$, each sell a product that is differentiated, including by the firm's standard of corporate social responsibility (CSR) $v_i \geq 0$. An increase in v_i can represent, for example, that firm i's product is manufactured using fewer natural resources, lower emissions production technologies, or a higher standard of care for workers and farm animals in the supply chain. The preferences of a representative consumer over these products, consumed in quantities $\mathbf{q} = q_1, ..., q_n$, are described by utility function

$$U(\mathbf{q}, \mathbf{v}, m) = \sum_{i=1}^{n}(\alpha + v_i)q_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + 2\gamma \sum_{i=1}^{n}\sum_{i>j} q_i q_j\right) + m, \tag{4.1}$$

in which $\mathbf{v} = v_1, ..., v_n$ are the firms' CSR levels, $\alpha > 0$ is a utility parameter, $\gamma \in (0, 1)$ measures the degree of symmetric horizontal product differentiation on other dimensions than CSR, and $m \geq 0$ is expenditure on any other goods.[20]

These preferences yield the following demand system from maximizing $U(\mathbf{q}, \mathbf{v}, m)$ subject to the budget constraint $\sum_{i=1}^{n} p_i q_i + m \leq I$, where p_i is the price of good i and I is representative income

$$p_i(\mathbf{q}, v_i) = \alpha + v_i - q_i - \gamma \sum_{i \neq j}^{n} q_j, \quad i = 1, ..., n. \tag{4.2}$$

Market demand captures that consumers are willing to pay more for products of firms that invest in higher CSR levels by v_i increasing the intercepts. Note that higher values of γ reflect that consumers consider the products to be closer substitutes.

For companies, investing in the transition to a higher level of CSR can be a profitable strategy. Let $\frac{tv_i^2}{2}$ be firm i's fixed cost of CSR effort v_i ($t \geq 1$). Regular marginal cost of production are c for all producers. Firm i's profit then is given by

$$\pi_i (\mathbf{q}, v_i) = \left(\alpha + v_i - q_i - \gamma \sum_{i \neq j}^{n} q_j - c \right) q_i - \frac{tv_i^2}{2}, \tag{4.3}$$

Note that CSR effort v_i can be interpreted as the net effect of willingness to pay for CSR and CSR-induced marginal cost changes on firm i's price-cost margin $p_i - c$. In Section 4.3.2 we extend the model to varying willingness to pay for CSR, and allow CSR efforts to affect the marginal cost of production.

Firms are for-profit organizations, if only under the pressure of shareholders and investors. They determine their CSR and production levels strategically by maximizing (4.3). While this is a reasonable baseline assumption, in the domain of socially responsible behavior firms may be motivated also by other objectives, ranging from a leader's genuine intrinsic willingness to do good to reputational gains not directly reflected in willingness to pay for CSR. In Section 4.3.3 we study the effects of additional intrinsic motivation for CSR by adding a firm's CSR efforts into it's objective function.

The interaction between the n firms involves two stages. In Stage 1, firms simultaneously choose their CSR efforts, which are assumed to be fully observable by consumers and firms. In Stage 2, given their CSR levels $\mathbf{v}$, firms simultaneously decide how much to produce. Note that our sequential setup implies that all firms have committed to their

[20]See Choné and Linnemer (2020) for a recent overview of this widely used preference structure, originally proposed in Shubik and Levitan (1980).

CSR efforts by the time they decide on production (or prices for that matter). In our motivating examples, strategic company commitment to transit into more sustainable sourcing and manufacturing precedes production volume and sales decisions. A company's CSR investments – such as investments in cleaner technology or filters – are costly to reverse and have strategic commitment value.[21]

As all firms are identical, we focus on symmetric pure strategy solutions. In normal competition, each firm i selects both strategic variables v_i and q_i independently, taking its rivals' decisions as given. This non-cooperative benchmark is denoted by superscript $*$, its unique Nash-equilibrium by (v^*, q^*). Firms compete on CSR in the sense that a firm, by increasing its CSR efforts, makes itself relatively more attractive to consumers to purchase from, allowing it to steal customers from its competitors. This business stealing-effect induces companies to invest more in CSR. We note that when competition is more intense (for high values γ and n), this can be such a strong force that the firms are whipped up to invest more in CSR than the social optimum that maximizes within-market welfare. Since the starting point of the initiatives to allow collaborations is that CSR efforts are too low in competition and need stimulation, we are most interested in markets in which higher CSR levels increase total within-market welfare. Proposition 4.7 in Section 4.4 specifies general conditions under which this is the case. Nonetheless, all of our results are derived for all parameter values.

4.3 Joint agreements to promote CSR

To study whether and how allowing companies to make voluntary joint agreements can increase their CSR efforts, we compare CSR levels and output under three types of agreements to the benchmark where no agreements are allowed. First, in a "CSR agreement" (csr) the firms cooperatively decide on the CSR efforts they each take and subsequently compete on quantities. This is the type of agreement that is proposed in practice to stimulate CSR, as set out in Section 1. The U.S. Business Roundtable and the European *CECED* case are examples. Cooperation is on CSR efforts, while competition is to remain on quantities (and prices). The symmetric solution is indicated by (v^{csr}, q^{csr}).

Second, in a "production agreement" (p) firms coordinate their output volumes, while still deciding on their CSR efforts independently. This is the opposite of a CSR agreement

[21]In Appendix 4.B, we show that our results carry through if firms select prices in Stage 2 instead of quantities. Whether the Stage 2 agreement is about output or price, in either case the drive to steal customers by trying to set a higher CSR level gets stronger when the margin on these customers is larger.

and essentially a classic cartel. Note however that since the firms compete also in CSR efforts, competition is not fully eliminated under this type of agreement. To the best of our knowledge, none of the advocates of using joint agreements to stimulate higher CSR efforts has so far advocated sole output coordination. The symmetric solution is indicated by (v^p, q^p).

Third, in a "full agreement" (f) the firms decide cooperatively on both their CSR levels and their output, thereby fully eliminating competition. While this is not what is currently proposed, it may result in practice because allowing firms to coordinate one dimension of competition may give them a forum for discussion that they can abuse to agree on the other dimensions as well. For a competition authority, it will be particularly difficult to monitor and assure that the firms it allows to exchange commercially sensitivity information for the purpose of coordinating their CSR efforts do not misuse that permission to secretly coordinate output (or prices) as well. It has been documented that well-intended cooperation can slide to hard core collusion, for example, for research joint ventures.[22] The symmetric solution is indicated by $\left(v^f, q^f\right)$.

In the main text, we study market-wide agreements in which all competitors participate. Exempted from cartel law, these agreements can in principle be contracted and made legally binding before a court. Therefore, even though their anticompetitive nature will typically create incentives for the members of these agreements to deviate, with different CSR efforts and production volumes than agreed upon, such defection would constitute a breach of contract that sufficiently large liabilities can prevent. This means that adherence to any agreement can be secured, so that we can follow the literature on semi-collusion and ignore the classic problems of internal and external stability that play in illegal market coordination.[23]

We begin by analyzing the baselines model in Section 4.3.1. In Sections 4.3.2 and 4.3.3, we subsequently show that our main result on the ranking of CSR efforts across the three types of joint agreements is robust to low willingness to pay with consumers for CSR, CSR efforts affecting the marginal cost of production, and firms being intrinsically motivated to invest in CSR in addition to their for-profit motives.

[22] Duso et al. (2014) find that cartel infringement follow in markets that were previously allowed to form RJVs. *Consumer Detergents* (2011) is a case in point.

[23] Freeriding on voluntary collective agreements is studied in Ahmed and Segerson (2011), Brau and Carraro (2011), and Kotchen and Segerson (2019).

4.3.1 Effective joint agreements

Our main finding is that the CSR levels resulting from the three different types of joint CSR agreements compare as follows to the non-cooperative CSR level v^*, for all parameter values (α, γ, c, t, n).

Proposition 4.1. $v^p > v^* > v^f > v^{csr}$.

Proof. See Appendix 4.A. ■

Proposition 4.1 states that allowing agreements that directly involve CSR efforts leads to lower CSR levels than would result in the non-cooperative benchmark. When two firms both increase CSR efforts, their business stealing effects cancel out, but the costs of increased CSR efforts remain. When coordinating their CSR levels, firms therefore reduce their CSR efforts and save on their investment costs. In contrast, a production agreement is found to raise CSR efforts compared to the non-cooperative benchmark. A production agreement increases price-cost margins in the second stage of the game. These higher rents give the firms stronger business stealing incentives for investing in CSR in the first stage, as each additional customer is now worth more.

Proposition 4.1 holds for a wide class of demand systems. To see this, consider the reduced form profit in Stage 1 for any firm i

$$\pi_i(\mathbf{q}(\mathbf{v}), v_i), \tag{4.4}$$

where $\mathbf{q}(\mathbf{v}) = q_1(\mathbf{v}), \ldots, q_n(\mathbf{v})$ are the conditional quantities, conditional on the choices of CSR in Stage 1, that solve Stage 2. In all four regimes $r \in \{*, csr, p, f\}$, firm i picks v_i to maximize

$$\pi_i(\mathbf{q}(\mathbf{v}), v_i) + \psi \sum_{i \neq j}^{n} \pi_j(\mathbf{q}(\mathbf{v}), v_j), \tag{4.5}$$

where $\psi = 1$ if CSR levels are chosen cooperatively in Stage 1 (in $r = csr$ or $r = f$) and $\psi = 0$ otherwise (in $r = *$ or $r = p$).

If firms select quantities non-cooperatively in the Stage 2, then $\forall i$, $\frac{\partial \pi_i}{\partial q_i} = 0$ and $q_i(\mathbf{v}) = q_i^*(\mathbf{v})$, where $q_i^*(\mathbf{v})$ is the Nash-equilibrium conditional quantity. If firms select quantities cooperatively in Stage 2, then, $\sum_i \frac{\partial \pi_i}{\partial q_j} = 0 \ \forall j$, and $q_i(\mathbf{v}) = q_i^c(\mathbf{v})$, where $q_i^c(\mathbf{v})$ is the cooperative conditional quantity (in either $r = p$ or $r = f$, that is). The first-order condition for firm i choosing v_i in the non-cooperative benchmark is

$$\sum_{i\neq j}^{n} \frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j^*}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} = 0. \tag{4.6}$$

For a CSR agreement, it is

$$\sum_{i\neq j}^{n} \frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j^*}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} + \sum_{i\neq j}^{n}\left(\sum_{i\neq j\neq k}^{n} \frac{\partial \pi_j}{\partial q_k}\frac{\partial q_k^*}{\partial v_i} + \frac{\partial \pi_j}{\partial q_i}\frac{\partial q_i^*}{\partial v_i}\right) = 0, \tag{4.7}$$

for a production agreement

$$\sum_{i\neq j}^{n} \frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j^c}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} + \frac{\partial \pi_i}{\partial q_i}\frac{\partial q_i^c}{\partial v_i} = 0, \tag{4.8}$$

and for a full agreement

$$\frac{\partial \pi_i}{\partial v_i} = 0. \tag{4.9}$$

Equation (4.6) reveals the two incentives to invest in CSR that exist in the non-cooperative benchmark. The first term in equation (4.6) is the business stealing effect. By increasing its CSR level, a firm becomes relatively more attractive to consumers, and the quantity of all other firms decreases as a result. The second term in equation (4.6) is the demand effect, best seen in equation (4.2). Increasing its CSR level allows a firm to increase its price, holding quantity constant. Because firms select quantities to maximize their conditional profit in Stage 2, $\frac{\partial \pi_i}{\partial q_i} = 0\ \forall i$, implying that each firm ignores the effect of CSR investment on own profit mediated by changes in own quantity.

The terms in brackets in equation (4.7) show the additional (dis)incentives to invest in CSR that exist for a CSR agreement. For $n \geq 3$, the business stealing effect imposes both positive and negative externalities on the profit of the firms in a CSR agreement. Firm i's investment in CSR decreases firm j's profit by increasing firm i's quantity, but increases firm j's profit by reducing quantities of all firms k ($i \neq j \neq k$). If $|\frac{\partial \pi_j}{\partial q_i}\frac{\partial q_i^*}{\partial v_i}| > \sum_{i\neq j\neq k}^{n} |\frac{\partial \pi_j}{\partial q_k}\frac{\partial q_k^*}{\partial v_i}|$, the negative externality dominates and a CSR agreement reduces CSR levels compared to the non-cooperative benchmark. Intuitively, the requirement for $v^* > v^{csr}$ is that firm i's CSR level influences firm i's quantity sufficiently more than it influences the quantity of all other firms.

A production agreement sets quantities cooperatively in Stage 2 such that $\sum_{i=1}^{n} \frac{\partial \pi_i}{\partial q_j} = 0$ $\forall j$. This implies that $\frac{\partial \pi_i}{\partial q_i} > 0$, as $\frac{\partial \pi_i}{\partial q_j} < 0$ ($i \neq j$). Firms in a production agreement take into account this positive effect of investing in CSR on own quantity, shown in the final term of equation (4.8). A production agreement increases price-cost margins, making it more profitable to attract extra consumers by investing in CSR. If $|\frac{\partial q_j^c}{\partial v_i}|$ is not too much smaller than $|\frac{\partial q_j^*}{\partial v_i}|$ $(i \neq j)$, then it follows that $v^p > v^*$.

A full agreement controls both quantity and CSR levels, so that it completely eliminates the business stealing effect, and CSR investment is only driven by the demand effect. Equation (4.9) can be written as $\sum_{i \neq j}^{n} \frac{\partial \pi_i}{\partial q_j} \frac{\partial q_j^*}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} - \sum_{i \neq j}^{n} \frac{\partial \pi_i}{\partial q_j} \frac{\partial q_j^*}{\partial v_i} = 0$. As long as $\frac{\partial \pi_i}{\partial q_j} \frac{\partial q_j^*}{\partial v_i} > 0$, comparing equation (4.6) to equation (4.9) shows that $v^* > v^f$. If $|\frac{\partial \pi_j}{\partial q_i} \frac{\partial q_i^*}{\partial v_i}| - \sum_{i \neq j \neq k}^{n} |\frac{\partial \pi_j}{\partial q_k} \frac{\partial q_k^*}{\partial v_i}| > |\sum_{i \neq j}^{n} \frac{\partial \pi_i}{\partial q_j} \frac{\partial q_j^*}{\partial v_i}|$, we have $v^f > v^{csr}$. This condition requires firm i's CSR level to influence firm i's demand sufficiently more than the demand of all other firms.

Hence, if raising CSR efforts is the goal, production agreements are the only type of joint agreement to consider allowing. Yet competitors will not voluntarily form a production agreement if competition is too strong in the non-cooperative benchmark, as the following proposition shows. Let $\pi(q^r, v^r)$ denote profit in regime $r \in \{*, csr, p, f\}$, where q^r is the concomitant quantity.

Proposition 4.2. $\pi(q^p, v^p) > \pi(q^*, v^*)$ for $\gamma \leq \Gamma(n)$, or $\gamma > \Gamma(n)$ and $t > T(\gamma, n)$.

Proof. See Appendix 4.A. ■

Firms only profit from engaging in a production agreement if their products are sufficiently differentiated, or otherwise if investing in CSR is sufficiently expensive.[24] If products are very similar ($\gamma > \Gamma(n)$) or investing in CSR is cheap ($t < T(\gamma, n)$), business stealing incentives are very high in production agreements. This causes firms to engage in a non-profitable 'arms race' in CSR efforts, as in equilibrium business stealing efforts between firms cancel out such that only the costs remain.[25] When companies are allowed to form a production agreement for the purpose of stimulating CSR efforts, they will only voluntarily form one if it does not induce them to invest too much in CSR thereby reducing profit compared to the non-cooperative benchmark.

Finally, we note that $\pi\left(q^f, v^f\right) > \pi\left(q^p, v^p\right)$ and $\pi\left(q^f, v^f\right) > \pi\left(q^{csr}, v^{csr}\right)$ always hold, confirming that firms allowed to coordinate on one dimension of competition between

[24]The exact expressions for the critical values of product homogeneity $\Gamma(n)$ and CSR costs $T(\gamma, n)$ are tedious and given in the proof of Proposition 4.2. They depend on n, with the parameter space where a production agreement is beneficial to the firms shrinking as n increases.

[25]The possibility that firms over-invest in either cost-reducing R&D or capacity in a non-cooperative first stage is also found in Fershtman and Gandal (1994), and in Brod and Shivakumar (1999) when spillovers are low or absent.

them are tempted to try to collude on the other(s) as well. It is straightforward that in a full agreement firms can always replicate the production or CSR agreement outcomes, and do better by restricting respectively their CSR investments and joint output. Such full elimination of competition would be illegal also under the policy to stimulate CSR by voluntary cooperative agreements – and therefore requires secrecy and stabilization against the threat of unilateral defection, entry and exit, which we leave aside. Nevertheless, if the risk of joint initiatives to promote companies taking more CSR sliding into full collusion is not strictly controlled, CSR levels may end up lower than in competition.

4.3.2 Willingness to pay and CSR-dependent marginal costs

Proponents of allowing firms to coordinate their CSR efforts have argued that collaboration is needed to increase CSR because consumer exhibit low, no, or even negative willingness to pay for the costly CSR efforts. A sufficiently high willingness to pay over CSR-related marginal cost increases would be needed for competition to be a stimulus for CSR efforts.[26] In particular, firms in competition would be held back by a first-mover disadvantage from unilaterally making investments in more responsible manufacturing, as this would decrease those firms' market shares and profitability. Only coordinated CSR investments would be able to break the deadlock.[27] To study the validity of these arguments, we extend the baseline model with varying willingness to pay for CSR and CSR-dependent marginal costs.

Recall that market demand is positively related to CSR because consumers are assumed to be willing to pay more for products of firms with high CSR levels. In the market demand function (4.2), the price is assumed to increase one-to-one with the level of CSR effort v_i. To see what the effect is of lower or higher willingness to pay for CSR, consider the slightly more general demand system (denoted by superscript δ)

$$p_i^\delta(\mathbf{q}, v_i) = \alpha + \beta v_i - q_i - \gamma \sum_{i \neq j}^{n} q_j, \quad i = 1, ..., n, \tag{4.10}$$

in which $\beta \geq 0$ scales the willingness to pay for CSR, that follows straightforwardly from multiplying v_i in utility (4.1) by β.

This generalization also allows for the analysis of cases in which CSR investments affect the marginal costs of production. Let the total marginal cost of production at CSR level v_i be given by $c(1 + \kappa v_i)$, in which $\kappa \geq 0$ ($\kappa < 0$) is the increase (decrease) in the

[26]See Dolmans et al. (2021).
[27]See ACM (2021).

marginal costs of production resulting from higher CSR effort. As discussed in Section 4.1, CSR induced marginal cost changes can be in either direction. While CSR terms such as better working conditions typically increase input costs, sustainable sourcing can increase access to funding and yield, and allow the company to pay lower interest rates and wages.

The profit of each firm i can then be written as

$$\pi_i^{\delta}(\mathbf{q}, v_i) = \left(\alpha + \delta v_i - q_i - \gamma \sum_{i \neq j}^{n} q_j - c\right) q_i - \frac{t v_i^2}{2}, \tag{4.11}$$

where $\delta \equiv \beta - \kappa c$ is the net effect of willingness to pay for CSR and CSR-induced marginal cost changes on firm i's price-cost margin $p_i - c$. In the basic model that underlies Proposition 4.1, $\delta = 1$ for simplicity. Obviously, for negligible cost increases, small values of δ reflect low willingness to pay for products of companies that take high CSR efforts. The value of δ remains positive as long as any marginal cost increases resulting from a higher CSR efforts are matched by a sufficiently strong consumer willingness to pay for them. Note that when $\delta \leq 0$, CSR levels only enter the profit function as a cost, so that no firm would invest in CSR regardless of the competitive regime.

From comparing CSR levels derived from the profit function in equation (4.11) across the four regimes, we find that their ranking is maintained – denoting the variation with subscript δ.

Proposition 4.3. $v_\delta^p > v_\delta^* > v_\delta^f > v_\delta^{csr}$ for all $\delta > 0$.

Proof. See Appendix 4.A. ■

We establish that the ranking op CSR levels given in Proposition 4.1 holds whenever consumers have at least some positive willingness to pay for more responsibly manufactured products over and above any marginal cost increase from the CSR advance, no matter how little that net willingness to pay is. When this is the case, corporations will each take more CSR efforts in competition than when they can coordinate their CSR actions.

The generality of this result can be seen again from the first-order conditions given in equations (4.6) to (4.9): these expressions are identical when $\delta > 0$. Scaling the willingness to pay to CSR simply scales all incentives related to CSR, as is made precise in the following proposition.

Proposition 4.4. $\frac{\partial(v_\delta^p - v_\delta^*)}{\partial\delta} > 0$, $\frac{\partial(v_\delta^* - v_\delta^f)}{\partial\delta} > 0$, and $\frac{\partial(v_\delta^f - v_\delta^{csr})}{\partial\delta} > 0$ for all $\delta > 0$.

Proof. See Appendix 4.A. ■

As a firm's price-cost margin increases, the differences between CSR levels in the different regimes increase. As δ scales the positive direct effect of CSR levels on profit, it also scales all incentives related to CSR. When δ increases, the business stealing effect of investing in CSR is magnified, further increasing incentives for CSR investments in a production agreement, and further decreasing incentives for CSR investments when firms coordinate such investments. If instead δ decreases, for instance due to increased marginal costs following CSR investments, the CSR levels in the different regimes converge and go to zero once β becomes non-positive.

The conclusion remains that CSR agreement do not stimulate CSR efforts compared to the non-cooperative benchmark: only production agreements do. There simply is no first-mover disadvantage due to "low" willingness to pay for the products and services of companies that take more social responsibility. Whenever firms can monetize their CSR efforts somewhat, by attracting more business or increasing their margin, even if only little, their incentives to invest in CSR are always stronger when they compete than when they are allowed to make CSR agreements. The crucial insight is that the difference in CSR efforts between competition and CSR cooperation is positive whenever there is a (net) positive willingness to pay. Moreover, if consumers have no positive (net) willingness to pay for CSR ($\delta \leq 0$), coordination can never break any first-mover disadvantage deadlock as firms will never invest in CSR.

4.3.3 Intrinsic motivation for CSR

To study the extent to which intrinsic motivation for CSR affects our main findings, while by-passing principal-agent complexities or other issues that may be behind this motivation, we simply extend firm i's objective function with an additive term for direct CSR motivation. That is, let firm i maximize

$$\pi_i(\mathbf{q}, v_i) + \theta v_i, \tag{4.12}$$

in which $\theta \geq 0$ is a scaling parameter that expresses each firm's valuation of CSR for intrinsic reasons and $\pi_i(\mathbf{q}, v_i)$ is given by equation (4.3).

In Stage 2 of the game, nothing changes compared to the baseline model and the conditional quantities v are still given by $q_i^*(\mathbf{v})$ if firms independently set quantities, and $q_i^c(\mathbf{v})$ if firms jointly set quantities. In Stage 1 of all four competitive regimes, firm i now picks v_i to maximize

$$\pi_i(\mathbf{q}(\mathbf{v}), v_i) + \theta v_i + \psi \sum_{i \neq j}^{n} (\pi_j(\mathbf{q}(\mathbf{v}), v_j) + \theta v_j), \tag{4.13}$$

where $\psi = 1$ if CSR levels are chosen cooperatively in Stage 1, and $\psi = 0$ otherwise. It is immediate from (4.13) that firms will invest more in CSR if they are intrinsically motivated than if they solely maximize profit ($\theta = 0$). The resulting CSR levels, denoted by a subscript I, compare as follows.

Proposition 4.5. $v_I^p > v_I^* > v_I^f > v_I^{csr}$ for all $\theta > 0$.

Proof. See Appendix 4.A. ■

We find that the ranking of CSR levels across the different competitive regimes is unaffected when firms are also intrinsically motivated to increase CSR. Still the only agreement that will increase CSR levels compared to the non-cooperative benchmark is a production agreement. The reason for this is as follows. Adding θ to the left-hand side of the first-order conditions given in equations (4.6) to (4.9) gives the first-order conditions when firms are also intrinsically motivated. This shows that the added incentive to invest in CSR due to intrinsic motivation is identical for all competitive regimes. Yet the lost profit from increasing CSR above the profit-maximizing level is not identical. In a production agreement, this lost profit is lowest as $\frac{\partial \pi_i}{\partial q_i} > 0$ and $\frac{\partial q_i^c}{\partial v_i} > 0$, so that the reduction in profit from pushing CSR efforts above the profit-maximizing amount is somewhat mitigated. For a CSR agreement the lost profit of a given CSR increase is highest, as each CSR increase decreases profit for all members of the agreement, which is exactly the externality a CSR agreement is trying to avoid. A CSR agreement will therefore only slightly increase its CSR efforts for a given level of intrinsic motivation. A full agreement combines both effects although the negative externality of CSR on the profit of all other firms in the agreement dominates. To see the generality of this result, note that the above arguments also carry through when intrinsic motivation is a smooth function of CSR, $f(v_i)$, in which case the term $\frac{\partial f(v_i)}{\partial v_i}$ is added to the left-hand side of first-order conditions (4.6) to (4.9).

The differences between the CSR levels of the different competitive regimes are increasing in the level of intrinsic motivation, as formalized in the next proposition.

Proposition 4.6. $\frac{\partial(v_I^p - v_I^*)}{\partial\theta} > 0$, $\frac{\partial(v_I^* - v_I^f)}{\partial\theta} > 0$, and $\frac{\partial(v_I^f - v_I^{csr})}{\partial\theta} > 0$ for all $\theta > 0$.

Proof. See Appendix 4.A. ■

The stronger the direct motivation for CSR, the higher are CSR levels that are selected non-cooperatively compared to CSR levels selected in coordination. The mechanisms underlying this result are those discussed in the previous paragraph. Allowing joint CSR agreements, therefore, is an increasingly ineffective way of inducing CSR efforts when companies' intrinsic motivation becomes a more important driver of CSR efforts. This is true for all finite θ – for some sufficiently high value of which, of course, immediate profit become negative. At best do all regimes converge on the same infinite CSR efforts – and infinite immediate losses – in the limit of θ going to infinity so that for-profit motivation is no longer part of a company's objective. We conclude that joint CSR agreements are never better than the benchmark, not even when corporations are directly motivated to do good, however strongly. The incentives for CSR efforts remain greatest in a production agreement.

4.4 Consumer and total welfare effects

To analyze the welfare effects of the different types of joint agreements, we return to the baseline model ($\delta = 1$, $\theta = 0$). Consumer welfare follows from substituting demand (4.2) into utility (4.1)

$$CS(\mathbf{q}) = \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + 2\gamma \sum_{i=1}^{n} \sum_{i>j} q_i q_j\right). \tag{4.14}$$

Note that CSR does not directly affect consumer surplus because the additional utility from higher CSR efforts in equation (4.1) is cancelled out by matching price increases in demand (4.2). In this model, CSR levels only have an indirect effect on consumer welfare, through the way in which the firms' quantities depend on their CSR efforts.[28] As quantities are symmetric, consumer surplus reduces to $CS(q^r) = \frac{n}{2}(\gamma(n-1)+1)(q^r)^2$, where $r \in$

[28]For this reason, consumer surplus expression (4.14) follows equivalently from substituting demand (4.10) into the corresponding utility function (4.1), in which v_i is multiplied by β. Consumer surplus, that is, does not directly depend on the willingness to pay of consumers for CSR efforts.

$\{*, csr, p, f\}$, so that the ranking of consumer welfare across different competitive regimes corresponds to the ranking of quantities q^r.[29]

First we establish that joint agreements that fail to increase CSR efforts always harm consumers: $CS(q^*) > CS(q^{csr}) > CS\left(q^f\right)$. A full agreement reduces consumer welfare on two accounts compared to the non-cooperative benchmark: it reduces conditional quantities in Stage 2 and CSR levels in Stage 1. A CSR agreement produces the non-cooperative quantity *conditional* on CSR levels in in Stage 2, but reduces CSR levels in Stage 1, reducing consumer welfare on one account compared to the non-cooperative benchmark.

To compare a CSR agreement to a full agreement, first note that if CSR efforts are identical across firms and equal to v, conditional quantities are given by

$$q^*(v) = \frac{A+v}{\gamma(n-1)+2} \text{ and } q^c(v) = \frac{A+v}{2(\gamma(n-1)+1)} \tag{4.15}$$

where $q^*(v)$ is the conditional quantity if firms select quantities non-cooperatively in Stage 2, $q^c(v)$ is the conditional quantity if firms select quantities cooperatively in Stage 2, and $A = \alpha - c$. The difference in consumer surplus between a CSR agreement and the non-cooperative benchmark can be written as $|\frac{\partial CS}{\partial q}\frac{\partial q^*}{\partial v}\Delta v^{csr}|$, where Δv^{csr} is $v^{csr} - v^* < 0$, and the difference in consumer surplus between a full agreement and the non-cooperative benchmark can be written as $|\frac{\partial CS}{\partial q}(\frac{\partial q^c}{\partial v}\Delta v^f + \Delta q^f)|$, where Δv^f is $v^f - v^* < 0$ and Δq^f is $q^f(v^*) - q^*(v^*) < 0$. As long as $|\frac{\partial q^*}{\partial v}\Delta v^{csr}| < |\frac{\partial q^c}{\partial v}\Delta v^f + \Delta q^f|$, a full agreement reduces consumer surplus by more than a CSR agreement. In essence, unless benchmark quantities react very strongly to changes in CSR, a full agreement reduces consumers surplus by more than a CSR agreement.

Second, we note that the ranking of profit across these three regimes is opposite to that of consumer surplus for all parameter values: $\pi(q^f, v^f) > \pi(q^{csr}, v^{csr}) > \pi(q^*, v^*)$. Combined as total welfare in the market, defined for regime r as

$$W(q^r, v^r) = CS(q^r) + n\pi(q^r, v^r).$$

Let $W(q^*(v), v)$ denote welfare when all firms set quantities non-cooperatively and identical CSR levels v. We find that welfare compares as follows.

Proposition 4.7. $W(q^*, v^*) > W(q^{csr}, v^{csr}) > W(q^f, v^f)$ and $\frac{\partial W(q^*(v),v)}{\partial v}|_{v=v^*} > (<)0$ if

[29]In Appendix 4.C, we show that our findings on welfare are robust to allowing CSR levels to directly influence consumer welfare.

$\gamma < (>) \Gamma'(n)$.

Proof. See Appendix 4.A. ■

Unsurprisingly, given Proposition 4.1, competition is unambiguously the superior regime amongst these three: it produces both higher CSR efforts and higher output, hence higher total within-market welfare. Proposition 4.7 also makes more precise in what sense competition should not be too strong, as mentioned in the introduction. When products are relatively homogeneous, beyond a critical level that decreases in the number of firms (n), it is no longer possible to improve within-market total welfare by inducing more investments in CSR. That is, only when competition is sufficiently imperfect is the optimal CSR level in the market higher than the level in the non-cooperative benchmark.[30]

In case of production agreements, there is a trade-off: consumers benefit from increased CSR efforts, but are harmed from reduced output and therefore higher prices. However, we find that welfare is never served by allowing voluntary production agreements either. While a production agreement increases CSR efforts, it reduces consumer welfare compared to competition, except for a small set of well-chosen duopolies in which the firms would not voluntarily form the agreement. The following set of results establishes this.

Proposition 4.8. $CS(q^*) > CS(q^p)$, unless $n = 2$ and $t < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$, in which case $CS(q^*) < CS(q^p)$ and $\pi(q^*, v^*) > \pi(q^p, v^p)$.

Proof. See Appendix 4.A. ■

The first part of the proposition states that only when there are two firms and investing in CSR is sufficiently cheap, which is more often the case when goods are very similar (γ close to 1), does a production agreement increase consumer welfare compared to the non-cooperative benchmark. In all other cases, consumers are worse off with a production agreement, despite the higher CSR levels.

The intuition is as follows. A production agreement creates two opposing effects on consumer surplus. From Proposition 4.1 we know that in all cases $\Delta v^p = v^p - v^* > 0$. Comparing conditional quantities (4.15) above shows that a production agreement reduces output conditional on CSR levels, and therefore $\Delta q^p = q^c(v^*) - q^*(v^*) < 0$. The total

[30]We note that the socially optimal level of CSR is loss-making for the firms. The social optimum requires prices to equal marginal costs, and therefore firms make a loss after taking into account the fixed costs of CSR investment.

difference in consumer surplus between a production agreement and the non-cooperative benchmark is therefore given by $|\frac{\partial CS}{\partial q}(\frac{\partial q^c}{\partial v}\Delta v^p + \Delta q^p)|$. In a duopoly, if goods are similar and investing in CSR is cheap, $t < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$, the business stealing effect is very strong and Δv^p becomes so large that the net effect on consumer surplus is positive. However, as n increases, the responsiveness of quantity to CSR levels diminishes and even when Δv^{pc} is high, consumers are worse off compared to the non-cooperative benchmark.

To see the consumer welfare trade-off, note that the difference in total quantity between a production agreement and the non-cooperative benchmark, conditional on a fixed CSR level $\overline{v}$ is given by

$$n(q^*(\overline{v}) - q^c(\overline{v})) = (A + \overline{v})\frac{\gamma n(n-1)}{2(\gamma(n-1)+2)(\gamma(n-1)+1)} \tag{4.16}$$

which monotonically increases to $(A + \overline{v})\frac{1}{2\gamma}$ as n goes to infinity. This implies that a production agreement hurts consumers by reducing conditional quantities regardless of market size, and that this negative effect on consumer surplus increases in n.

From Proposition 4.1 we know that $v^p > v^*$, but whether this also results in increased consumer surplus depends on the responsiveness of quantity to CSR levels in both competitive regimes. The conditional quantities in equations (4.15) show that output is less responsive to CSR levels in a production agreement than in the non-cooperative benchmark, and that this difference in responsiveness is increasing in n. In a duopoly, the responsiveness of quantity to CSR levels is highest, so high in fact that when investing is sufficiently cheap a production agreement's CSR level might lead to a higher quantity compared to the non-cooperative benchmark. However, as n increases the responsiveness of quantity to CSR levels quickly drops off, and the reduction of conditional quantities eventually dominates the increase in CSR levels.

The trade-off between higher CSR levels and lower conditional quantities holds generally, but the tipping point at $n = 2$ is specific to this model.[31] In these specific cases in which consumer could benefit from a production agreement, however, the companies prefer to compete instead, as business stealing incentives in a production agreement are so strong that over-investing in CSR reduces profit. The only output agreements that simultaneously increase CSR efforts and consumer welfare, therefore, will not be voluntarily engaged in by companies.

We conclude that no CSR agreement exists that simultaneously increases CSR efforts,

[31]In Appendix 4.B we find that the tipping point occurs before $n = 2$ when firms set prices instead of quantities in Stage 2, so that a production agreement can never increase consumer surplus compared to the non-cooperative benchmark.

consumer welfare and profit compared to the non-cooperative benchmark. Therefore, unconditionally allowing firms to coordinate their output volumes in order to advance CSR always decreases consumer surplus. In fact, in the baseline model, production agreements do not generate surplus wealth at all.

Proposition 4.9. $W(q^*, v^*) > W(q^p, v^p)$.

Proof. See Appendix 4.A. ■

Propositions 4.7 and 4.9 together show that all types of joint agreements always reduce total within-market welfare. The reason is straightforward: any reduction of competition inescapably creates a deadweight loss.

4.5 Exempting joint agreements from antitrust

With joint output (or price) agreements being the only effective means to stimulate CSR efforts, antitrust laws are a major obstacle to firm-led CSR initiatives. However, some competition authorities are opening up the idea of allowing, under conditions, anticompetitive agreements that promote CSR objectives. Most advanced in this respect is a framework to exempt sustainability agreements from the European cartel prohibition, Article 101 of the Treaty. Article 101 specifies four cumulative requirements for such an exemption.[32] In essence, the advance of CSR should be (i) concrete and objectively measurable "economic progress", benefits of which (ii) consumers should receive "a fair share" of. The restrictions of competition should be (iii) "not indispensable" for attaining the objectives, and should (iv) not eliminate competition on all dimensions in the market. In this section, we consider these requirements in light of our findings on joint agreements.

The focus of competition authorities that are open to permitting joint agreements, if they stimulate CSR, has so far been exclusively on agreements about CSR directly. Yet these we have found to *reduce* CSR efforts. At first sight, CSR agreements may appear sympathetic and traditional price cartels damaging, but some reflection on the company's incentives has led to the insight that the opposite is in fact the case. Only production agreements can generate concrete CSR benefits, provided that consumers have some, if only little appreciation for the type of CSR efforts advanced – and otherwise no agreement can. Therefore, if cartel law exemptions on CSR grounds are to be considered at all, it

[32]These exemption conditions are given in Article 101(3) TFEU.

must be for production agreements, not CSR agreements. In principle, this should be possible under the European Treaty conditions.

The second requirement, that consumers benefit, is more problematic. In its current interpretation in case law, the buyers of the products concerned are to be fully compensated, on average, for any anticompetitive effects that they suffer because of the agreement, by the benefits that the agreement brings about.[33] Consumers should, in other words, not be worse off with the agreement in place. However, we find that no joint agreements exist that both increase CSR and consumer welfare, and that the companies would voluntarily engage in. Competition authorities would therefore always need to strictly demand compensation from firms that it allows to form a production agreement, and ensure that this compensation is indeed delivered to consumers for as long as the agreement is exempted. This changes the agencies' market oversight role fundamentally and requires information that they do not typically have available. Identifying genuine and effective CSR agreements, and monitoring them permanently, will be demanding on time and budget, and crowd out other important competition enforcement objectives. The policy therefore presents a risk of abuse by companies colluding under the guise of corporate social responsibility.

Having said that, our model does offer a direct mechanism to make consumers indifferent: they can be given monetary compensation out of the firms' post-agreement profit directly via m in utility function (4.1). However, by Proposition 4.9 there is no surplus wealth for full consumer compensation: total within-market welfare is lower under the production agreement than in competition. Compensation by redistributing profit is therefore not possible. In addition, requiring compensation would also undermine the incentives to invest in CSR, as the business stealing incentive is reduced.

A competition authority that wants to accommodate a production agreement for the purpose of inducing CSR efforts will have to give up the requirement that consumers are to be fully compensated, and add benefits of the agreement to others, who are not buyers of the products concerned. This is the approach of the Dutch competition authority ACM – with a focus on "sustainability agreements".[34] The agency interprets "a fair share" as benefits that can be less than fully compensating and adds "out-of-market-efficiencies" or "externality benefits" that would be obtained by third parties to the agreement. The latter are easily many, since CSR efforts that reduce negative externalities, such as pollution or unfair trading, will be appreciated by many non-buyers who value CSR more than the

[33]See European Commission (2004) at recital 85/87.

[34]ACM (2021). Several other antitrust agencies are following suit.

actual consumers.[35]

To see the effects of including negative out-of-market externalities in our analysis, consider as externality

$$E(\mathbf{q}, \mathbf{v}) = \sum_{i=1}^{n} \frac{q_i}{v_i}. \tag{4.17}$$

This expression has the appealing feature that for each firm, the increase of the negative externality due to producing one more unit of output is decreasing in that firm's CSR level. In addition, the marginal positive effect of a firm's CSR level on the externality that its production generates is decreasing in that firm's CSR level. The reduction in externalities in regime r compared to the externalities caused in the non-cooperative benchmark is $\Delta E(q^r, v^r) = n(\frac{q^*}{v^*} - \frac{q^r}{v^r})$. These compare across the different competitive regimes as follows.

Proposition 4.10. $\Delta E(q^p, v^p) > 0 > \Delta E(q^f, v^f) > \Delta E(q^{csr}, v^{csr})$.

Proof. See Appendix 4.A. ■

Adding out-of-market externality benefits does not justify joint agreements on CSR directly. CSR agreements increase negative externalities compared to the non-cooperative benchmark. Only production agreements decrease negative externalities. This is intuitive, since a production agreement was found to be the only type of joint agreement that increases CSR efforts, while it reduces conditional quantities at the same time. $\Delta E(q^p, v^p) > 0$ holds as long as externalities are increasing in output and decreasing in CSR. CSR agreements and full agreements also reduce output, but they decrease CSR levels. Which effect on negative externalities dominates depends on the relative weights that are given in the externality function to changes in CSR levels and changes in output. $\Delta E(q^{csr}, v^{csr}) < 0$ and $\Delta E\left(q^f, v^f\right) < 0$ hold more generally for externalities that increase in output and decrease in CSR efforts, as long as the externality is a function of $\frac{q^r}{v^r}$. The conclusion remains that if a joint agreement is to be exempted from cartel law at all, it better be a production agreement. Adding out-of-market-efficiencies does not help to justify the exemption of CSR agreements.

The third requirement for a cartel exemption states that some competition must remain under the agreement, for example on the dimensions of price, brand image or tech-

[35] In fact, so rich are benefits elsewhere likely to be, that a risk of this "citizens' welfare standard" is that it will become hard for the competition authority to say "no" to production agreements at all. See Schinkel and Treuren (2021b) for an elaborate discussion.

nological development. Importantly, our result that production agreements can increase CSR efforts holds *provided* that competition on CSR remains, which should satisfy this requirement. In practice, agreements aimed at improving CSR efforts often involve only a subset of all firms in the market, leaving a competitive fringe. The existence of remaining competition in CSR efforts and output affects the incentives of the competitors that do make joint agreements.

In Appendix 4.D we show that our main findings on joint agreements still hold for partial agreements involving m firms that leave remaining fringe competition ($m < n$). Residual competition simply reduces the possibilities for firms to benefit from an agreement. This causes all outcomes to lie in between the non-cooperative outcome and the outcome with a market-wide agreement. Therefore, partial agreements on CSR reduce CSR and output compared to the benchmark, but by less than market-wide agreements directly on CSR. Likewise, partial agreements on production increase CSR and reduce conditional quantities compared to the benchmark, but by less that market-wide production agreements. Still, no agreement can profitably increase CSR levels and consumer welfare.

Finally, the fourth condition for a cartel exemption under Article 101(3) TFEU is that the restriction of competition must be necessary to obtain the benefits, in this case CSR benefits. In practice, the interpretation of this requirement has been rather narrow – it suffices that the agreement does not go beyond what is necessary to generate the projected increase in CSR efforts compared to competition. This we have found to be the case only for production agreements. The condition may also be read wider, as a broad duty of the competition authority to consider and give priority to alternative ways in which the projected CSR benefits could be achieved – in particular government regulation. In that case, a simple and far superior solution to excusing collusion exists in regulation.

For any industry-wide regulated CSR level $v > 0$, let $W(q^*(v), v)$ be within-market welfare if the conditional quantities are set non-cooperatively, and let $W(q^c(v), v)$ be within-market welfare if the conditional quantities are set cooperatively (in either a production agreement or a full agreement).[36] We then obtain the following result.

Proposition 4.11. $W(q^*(v), v) > W(q^c(v), v)$ for all $v > 0$.

Proof. See Appendix 4.A. ■

[36]Obviously, first allowing a CSR agreement and then regulating it to a higher CSR level makes little sense. With regulation, only the conditional quantities are relevant.

The proposition establishes that for any CSR level, total within-market welfare is always higher when that CSR level is simply required from firms that remain in competition, for example by regulation, than when it is provided by firms that coordinate their output. The advance in CSR efforts that would result from a production agreement ($v^p > v^*$), the government can simply demand by regulating CSR levels. Hence, there is no necessity to restrict competition to stimulate CSR. On the contrary: it is an inferior tool, since any level of CSR that government deems an improvement ($v > v^*$) it better simply imposes than left to an output-coordinating agreement. We do note that, since a regulated CSR level does not induce the same output restriction as a production agreement would, the reduction of negative externalities will typically be less with regulation than with a production agreement. Yet governments can easily be more ambitious and set higher CSR goals to account for externalities.

4.6 Concluding remarks

Whenever consumers are more inclined to buy from companies with a stronger CSR profile, joint agreements on CSR turn out to reduce CSR efforts. The reason is that by showing CSR, firms steal business from their rivals, and this dimension of competition is eliminated by firms jointly deciding on their costly CSR efforts. If incentives to invest in CSR need strengthening by reducing competition at all, coordination should not be permitted on CSR efforts directly, but only on output (or prices). Collusion on the output market stimulates CSR efforts indirectly: it increases profit per consumer, which makes it even more attractive for the firms competing for that profit to heighten their CSR profile and attract additional customers. Neither low willingness to pay for CSR with consumers, nor intrinsic motivations for CSR with firms provide reason to think that companies will increase their CSR investments if they can jointly decide on them. There is also no reason to expect more CSR efforts from private coordination if there is no or negative willingness to pay for CSR.

CSR agreements are better avoided altogether if the goal is to stimulate firms to take more responsibility for environmental and social objectives. These findings are in stark contrast to the popular calls in the business literature and practice, where it is suggested that collaboration would be imperative to stimulate CSR efforts. The policy paradox is that society can only induce companies to invest more in CSR than they do in competition by allowing them to reap the benefits of their additional CSR efforts. Output agreements, however, raise competition law concerns and reduce the sum of consumer welfare and profit in the market, so that consumers cannot be compensated for their antitrust damage. The latter is a requirement under the going interpretation of the European Treaty articles on horizontal agreements that therefore cannot be met.

CSR by its nature can have wider benefits than just within-market welfare, where it reduces negative production externalities such as pollution or human rights violations. Taking these out-of-market efficiencies into account may help to justify voluntary production agreements in particular, as they increase CSR efforts and reduce output.[37] However, permitting production agreements on these grounds is unprecedented in competition policy and comes with major risks. By blurring the bright-line rule against hard core price fixing, deterrence may be undermined. A competition agency that does exempt a market agreement, must permanently monitor that the companies involved indeed deliver on CSR and do not overcharge their customers. It will become increasingly difficult for the agency to know the but-for CSR efforts that would have been, had competition been preserved. In addition to such greenwashing concerns, joint agreements on one aspect of competition are known to spill over to other aspects, and even other markets.

If companies are sincere in their statements that they are discouraged to pursue CSR initiatives by antitrust liability concerns, then the question rises why they do not lobby regulators for implementation of higher CSR standards – rather than competition agencies for permission to reduce competition. Indeed, voluntary agreements have been identified as a possible strategic means to preempt future regulation.[38] Government regulation seems to be superior to collaborative self-regulation. Before rushing ahead to relax the cartel laws on the basis of an unproven claim that collaboration would be needed to advance CSR, more comparative study of alternative public and private regulatory approaches to CSR stimulation should be done.

Corporate social responsibility can and has to play an important role in resolving pressing social problems, such as climate change and unfair business practices, that require urgent and drastic action that governments often fail to take. There is no compelling evidence that business collaboration in restraint of competition would help this cause. Instead, growing consumer awareness, and increasing willingness to buy from and invest in companies that are serious about their CSR, are ever stronger motivators for firms to differentiate themselves from their competitors. CSR is a business model and a hopeful gathering force for more responsible corporate behavior. Competition strengthens these

[37]The latter effect appeals to claims that fighting climate change requires reducing "overconsumption" (Wiedmann et al., 2020).

[38]Lutz et al. (2000) show how self-regulated quality standards can weaken and delay better regulation. Innes and Sam (2008) finds that firms voluntarily reduce pollution in an attempt to relax future regulatory scrutiny. Malhotra et al. (2019) argue that firms can use modest private regulation to preempt more stringent public regulations.

incentives to do well by doing good, and is therefore an engine for corporate social performance. It should be given free rein and not be throttled by corporate collaboration that risks collusion. While voluntary collective agreements have their merits in other contexts, for example in reaping R&D synergies, we contribute that agreements on CSR weaken competition as an important driver of corporate social efforts.

4.A Proofs of propositions

Proof of Proposition 4.1. (Effective joint agreements)
Define $A = \alpha - c$, $\beta_1 = \gamma(n-1)+2$, $\beta_2 = \gamma(n-2)+2$, and $\beta_3 = \gamma(n-3)+2$. In Stage 2, firms in the non-cooperative benchmark or a CSR agreement maximize (4.3) with respect to q_i, resulting in Nash-equilibrium conditional quantities

$$q_i^*(\mathbf{v}) = \frac{\beta_2(A+v_i) - \gamma\sum_{i\neq j}^{n}(A+v_j)}{(2-\gamma)\beta_1}, \quad i = 1, ..., n, \tag{4.18}$$

while firms in a production agreement or a full agreement choose quantities to maximize the sum of members' profit, conditional on $\mathbf{v}$, resulting in conditional quantities (superscript c for "coordinated")

$$q_i^c(\mathbf{v}) = \frac{(1-\gamma)A + (\beta_2 - 1)v_i - \gamma\sum_{i\neq j}^{n} v_j}{2(1-\gamma)(\beta_1 - 1)}, \quad i = 1, ..., n. \tag{4.19}$$

In Stage 1, firms in the non-cooperative benchmark pick v_i to maximize $\pi_i(\mathbf{q}^*(\mathbf{v}), v_i)$, resulting in Nash-equilibrium CSR level

$$v^* = A\frac{2\beta_2}{t(2-\gamma)\beta_1^2 - 2\beta_2}. \tag{4.20}$$

Firms in a CSR agreement select $\mathbf{v}$ to maximize $\sum_{i=1}^{n}\pi_i(\mathbf{q}^*(\mathbf{v}), v_i)$ in Stage 1, resulting in CSR level

$$v^{csr} = A\frac{2}{t\beta_1^2 - 2}. \tag{4.21}$$

Members of a production agreement determine v_i by maximizing $\pi_i(\mathbf{q}^c(\mathbf{v}), v_i)$, so that the CSR level is

$$v^p = A\frac{\beta_3}{4t(1-\gamma)(\beta_1 - 1) - \beta_3}. \tag{4.22}$$

A full agreement chooses $\mathbf{v}$ to maximize $\sum_{i=1}^{n}\pi_i(\mathbf{q}^c(\mathbf{v}), v_i)$ in Stage 1. The resulting CSR level is

$$v^f = A\frac{1}{2t(\beta_1 - 1) - 1}. \tag{4.23}$$

Note that conditional quantities (4.18) and (4.19) are symmetric by implication. To ensure that all second-order conditions hold, and restricting our attention to interior solutions, in all proofs in this appendix we impose $8t(1-\gamma)^2(\beta_1 - 1) - \beta_3^2 > 0$. The ranking follows from

$$\begin{aligned} v^p - v^* &= A\frac{\gamma^2 t(n-1)(4n+2\gamma(n-1)(n-2)-\gamma^2(n-1)(n-3))}{(4t(1-\gamma)(\beta_1-1)-\beta_3)(t(2-\gamma)\beta_1^2-2\beta_2)} > 0, \\ v^* - v^f &= A\frac{\gamma t(1-n)(4+\gamma(2+\gamma)(n-1))}{(2t(\beta_1-1)-1)(t(2-\gamma)\beta_1^2-2\beta_2)} > 0, \text{ and} \\ v^f - v^{csr} &= A\frac{t(\beta_1-2)^2}{(2t(\beta_1-1)-1)(t\beta_1^2-2)} > 0. \blacksquare \end{aligned}$$

Proof of Proposition 4.2. (Profitability)
Benchmark profit $\pi(q^*, v^*)$ is obtained by substituting equations (4.20) and (4.18) into equation (4.3). Profit in a production agreement, $\pi(q^p, v^p)$, is obtained by substituting (4.22) and (4.19) into equation (4.3). Comparing $\pi(q^*, v^*)$ to $\pi(q^p, v^p)$ shows that $\pi(q^p, v^p) > \pi(q^*, v^*)$ if $\gamma \leq \Gamma(n)$ or $\gamma > \Gamma(n)$ and $t > T(\gamma, n)$, and $\pi(q^*, v^*) \geq \pi(q^p, v^p)$ otherwise. Here, $T(\gamma, n)$ is given by

$$\begin{aligned} T(\gamma,n) = \frac{1}{16}[&\frac{16(1-2n)}{n^2(\gamma-2)^2} - \frac{16(n-1)}{n^3(\gamma-2)} + \frac{(1+n)^2}{n(\gamma-1)^2} + \frac{n(n(n-5)+3)+1}{n^2(\gamma-1)} + \frac{(n-1)^2}{n^2(\beta_1-1)} + \frac{16}{n^2\beta_1^2} + \frac{16(n-1)^2}{n^3\beta_1} \\ &+ \sqrt{\frac{\gamma^2(4n+2\gamma(n-1)(n-2)-\gamma^2(n-1)(n-3))^2(\rho(\gamma,n))}{(\gamma-2)^4(\gamma-1)^4(\beta_1-1)^2\beta_1^4}}], \\ \rho(\gamma,n) = 256 &+ 128\gamma(4n-7) + 16\gamma^2(76+n(21n-88)) + 80\gamma^3(n-1)(n(n-8)+10) + 4\gamma^4(n-1)(n(n-31)+102) \\ &- 4\gamma^5(n-1)^2(n(n-13)_14) + \gamma^6(n^2-4n+3)^2. \end{aligned}$$

and $\Gamma(n)$ is given by the 4th smallest root of the following polynomial in x

$$\begin{aligned} f(x) = 32 &+ x(64n-192) + x^2(24n^2-368n+472) + x^3(-8n^3-192n^2+792n-640) + x^4(-4n^4-20n^3+402n^2-896n+526) \\ &+ x^5(4n^4+60n^3-372n^2+580n^n-272) + x^6(-n^4-40n^3+162n^2-200n+79) + x^7(8n^3-24n^2+24n-8). \end{aligned}$$

$\blacksquare$

Proof of Proposition 4.3. (Willingness to pay)
In Stage 2, firms in the non-cooperative benchmark or a CSR agreement maximize (4.11) with respect to q_i, resulting in Nash-equilibrium conditional quantities

$$q^*_{\delta,i}(\mathbf{v}) = \frac{\beta_2(A+\delta v_i) - \gamma\sum_{i\neq j}^n (A+\delta v_j)}{(2-\gamma)\beta_1}, \quad i = 1, ..., n, \tag{4.24}$$

while firms in a production agreement or a full agreement choose quantities to maximize the sum of members' profit, conditional on $\mathbf{v}$, resulting in conditional quantities

$$q^c_{\delta,i}(\mathbf{v}) = \frac{(\beta_2-1)(A+\delta v_i) - \gamma\sum_{i\neq j}^n (A+\delta v_j)}{2(1-\gamma)(\beta_1-1)} \quad i = 1, ..., n. \tag{4.25}$$

Let $\mathbf{q}^*_\delta = q^*_{\delta,1}(\mathbf{v}), q^*_{\delta,2}(\mathbf{v}), \ldots, q^*_{\delta,n}(\mathbf{v})$. In Stage 1, firms in the non-cooperative benchmark pick v_i to maximize $\pi_i(\mathbf{q}_\delta^*(\mathbf{v}), v_i)$, resulting in Nash-equilibrium CSR level

$$v_\delta^* = A\frac{2\delta\beta_2}{t(2-\gamma)\beta_1^2 - 2\delta^2\beta_2}. \tag{4.26}$$

A CSR agreement chooses $\mathbf{v}$ to maximize $\sum_{i=1}^n \pi_i(\mathbf{q}_\delta^*(\mathbf{v}), v_i)$ in Stage 1, so that the CSR level is

$$v_\delta^{csr} = A\frac{2\delta}{t\beta_1^2 - 2\delta^2}. \tag{4.27}$$

Let $\mathbf{q}_\delta^c = q_{\delta,1}^c(\mathbf{v}), q_{\delta,2}^c(\mathbf{v}), \ldots, q_{\delta,n}^c(\mathbf{v})$. Members of a production agreement determine v_i by maximizing $\pi_i(\mathbf{q}_\delta^c(\mathbf{v}), v_i)$, so that the CSR level is

$$v_\delta^p = A\frac{\delta\beta_3}{4t(1-\gamma)(\beta_1-1) - \delta^2\beta_3}. \tag{4.28}$$

Finally, a full agreement chooses $\mathbf{v}$ to maximize $\sum_{i=1}^n \pi_i(\mathbf{q}_\delta^c(\mathbf{v}), v_i)$ in Stage 1. The resulting CSR level is

$$v_\delta^f = A\frac{\delta}{2t(\beta_1-1) - 1}. \tag{4.29}$$

The ranking follows from

$$\begin{aligned}
v_\delta^p - v_\delta^* &= \delta A\frac{\gamma^2 t(n-1)(4n+2\gamma(n-1)(n-2)-\gamma^2(n-1)(n-3))}{(4t\,(1-\gamma)\,(\beta_1-1)-\delta^2\beta_3)(t(2-\gamma)\beta_1^2-2\delta^2\beta_2)} > 0,\\
v_\delta^* - v_\delta^f &= \delta A\frac{\gamma t(1-n)(4+\gamma(2+\gamma)(n-1))}{(2t(\beta_1-1)-\delta^2)(t(2-\gamma)\beta_1^2-2\delta^2\beta_2)} > 0, \text{ and}\\
v_\delta^f - v_\delta^{csr} &= \delta A\frac{t(\beta_1-2)^2}{(2t(\beta_1-1)-\delta^2)(t\beta_1^2-2\delta^2)} > 0. \blacksquare
\end{aligned}$$

Proof of Proposition 4.4. (Polarization in willingness to pay)

The difference $v_\delta^p - v_\delta^*$ is constructed from equations (4.28) and (4.26). Taking the derivative with respect to δ gives

$$\frac{\partial(v_\delta^p - v_\delta^*)}{\partial\delta} = \frac{A\beta_3(4t(1-\gamma)(\beta_1-1)+\delta^2\beta_3)}{(4t(\gamma-1)(\beta_1-1)+\delta^2\beta_3)^2} + \frac{2A\beta_2(t(\gamma-2)\beta_1^2-2\delta^2\beta_2)}{(t(\gamma-2)\beta_1^2+2\delta^2\beta_2)^2} > 0.$$

The difference $v_\delta^* - v_\delta^f$ is constructed from equations (4.26) and (4.29). Taking the derivative with respect to δ gives

$$\frac{\partial(v_\delta^* - v_\delta^f)}{\partial\delta} = \frac{2A\beta_2(t(2-\gamma)\beta_1^2+2\delta^2\beta_2)}{(t(\gamma-2)\beta_1^2+2\delta^2\beta_2)^2} - \frac{A(\delta^2+2t(\beta_1-1))}{(\delta^2-2t(\beta_1-1))^2} > 0.$$

The difference $v_\delta^f - v_\delta^{csr}$ is constructed from equations (4.29) and (4.27). Taking the derivative with respect to δ gives

$$\frac{\partial(v_\delta^f - v_\delta^{csr})}{\partial\delta} = \frac{A(\delta^2 + 2t(\beta_1 - 1))}{(\delta^2 - 2t(\beta_1 - 1))^2} - \frac{2A(t\beta_1^2 + 2\delta^2)}{(t\beta_1^2 - 2\delta^2)^2} > 0. \blacksquare$$

Proof of Proposition 4.5. (Intrinsic motivation)
Intrinsic motivation does not affect the conditional quantities that solve Stage 2 of the game. In Stage 2, firm i in the non-cooperative benchmark or a CSR agreement maximizes objective function (4.12) with respect to q_i, resulting in conditional quantity given by equation (4.18). Firm i in a production agreement or a full agreement choose quantities to maximize $\sum_{i=1}^n (\pi_i(\mathbf{q}, v_i) + \theta v_i)$ resulting in conditional quantity given by equation (4.19).

In Stage 1, firms in the non-cooperative benchmark pick v_i to maximize $\pi_i(\mathbf{q}^*(\mathbf{v}), v_i) + \theta v_i$, resulting in Nash-equilibrium CSR level

$$v_I^* = v^* + \frac{(2-\gamma)\beta_1^2\theta}{t(2-\gamma)\beta_1^2 - 2\beta_2} = \frac{2\beta_2 A + (2-\gamma)\beta_1^2\theta}{t(2-\gamma)\beta_1^2 - 2\beta_2}. \tag{4.30}$$

Firms in a CSR agreement choose $\mathbf{v}$ to maximize $\sum_{i=1}^n (\pi_i(\mathbf{q}^*(\mathbf{v}), v_i) + \theta v_i)$ in Stage 1, with the resulting CSR level given by

$$v_I^{csr} = v^{csr} + \frac{\beta_1^2\theta}{t\beta_1^2 - 2} = \frac{2A + \beta_1^2\theta}{t\beta_1^2 - 2}. \tag{4.31}$$

The members of a production agreement determine v_i by maximizing $\pi_i(\mathbf{q}^c(\mathbf{v}), v_i) + \theta v_i$, so that the CSR level is

$$v_I^p = v^p + \frac{4(1-\gamma)(\beta_1 - 1)\theta}{4t(1-\gamma)(\beta_1 - 1) - \beta_3} = \frac{\beta_3 A + 4(1-\gamma)(\beta_1 - 1)\theta}{4t(1-\gamma)(\beta_1 - 1) - \beta_3}. \tag{4.32}$$

Finally, firms in a full agreement choose $\mathbf{v}$ to maximize $\sum_{i=1}^n (\pi_i(\mathbf{q}^c(\mathbf{v}), v_i) + \theta v_i)$ in Stage 1. The resulting CSR level is

$$v_I^f = v^f + \frac{2(\beta_1 - 1)\theta}{2t(\beta_1 - 1) - 1} = \frac{A + 2(\beta_1 - 1)\theta}{2t(\beta_1 - 1) - 1}. \tag{4.33}$$

The ranking follows from

$$\begin{aligned} v_I^p - v_I^* &= (At+\theta)\frac{\gamma^2(n-1)(\gamma^2(n-1)(n-3)-2\gamma(n-1)(n-2)-4n)}{(4t(\gamma-1)(\beta_1-1)+\beta_3)(t(2-\gamma)\beta_1^2-2\beta_2)} > 0, \\ v_I^* - v_I^f &= (At+\theta)\frac{\gamma(n-1)(\gamma(2+\gamma)(n-1)+4)}{(2t(\beta_1-1)-1)(t(2-\gamma)\beta_1^2-2\beta_2)} > 0, \text{ and} \\ v_I^f - v_I^{csr} &= (At+\theta)\frac{\gamma^2(n-1)^2}{(2t(\beta_1-1)-1)(t\beta_1^2-2)} > 0. \blacksquare \end{aligned}$$

Proof of Proposition 4.6. (Polarization in intrinsic motivation)
The difference $v_I^p - v_I^*$ is constructed from equations (4.32) and (4.30). Taking the derivative with respect to θ gives

$$\frac{\partial(v_I^p - v_I^*)}{\partial\theta} = \frac{\gamma^2(n-1)(4n+2\gamma(n-1)(n-2)-\gamma^2(n-1)(n-3))}{(4t(\gamma-1)(\beta_1-1)+\beta_3)(t(\gamma-2)\beta_1^2+2\beta_2)} > 0.$$

The difference $v_I^* - v_I^f$ is constructed from equations (4.30) and (4.33). Taking the derivative with respect to θ gives

$$\frac{\partial(v_I^* - v_I^f)}{\partial\theta} = \frac{\gamma(1-n)(\gamma(2+\gamma)(n-1)+4)}{(2t(\beta_1-1)-1)(t(\gamma-2)\beta_1^2+2\beta_2)} > 0.$$

The difference $v_I^f - v_I^{csr}$ is constructed from equations (4.33) and (4.31). Taking the derivative with respect to θ gives

$$\frac{\partial(v_I^f - v_I^{csr})}{\partial\theta} = \frac{\gamma^2(n-1)^2}{(2t(\beta_1-1)-1)(t\beta_1^2-2)} > 0. \blacksquare$$

Proof of Proposition 4.7. (Welfare CSR agreements)
Substituting equations (4.18) and (4.20) into equations (4.3) and (4.14), and then adding total profit of all firms to consumer surplus gives Nash-equilibrium welfare in the non-cooperative benchmark

$$W(q^*, v^*) = A^2nt\frac{t(\gamma-2)^2(\beta_1+1)\beta_1^2-4\beta_2^2}{2(t(\gamma-2)\beta_1^2+2\beta_2)^2}. \tag{4.34}$$

Substituting equations (4.18) and (4.21) into equations (4.3) and (4.14), and then adding total profit of all firms to consumer surplus gives welfare in a CSR agreement

$$W(q^{csr}, v^{csr}) = A^2nt\frac{t(\beta_1+1)\beta_1^2-4}{2(t\beta_1^2-2)^2}. \tag{4.35}$$

Substituting equations (4.19) and (4.23) into equations (4.3) and (4.14), and then adding total profit of all firms to consumer surplus gives welfare in a full agreement

$$W(q^f, v^f) = A^2 nt \frac{3t(\beta_1 - 1) - 1}{2(2t(\beta_1 - 1) - 1)^2}. \tag{4.36}$$

Straightforward calculations deliver $W(q^*, v^*) - W(q^{csr}, v^{csr}) > 0$, and $W(q^{csr}, v^{csr}) - W(q^f, v^f) > 0$.

Imposing $v_i = v \ \forall i$, substituting equation (4.18) into equation (4.3) and equation (4.14), and adding total profit of all firms to consumer surplus gives

$$W(q^*(v), v) = \frac{n(3A^2 + 6Av + \gamma(n-1)(A+v)^2 - (t\beta_1^2 - 3)v^2)}{2\beta_1^2}. \tag{4.37}$$

Taking the derivative of equation (4.37) with respect to v, and then imposing $v = v^*$ gives

$$\frac{\partial W(q^*(v), v)}{\partial v}|_{v=v^*} = Ant \frac{\gamma(\beta_1 - 1) - 2}{t(\gamma - 2)\beta_1^2 + 2\beta_2},$$

where $\frac{\partial W(q^*(v),v)}{\partial v}|_{v=v^*} \geq 0$ if $\gamma \leq \Gamma'$, $\frac{\partial W(q^*(v),v)}{\partial v}|_{v=v^*} < 0$ if $\gamma > \Gamma'$, and $\Gamma' = \frac{1}{2}\sqrt{\frac{8n-7}{(n-1)^2}} - \frac{1}{2(n-1)}$. ■

Proof of Proposition 4.8. (Consumer welfare production agreement)
In competitive regime r, $r \in \{*, csr, p, f\}$, consumer surplus (4.14) can be written as $CS(q^r) = \frac{n}{2}(\gamma(n-1)+1)(q^r)^2$ as quantities and CSR levels are symmetric. Therefore, the ranking of consumer surpluses is equivalent to that of quantities. We have

$$q^p - q^* = At \frac{\gamma(1-n)(2t(\gamma-2)(\gamma-1)\beta_1 + \gamma(\gamma-2)(n-3) - 4)}{(4t(\gamma-1)(\beta_1-1) + \beta_3)(t(\gamma-2)\beta_1^2 + 2\beta_2)},$$

which is always negative for $n > 2$, and positive for $n = 2$ as long as $t < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$. Nash-equilibrium profit of a firm in the non-cooperative benchmark follows from substituting equations (4.18) and (4.20) into equation (4.3)

$$\pi(q^*, v^*) = A^2 t \frac{t(\gamma-2)^2\beta_1^2 - 2\beta_2^2}{(t(\gamma-2)\beta_1^2 + 2\beta_2)^2}. \tag{4.38}$$

Profit of a firm in a production agreement follows from substituting equations (4.19) and

(4.22) into equation (4.3)

$$\pi(q^p, v^p) = A^2 t \frac{8t(\gamma-1)^2(\beta_1-1)-\beta_3^2}{2(4t(\gamma-1)(\beta_1-1)+\beta_3)^2}. \tag{4.39}$$

Imposing $n = 2$ and $t < \frac{4-2\gamma+\gamma^2}{2(1-\gamma)(4-\gamma^2)}$ gives $\pi(q^*, v^*) > \pi(q^p, v^p)$. ■

Proof of Proposition 4.9. (Welfare production agreement)
Substituting equations (4.19) and (4.22) into equations (4.3) and (4.14), and then adding total profit of all firms to consumer surplus gives welfare in a production agreement

$$W(q^p, v^p) = A^2 nt \frac{12t(\gamma-1)^2(\beta_1-1)-\beta_3^2}{2(4t(\gamma-1)(\beta_1-1)+\beta_3)^2}. \tag{4.40}$$

Comparing equation (4.34) to equation (4.40) shows that $W(q^*, v^*) > W(q^p, v^p)$. ■

Proof of Proposition 4.10. (Externalities)
We have $E(q^r, v^r) = n\frac{q^r}{v^r}$, $r \in \{*, csr, p, f\}$, as quantities and CSR levels are symmetric, so that the ranking of externalities across competitive regimes corresponds to the ranking of the ratio of quantity to CSR level. Substituting equations (4.18) to (4.23) in $E(q^r, v^r)$ and taking differences gives

$$\begin{aligned} E(q^{csr}, v^{csr}) - E(q^f, v^f) &= \frac{\gamma tn(n-1)}{2} > 0, \\ E(q^f, v^f) - E(q^*, v^*) &= \frac{\gamma^2 tn(n-1)}{2\beta_2} > 0, \text{ and} \\ E(q^*, v^*) - E(q^p, v^p) &= \frac{\gamma tn(n-1)(\gamma(2-\gamma)(n-3)+4)}{2\beta_2\beta_3} > 0, \end{aligned}$$

from which the ranking follows. ■

Proof of Proposition 4.11. (Regulation)
Substituting equation (4.18) into equations (4.3) and (4.14), imposing $v_i = v \ \forall i$, and adding total profit of all firms to consumer surplus, gives welfare when quantities are chosen non-cooperatively and CSR levels are regulated to v

$$W(q^*(v), v) = n\frac{3A^2 + 6Av + (3-4t(\beta_1-1))v^2}{8(\beta_1-1)}. \tag{4.41}$$

Substituting equation (4.19) into equations (4.3) and (4.14), imposing $v_i = v \ \forall i$, and adding total profit of all firms to consumer surplus, gives welfare when quantities are chosen cooperatively and CSR levels are regulated to v

$$W(q^c(v), v) = n\frac{3A^2 + 6Av + \gamma(n-1)(A+v)^2 + (3 - t\beta_1^2)v^2}{2\beta_1^2}. \tag{4.42}$$

Subtracting equation (4.42) from equation (4.41) gives

$$W(q^*(v), v) - W(q^c(v), v) = (A+v)^2 \frac{\gamma n(n-1)(\beta_1+2)}{8(\beta_1-1)\beta_1^2} > 0. \blacksquare$$

4.B Price setting

In this appendix, we verify that our results on CSR levels carry through when firms set prices in Stage 2 instead of quantities. An agreement in Stage 2 only, now titled a "price agreement", remains the sole agreement that increases CSR levels compared to the non-cooperative benchmark. As in the baseline model, price agreements increase CSR because coordination in the product market increases the profit margin per consumer, increasing incentives to attract additional consumers by investing in CSR. Consumer welfare results are different when firms set prices in Stage 2 of the game. In this setting, all agreements always reduce consumer welfare. The reason is primarily that, with price setting, the non-cooperative benchmark becomes more competitive and consumer welfare increases compared to the quantity setting benchmark in the main text. Therefore, the reduction in consumer welfare due to a price agreement increasing conditional prices can never be offset by higher CSR levels. As with quantity setting, taking out-of-market externalities into account can justify a price agreement on total welfare grounds when firms set prices in Stage 2, as long as the externalities get sufficient weight in the welfare function.

We start by deriving the profit function of the price setting game. Summing over all firms, demand (4.2) is

$$\sum_{i=1}^{n} p_i = \sum_{i=1}^{n} (\alpha + v_i) - (\beta_1 - 1) \sum_{i=1}^{n} q_i. \tag{4.43}$$

Noting that $\sum_{i \neq j}^{n} q_j = \sum_{k=1}^{n} q_k - q_i$, and substituting for $\sum_{i \neq j}^{n} q_j$ into equation (4.2), the quantity of each firm i can be written as

$$q_i(\mathbf{p}, \mathbf{v}) = \frac{(\beta_2 - 1)(\alpha + v_i - p_i) - \gamma \sum_{i \neq j}^{n} (\alpha + v_j - p_j)}{(1 - \gamma)(\beta_1 - 1)}, \tag{4.44}$$

where $\mathbf{p} = p_1, p_2, \ldots, p_n$. The profit of each firm i is given by

$$\pi_i\left(\mathbf{p}, \mathbf{v}\right) = (p_i - c) \left(\frac{(\beta_2 - 1)(\alpha + v_i - p_i) - \gamma \sum_{i \neq j}^{n} (\alpha + v_j - p_j)}{(1 - \gamma)(\beta_1 - 1)} \right) - \frac{t v_i^2}{2}. \tag{4.45}$$

Equation (4.45) makes clear that each firm's profit is directly affected by the CSR levels of all other firms, in contrast to the quantity setting game where profit (4.3) depends only on the other firms' CSR levels indirectly through the conditional quantities that solve Stage 2 of the game. Firms play a two-stage game. In Stage 1 each firm selects its CSR level v_i. In Stage 2, given CSR levels $\mathbf{v}$, each firm selects its price p_i.

Comparing CSR levels – denoting the price setting game with subscript B – across the four competitive regimes gives.

Proposition 4.B1 $v_B^p > v_B^* > v_B^f > v_B^{csr}$.

Proof.
In Stage 2, firms in the non-cooperative benchmark or a CSR agreement maximize (4.45) with respect to p_i, resulting in Nash-equilibrium conditional price of firm i

$$p_i^*(\mathbf{v}) = \frac{(\beta_3(\beta_2-1)+\gamma(1-\gamma))(\alpha+v_i) - \gamma(\beta_2-1)\sum_{i\neq j}^{n}(\alpha+v_j) + (\gamma(2n-3)+2)(\beta_2-1)c}{(\gamma(2n-3)+2)\beta_3}, \tag{4.46}$$

while firms in a price agreement or a full agreement choose prices to maximize the sum of members' profit, conditional on $\mathbf{v}$, resulting in conditional price

$$p_i^c(v_i) = \frac{\alpha+v_i+k}{2}, \quad i=1,...,n. \tag{4.47}$$

Let $\mathbf{p}^*(\mathbf{v}) = p_1^*(\mathbf{v}), p_2^*(\mathbf{v}), \ldots, p_n^*(\mathbf{v})$. In Stage 1, firms in the non-cooperative benchmark pick v_i to maximize $\pi_i(\mathbf{p}^*(\mathbf{v}), \mathbf{v})$, resulting in Nash-equilibrium CSR level

$$v_B^* = A\frac{2(\gamma(n-2)+1)(\gamma^2n^2-5\gamma^2n+5\gamma^2+3\gamma n-6\gamma+2)}{t(\gamma(2n-3)+2)(\beta_1-1)\beta_3^2 - 2(\gamma(n-2)+1)(\gamma^2n^2-5\gamma^2n+5\gamma^2+3\gamma n-6\gamma+2)}. \tag{4.48}$$

Firms in a CSR agreement select $\mathbf{v}$ to maximize $\sum_{i=1}^n \pi_i(\mathbf{p}^*(\mathbf{v}), \mathbf{v})$ in Stage 1, resulting in CSR level

$$v_B^{csr} = A\frac{2(1-\gamma)(\beta_2-1)}{t(\beta_1-1)\beta_3^2 - 2(1-\gamma)(\beta_2-1)}. \tag{4.49}$$

Let $\mathbf{p}^c(\mathbf{v}) = p_1^c(v_1), p_2^c(v_2), \ldots, p_n^c(v_n)$. Members of a price agreement determine v_i by maximizing $\pi_i(\mathbf{p}^c(\mathbf{v}), \mathbf{v})$, so that the CSR level is

$$v_B^p = A\frac{\beta_3}{4t(1-\gamma)(\beta_1-1)-\beta_3}. \tag{4.50}$$

A full agreement chooses $\mathbf{v}$ to maximize $\sum_{i=1}^n \pi_i(\mathbf{p}^c(\mathbf{v}), \mathbf{v})$ in Stage 1. The resulting CSR level is

$$v_B^f = A\frac{1}{2t(\beta_1-1)-1}. \tag{4.51}$$

Note that conditional prices (4.46) and (4.47) are symmetric by implication. To ensure that all second-order conditions hold, and restricting our attention to interior solutions, in all proofs in this appendix we impose $8t(1-\gamma)^2(\beta_1-1)-\beta_3^2 > 0$. The ranking follows from

$$
\begin{aligned}
v_B^p - v_B^* &= A\frac{t\gamma^2(1-n)(\beta_1-1)(\gamma^2(n(n-2)(2n-7)-1)+2\gamma n(3n-7)+4n)}{(4t(\gamma-1)(\beta_1-1)+\beta_3)(t(\gamma(2n-3)+2)(\beta_1-1)\beta_3^2-2(\beta_2-1)(\gamma(n(\gamma(n-5)+3)+5\gamma-6)+2))} > 0,\\
v_B^* - v_B^f &= A\frac{t\gamma(n-1)(\beta_1-1)(\gamma(n(\gamma(2n-11)+6)+13\gamma-14)+4)}{(2t(\beta_1-1)-1)(t(\gamma(2n-3)+2)(\beta_1-1)\beta_3^2-2(\beta_2-1)(\gamma(n(\gamma(n-5)+3)+5\gamma-6)+2))} > 0, \text{ and}\\
v_B^f - v_B^{csr} &= A\frac{t\gamma^2(n-1)^2(\beta_1-1)}{(2t(\beta_1-1)-1)(t(\beta_1-1)\beta_3^2+2(\gamma-1)(\beta_2-1))} > 0.
\end{aligned}
$$

■

Proposition 4.B1 verifies that the ranking of CSR levels across competitive agreements is unaffected by whether firms select prices or quantities in Stage 2. The business stealing effect is the driving force behind Proposition 4.B1, just like it was behind Proposition 4.1 when firms set quantities in Stage 2 of the game. The intuition is also identical, and discussed in Section 4.3.1 of the main text.

As a CSR agreement does not adjust conditional prices, and by Proposition 4.B1 reduces CSR levels compared to the benchmark, consumer welfare always decreases with a CSR agreement. Comparing conditional prices (4.46) and (4.47) shows that a full agreement increases conditional prices compared to the benchmark. By Proposition 4.B1 a full agreement reduces CSR levels, so that consumer welfare is reduced on two accounts compared to the benchmark. As a results, the ranking of consumer welfare obtained in the main text is also valid when firms set prices instead of quantities. Denote quantity when firms set prices by subscript B.

Proposition 4.B2. $CS(q_B^*) > CS(q_B^{csr}) > CS(q_B^f)$.

Proof.
In competitive regime r, consumer surplus (4.14) can be written as $CS(q^r) = \frac{n}{2}(\gamma(n-1)+1)(q^r)^2$ as both quantities and CSR levels are symmetric. Therefore, the ranking of consumer surpluses is equivalent to that of quantities. The ranking follows from

$$
q_B^* - q_B^{csr} = A\frac{2t\gamma(n-1)(\beta_2-1)^2\beta_3}{(t(\beta_1-1)\beta_3^2+2(\gamma-1)(\beta_2-1))(t(\gamma(2n-3)+2)(\beta_1-1)\beta_3^2-2(\beta_2-1)(\gamma(n(\gamma(n-5)+3)+5\gamma-6)+2))} > 0,
$$

and

$$
q_B^{csr} - q_B^f = A\frac{t\gamma(n-1)(t(\beta_1-1)\beta_3-\gamma(n-2)-1)}{(t(\beta_1-1)\beta_3^2+2(\gamma-1)(\beta_2-1))(2t(\beta_1-1)-1)} > 0.
$$

■

Compared to the non-cooperative benchmark, a price agreement increases conditional prices in Stage 2 and increases CSR levels in Stage 1. Which of these two forces dominates is *a priori* unclear, and Proposition 4.8 shows that a production agreement in a duopoly can increase consumer welfare if firms set quantities in Stage 2, investing is very cheap, and goods are sufficiently similar. This result does not generalize to price competition in Stage 2, where a price agreement will always decrease consumer welfare compared to the benchmark.

Proposition 4.B3. $CS(q_B^*) > CS(q_B^p)$.

Proof.
The ranking follows from

$$q_B^* - q_B^p = A\frac{t\gamma(n-1)(2t(\gamma-1)(\gamma(2n-3)+2)(\beta_1-1)\beta_3+(\beta_2-1)(n(\gamma(2n-9)+6)+7\gamma-10))}{(4t(\gamma-1)(\beta_1-1)+\beta_3)(t(\gamma(2n-3)+2)(\beta_1-1)\beta_3^2-2(\beta_2-1)(\gamma(n(\gamma(n-5)+3)+5\gamma-6)+2)} > 0.$$

■

The reason why a price agreement in which firms jointly select conditional prices can never benefit consumers is primarily that the non-cooperative benchmark produces more consumer surplus when firms select prices in Stage 2 than when firms select quantities in Stage 2. Since prices are strategic complements and quantities are strategic substitutes, price setting generates a more competitive benchmark outcome with more output than quantity setting. As a price agreement reduces quantities and increases CSR compared to the benchmark, also when firms set prices could total welfare increase if out-of-market externalities such as those given in equation (4.17) are taken into account.

4.C Alternate consumer preferences

In this appendix we show that our consumer welfare results are robust to altering the preference structure to allow for a direct effect of CSR on consumer welfare. When firms jointly select CSR levels, our consumer welfare results are general as long as consumer welfare depends positively on both output and CSR levels. This is because both a CSR agreement and a full agreement decrease output and CSR efforts compared to the non-cooperative benchmark. A production agreement always increases CSR levels compared to the non-cooperative benchmark, and decreases conditional quantities. The net effect of these two opposing forces on consumer surplus therefore depends on the demand structure and underlying preferences that are assumed.

In our baseline quasi-linear quadratic utility model, CSR levels only indirectly influence consumer welfare, through the effect of CSR levels on quantities. To shed light on the robustness of our consumer welfare comparison between a production agreement and the non-cooperative benchmark, we therefore revisit this comparison in the context of Salop's (1979) model of product differentiation. In this model, consumer welfare is directly and positively influenced by CSR levels. The results are in line with those obtained in the main text: a (partial) production agreement always increases CSR levels compared to the non-cooperative benchmark, but only increases consumer welfare when goods are very similar, and investing is very cheap.

As in our baseline model, these results are mainly driven by business stealing incentives. Firms can capture a larger market share by investing in CSR in Stage 1. Given that a production agreement results in higher conditional prices in Stage 2, capturing an additional consumers is more profitable in a production agreement that in the non-cooperative benchmark. When investing is cheap and products are similar, this business stealing incentive becomes so strong in a production agreement that the positive direct effect of increased CSR levels on consumer welfare can more than compensate for the reduction in conditional prices.

Assume that all firms, and a unit mass of consumers, are equidistantly located on a circle with circumference $L > 0$. Firms play a two-stage game. In Stage 1, firm i sets CSR level v_i at cost $\frac{tv_i^2}{2}$. In Stage 2, each firm i selects price p_i. The consumer located at x buys one unit of the good from the firm i that maximizes her indirect utility

$$V_i = \alpha + v_i - \tau|l_i - x| - p_i, \tag{4.52}$$

where $\tau > 0$ is the unit transportation cost of the consumer, l_i is the location of firm i

and $\alpha > 0$ is a utility parameter.[39] The quasi-linear utility function of the representative consumer given in equation (4.1) results in direct effects of CSR changes on consumer welfare being exactly offset by price changes. In contrast, in the indirect utility function given in equation (4.52) the direct effects of CSR levels and prices are what determine consumer welfare.

The location of the consumer indifferent between consuming firm i's product, or the product of its neighbour firm j, is

$$\hat{x}_{ij} = \frac{(v_i - v_j) - (p_i - p_j)}{2\tau} + \frac{L}{6}. \tag{4.53}$$

The profit of each firm i then depends on the prices and CSR levels of its two neighbours j and k

$$\pi_i = (p_i - c)(\hat{x}_{ij} + \hat{x}_{ik}) - \frac{tv_i^2}{2}. \tag{4.54}$$

We analyze the case of three firms for tractability reasons. In Stage 2 of the non-cooperative benchmark each firm i selects p_i to maximize profit (4.54), resulting in conditional price $p_i^*(v_i, v_j, v_k)$. In Stage 1 of the non-cooperative benchmark each firm i selects v_i to maximize $\pi_i(p_i^*(v_i, v_j, v_k), p_j^*(v_i, v_j, v_k), p_k^*(v_i, v_j, v_k), v_i, v_j, v_k)$. Denote the resulting price and CSR level as p_S^* and v_S^*, respectively. Focus on a partial production agreement where two firms, without loss of generality firm 1 and firm 2, form a production agreement, and firm 3 does not participate in the agreement. In Stage 2 of a production agreement, firms 1 and 2 select p_1 and p_2 to maximize $\pi_1 + \pi_2$, while firm 3 selects p_3 to maximize π_3, resulting in conditional prices $p_1^c(v_1, v_2, v_3)$, $p_2^c(v_1, v_2, v_3)$, and $p_3^{**}(v_1, v_2, v_3)$. In Stage 1 of a production agreement, each firm i selects v_i to maximize $\pi_i(p_1^c(v_1, v_2, v_3), p_2^c(v_1, v_2, v_3), p_3^{**}(v_1, v_2, v_3), v_1, v_2, v_3)$.

Denote the resulting price and CSR level of the two firms in the production agreement as p_S^p and v_S^p, respectively. CSR levels of insiders and firms in the non-cooperative benchmark compare as follows (denoted by subscript S).

Proposition 4.C1 $v_S^p > v_S^*$.

Proof.

[39]The standard assumption that each consumer buys one unit implies that α must be sufficiently large such that utility (4.52) is positive for all consumers.

The Nash-equilibrium conditional price of firm i in the non-cooperative benchmark is

$$p_i^* = c + \frac{5L\tau + 6v_i - 3\sum_{i\neq j}^n v_j}{15}, \tag{4.55}$$

The conditional price of firm 1 in a production agreement is

$$p_1^c = c + \frac{(20L\tau + 15v_1 - 3v_2 - 12v_3)}{36}, \tag{4.56}$$

and the conditional price of firm 2 by symmetry results when subscripts 1 and 2 are exchanged in equation (4.56). The conditional price of firm 3, not participating in the production agreement, is

$$p_3^{**} = c + \frac{(8L\tau + 6v_3 - 3\sum_{i\neq 3}^n v_i)}{18}. \tag{4.57}$$

The Nash-equilibrium CSR level in the non-cooperative benchmark is

$$v_S^* = \frac{4L}{15t}. \tag{4.58}$$

The CSR level of a production agreement insider is

$$v_S^p = \frac{2L(5t\tau - 2)}{3t(9t\tau - 4)}. \tag{4.59}$$

In all proofs in this appendix, we consider parameter values such that an interior solution is guaranteed and the second-order conditions are satisfied: α large enough so that all consumers buy, and $t\tau > \frac{1}{2}$. The ranking follows from

$$v_S^p - v_S^* = \frac{2L(7t\tau - 2)}{15t(9t\tau - 4)} > 0. \blacksquare$$

Proposition 4.C1 is in line with the baseline model: firms in a production agreement always increase CSR levels compared to the non-cooperative benchmark. By increasing conditional prices in the Stage 2, firms in a production agreement increase the incentive to invest as servicing an additional consumer is more profitable. Prices of insiders and firms in the non-cooperative benchmark compare as follows.

Proposition 4.C2 $p_S^p > p_S^*$.

Proof.

Substituting v_S^* into equation (4.55) gives

$$p_S^* = k + \frac{L\tau}{3}. \tag{4.60}$$

Substituting v_S^p and the Nash-equilibrium CSR level of firm 3 in a production agreement into equation (4.56) gives

$$p_S^p = k + \frac{L\tau(5t\tau - 2)}{9t\tau - 4}. \tag{4.61}$$

The ranking follows from

$$p_S^p - p_S^* = \frac{2L\tau(3t\tau - 1)}{3(9t\tau - 4)} > 0. \blacksquare$$

Proposition 4.C2 states that firms in a production agreement always increase prices compared to the non-cooperative benchmark. Like in the baseline model, we see that a production agreement increases consumer welfare by increasing CSR levels, but decreases consumer welfare by increasing prices. The next two propositions investigate the net effect on consumer welfare of a production agreement. First, note from equation (4.52) that the net effect of v_i and p_i on a consumer who purchases from firm i is $v_i - p_i$. This net effect on utility compares as follows across production agreement insiders and firms in the non-cooperative benchmark.

Proposition 4.C3 $v_S^* - p_S^* > v_S^p - p_S^p$ unless $\tau < \frac{1}{15}(6 + \sqrt{6})$ and $t < \frac{1}{5}\sqrt{\frac{2}{3\tau^2}} + \frac{2}{5\tau}$.

Proof.
Constructing $(v_S^* - p_S^*) - (v_S^p - p_S^p)$ from equations (4.58) to (4.61) gives

$$(v_S^* - p_S^*) - (v_S^p - p_S^p) = \frac{2L(3t\tau(5t\tau - 4) + 2)}{15t(9t\tau - 4)},$$

which is greater than 0 unless $\tau < \frac{1}{15}(6 + \sqrt{6})$ and $t < \frac{1}{5}\sqrt{\frac{2}{3\tau^2}} + \frac{2}{5\tau}$. $\blacksquare$

Proposition 4.C3 states that the net utility due to CSR levels and prices offered by an insider in a production agreement is less than the net utility offered by a firm in the non-cooperative benchmark, unless products are very similar in the horizontal sense (τ is small) and investing is cheap (t is small). As in the baseline model, when goods are similar and investing is cheap the business stealing incentives are very large, so that firms in a production agreement invest heavily in CSR. Proposition 4.C3 only investigates the situation for consumers who purchase from either firm 1 or 2 in both competitive regimes. However, the increased conditional prices of the firms in a production agreement causes the market share of firm 3 to increase compared to the non-cooperative benchmark. The next proposition therefore compares total consumer surplus across the two competitive regimes.

Proposition 4.C4 $CS_S^* > CS_S^p$, unless $\tau < \frac{8}{15}$ and $t < \frac{8}{15\tau}$.

Proof.
Ignoring travel costs, each consumer in the non-cooperative benchmark has utility $\alpha - v_S^* - p_S^*$, while in a production agreement consumers of firm 1 or 2 have utility $\alpha + v_S^p - p_S^p$, and consumers of firm 3 have utility $\alpha + v_S^{**} - p_S^{**}$. In the non-cooperative benchmark, the indifferent consumers are located halfway between adjacent firms leading to the lowest possible total travel cost: $\frac{\tau L^2}{12}$. With a production agreement, the indifferent consumers between firm 3 and a firm in the agreement are located $\frac{L(3t\tau-1)}{3(9t\tau-4)}$ from the firms 1 and 2, while the indifferent consumer between firms 1 and 2 is located halfway between them, leading to total travel cost: $\frac{L^2\tau(3t\tau(87t\tau-80)+56)}{36(4-9t\tau)^2}$. Summing the difference in utility net of travel costs for all consumers across the two regimes, and the difference in total travel cost, gives the difference in consumer surplus

$$CS_S^p - CS_S^* = L^2\frac{(8-15t\tau)(t\tau(87t\tau-64)+12)}{90r(4-9t\tau)^2},$$

which is positive if $\tau < \frac{8}{15}$ and $t < \frac{8}{15\tau}$, and negative otherwise. ■

Proposition 4.C4 shows that a production agreement leads to a reduction in consumer welfare in the vast majority of all cases. The results presented in Proposition 4.C3 and Proposition 4.C4 are in line with our results in the baseline model. Although a production agreement will always increase CSR levels compared to the non-cooperative benchmark, consumer welfare typically decreases, unless goods are very similar and investing is very cheap.

4.D Partial agreements with fringe competition

In this appendix we show that the results from our baseline model extend to partial agreements that consist of m out of the n firms, with the remaining $n-m$ firms forming a competitive fringe ($m < n$). Residual competition reduces the possibilities for firms to benefit from an agreement. This causes all outcomes to lie in between the non-cooperative outcome and the outcome with a market-wide agreement. Therefore, partial agreements on CSR reduce CSR and output compared to the benchmark, but by less than market-wide agreements directly on CSR. Likewise, partial agreements on production increase CSR and reduce conditional quantities compared to the benchmark, but by less that market-wide production agreements. A two-firm production agreement in markets of up to five firms can increase its output compared to the non-cooperative benchmark if investing is very cheap and goods are very similar, but in that case the firms in the production agreement make less profit than they would in the non-cooperative benchmark. No profitable agreement exists that simultaneously increases consumer welfare and CSR compared to the benchmark.

Without loss of generality, let $i = 1, ..., m$ be the firms participating in the agreement, so $i = m + 1, ..., n$ are the firms remaining in competition. We refer to members of the agreement as insiders, and firms in the competitive fringe as outsiders. Firms play the two stage game described in the main text, serving demand (4.2) at marginal production costs c and CSR investment costs $\frac{tv_i^2}{2}$. Let v_P^r denote the CSR level of a member of a partial agreement in competitive regime $r \in \{csr, p, f\}$. CSR levels of agreement insiders and firms in the non-cooperative benchmark compare as follows.[40]

Result 4.D1. $v_P^p > v^* > \{v_P^f, v_P^{csr}\}$.

Result 4.D1 states that a partial production agreement is the only partial agreement

[40]CSR levels for the general m-of-n setup are extremely lengthy and therefore omitted here. Comparing outcomes across different competitive regimes for all n and m is computationally infeasible. In this section we therefore report results for $3 \leq n \leq 10$ and all $2 \leq m \leq n-1$. Note that these are not simulations: for each n-m combination, results hold for all parameter values of A, γ, and t. As the expressions of quantities and CSR levels are too elaborate to present, we label our comparisons "Results" instead of "Propositions", and omit the proofs. CSR levels that solve the general game and Mathematica syntax for all the results in this section are available upon request. See Treuren and Schinkel (2018) for a more elaborate discussion of partial agreements, including quantities and CSR levels of outsiders and results for $n > 10$. Allowing for $n > 10$, as in Treuren and Schinkel (2018), does not affect the results presented in this appendix.

that increases CSR levels compared to the non-cooperative benchmark.[41] The first-order condition for firm i, who is an insider in a partial CSR agreement, is

$$\sum_{i\neq j}^{n} \frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j^*}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} + \sum_{i\neq j}^{m}\left(\sum_{i\neq j\neq k}^{n} \frac{\partial \pi_j}{\partial q_k}\frac{\partial q_k^*}{\partial v_i} + \frac{\partial \pi_j}{\partial q_i}\frac{\partial q_i^*}{\partial v_i}\right) = 0. \tag{4.62}$$

Comparing (4.62) to (4.7) shows that each insider in a partial CSR agreement only considers the negative externality of its CSR level on $m-1$, instead of $n-1$, other firms' profit. As m goes to zero, the non-cooperative outcome is approached. As m goes to n, CSR levels converge to those of a market-wide CSR agreement. Therefore, CSR levels are always lower in a partial CSR agreement than in the non-cooperative benchmark, and the extent to which they differ is increasing in the size of the agreement: $v^* > v_P^{csr} > v^{csr}$.

Denote the Nash-equilibrium conditional quantities set by insiders in a partial production agreement or a partial full agreement by $q^{in}(\mathbf{v})$, and the conditional quantities set by outsiders by $q^{out}(\mathbf{v})$.[42] The first-order condition for a firm i, who is an insider in a partial production agreement, is

$$\sum_{i\neq j}^{m} \frac{\partial \pi_i}{\partial q_j}\frac{\partial q_j^{in}}{\partial v_i} + \sum_{k=m+1}^{n} \frac{\partial \pi_i}{\partial q_k}\frac{\partial q_k^{out}}{\partial v_i} + \frac{\partial \pi_i}{\partial v_i} + \frac{\partial \pi_i}{\partial q_i}\frac{\partial q_i^{in}}{\partial v_i} = 0. \tag{4.63}$$

Comparing equation (4.63) to equation (4.8) shows that the only difference between the first-order conditions of a partial and market-wide production agreement is that the conditional quantities in a partial production agreement differ from those in a market-wide production agreement. Because $|\frac{\partial q_i^{in}}{\partial v_i}|$, $|\frac{\partial q_j^{in}}{\partial v_i}|$, $|\frac{\partial q_j^{out}}{\partial v_i}|$ are lowest when m is small, incentives to invest for insiders in a partial production agreement increase with the size of the agreement. When $m = n$, $q^{in}(\mathbf{v}) = q^c(\mathbf{v})$, and equation (4.63) reduces to equation (4.8). For all n and m, insiders increase their CSR levels compared to the non-cooperative benchmark because $\frac{\partial \pi_i}{\partial q_i} > 0$: $v^p > v_P^p > v^*$.

The first-order condition for firm i, who is an insider in a partial full agreement, is

$$\frac{\partial \pi_i}{\partial v_i} + \sum_{j=1}^{m}\sum_{k=m+1}^{n} \frac{\partial \pi_j}{\partial q_k}\frac{\partial q_k^{out}}{\partial v_i} = 0. \tag{4.64}$$

Comparing (4.64) to (4.9) shows that an insider in a partial full agreement has an ad-

[41] The curly brackets in Result 4.D1 indicate that the ordering of v_P^f and v_P^{csr} can vary. See Treuren and Schinkel (2018) for a detailed discussion.

[42] $q_i = q^{in}(\mathbf{v})$ and $q_i = q^{out}(\mathbf{v})$ solve $max_{q_i} \sum_{k=1}^{m} \pi_k(\mathbf{q}, v_k)$ for $i = 1, \ldots, m$, and $max_{q_i}\pi_i(\mathbf{q}, v_i)$ for $i = m+1, \ldots, n$.

ditional incentive to invest in CSR compared to a market-wide full agreement. For each insider i and outsider j we have $\frac{\partial \pi_i}{\partial q_j} < 0$ and $\frac{\partial q_j^{out}}{\partial v_i} < 0$, which shows that investing in CSR increases profit for all insiders by reducing the quantity of outsiders. This effect is larger the smaller is m. As m increases from 0 to n incentives to invest in CSR decrease as the first-order condition for an insider converges from the non-cooperative first-order condition (4.6) to the market-wide full agreement first-order condition (4.9): $v^* > v_P^{fc} > v^p$.[43]

Consumer surplus is a function of the quantities of all insiders and outsiders in a partial agreement, as shown by equation (4.14). As we are interested in the behaviour of insiders, and as in consumer surplus is a function of quantities, we focus on the quantities of insiders as a measure of the agreement's contribution to consumer surplus. Denote by q_P^r the quantity of an agreement insider in competitive regime $r \in \{csr, p, f\}$. Comparing quantities across the benchmark, a CSR agreement, and a full agreement, we obtain the following result.

Result 4.D2. $q^* > q_P^{csr} > q_P^f$.

Result 4.D2 states that allowing insiders to coordinate their CSR levels decreases the quantity they produce compared to the non-cooperative benchmark, regardless of the size of the competitive fringe. A CSR agreement produces the non-cooperative quantity conditional on CSR levels in Stage 2. By Result 4.D1 and the discussion following it, we know that a partial CSR agreement decreases CSR levels compared to the non-cooperative benchmark, and that CSR levels are reduced by more the more firms take part in the agreement. It follows that $q^* > q_P^{csr} > q^{csr}$.

Insiders in a partial full agreement reduce quantities both by reducing conditional quantities in Stage 2, and by reducing CSR levels in Stage 1. The first-order condition of an insider in Stage 2 of a partial full agreement or a partial production agreement is

$$\frac{\partial \pi_i}{\partial q_i} + \sum_{i \neq j}^{m} \frac{\partial \pi_j}{\partial q_i} = 0, \tag{4.65}$$

which shows that an insider's incentive to reduce its conditional quantity compared to the non-cooperative benchmark is increasing in agreement size m, as $\frac{\partial \pi_j}{\partial q_i} < 0$. For insiders in a partial full agreement, by Result 4.D1 we know that the incentive to decrease CSR levels compared to the non-cooperative benchmark also increases in m. It follows that

[43] If $|\sum_{i \neq j}^{n} \frac{\partial \pi_i}{\partial q_j} \frac{\partial q_j^*}{\partial v_i}| + \sum_{i \neq j}^{m} \sum_{i \neq j \neq l}^{n} |\frac{\partial \pi_j}{\partial q_l} \frac{\partial q_l^*}{\partial v_i}| - \sum_{i \neq j}^{m} |\frac{\partial \pi_j}{\partial q_i} \frac{\partial q_i^*}{\partial v_i}| > |\sum_{j=1}^{m} \sum_{k=m+1}^{n} \frac{\partial \pi_j}{\partial q_k} \frac{\partial q_k^{out}}{\partial v_i}|$ then $v_P^{csr} > v_P^f$. This happens when consumers view products as close substitutes (γ is close to 1).

$q^* > q_P^f > q^f$.[44] Quantities of partial production agreement insiders and firms in the non-cooperative benchmark compare as follows.

Result 4.D3. $q^* > q_P^p$ unless $m = 2$, $n \in \{3, 4, 5\}$, and $t < T_P(\gamma, n)$, in which case $\pi^* > \pi_{in}^{pc}$.[45]

Result 4.D3 states that insiders in a partial production agreement will decrease their output compared to the non-cooperative benchmark unless the production agreement consists of two firms, there are no more than three outsiders, investing is very cheap (t is low), and goods are very similar (γ is high). When $q_P^p > q^*$, insiders in a partial production agreement make less profit than firms in the non-cooperative benchmark. Recall that a production agreement increases CSR levels, but reduces conditional quantities, compared to the non-cooperative benchmark. In a market-wide production agreement, the reduction of conditional quantities is increasing in n, as the benchmark quantity is increasing in n. In a partial production agreement, the reduction of conditional quantities is still increasing in n, but equation (4.65) shows that the reduction of conditional quantities is also increasing in m, such that the reduction of conditional quantities is smallest if both m and n are small. In that case, insiders can increase quantities compared to the non-cooperative benchmark if investing is very cheap and products are very similar. Just as in the market-wide agreement case, these parameters result in the firms engaging in a CSR arms race that leaves firms worse off compared to the non-cooperative benchmark.[46]

[44] Let $\Delta v_P^{csr} = v_P^{csr} - v^*$, $\Delta v_P^f = v_P^f - v^*$, and $\Delta q^{in} = q^{in}(v^*) - q^*(v^*)$. As $|\frac{\partial q^{in}}{\partial v}\Delta v_P^f + \Delta q^{in}| > |\frac{\partial q^*}{\partial v}\Delta v_P^{csr}|$, we have $q_P^{csr} > q_P^f$.

[45] $T_P(\gamma,3) = \frac{4+5\gamma-2\gamma^2-\gamma^3}{4(2+2\gamma-3\gamma^2-2\gamma^3+\gamma^4)} + \frac{1}{4}\sqrt{\frac{-2\gamma^2-15\gamma^3-16\gamma^4+2\gamma^5-6\gamma^6+\gamma^7}{(\gamma-2)(\gamma^2-1)^2(\gamma^2-2\gamma-2)^2}}$, $T_P(\gamma,4) = \frac{-32-64\gamma+16\gamma^2+30\gamma^3-7\gamma^4-3\gamma^5}{4(4+4\gamma-5\gamma^2+\gamma^3)(-4-4\gamma+5\gamma^2+3\gamma^3)} + \frac{1}{4}\sqrt{\frac{256\gamma^2+1536\gamma^3+2112\gamma^4-416\gamma^5-444\gamma^6+588\gamma^7+61\gamma^8-102\gamma^9+9\gamma^{10}}{(4+4\gamma-5\gamma^2+\gamma^3)^2(-4-4\gamma+5\gamma^2+3\gamma^3)^2}}$, and $T_P(\gamma,5) = \frac{-8-26\gamma-9\gamma^2+16\gamma^3+\gamma^4-4\gamma^5}{4(4+6\gamma-6\gamma^2+\gamma^3)(-1-2\gamma+\gamma^2+2\gamma^3)} + \frac{1}{4}\sqrt{\frac{36\gamma+252\gamma^3+505\gamma^4+132\gamma^5-234\gamma^6+136\gamma^7+129\gamma^8-72\gamma^9+16\gamma^{10}}{(4+6\gamma-6\gamma^2+\gamma^3)^2(-1-2\gamma+\gamma^2+2\gamma^3)^2}}$.

[46] It is noteworthy that for $n > 3$ total quantity will always decrease as outsiders actually reduce quantity in Nash-equilibrium compared to the non-cooperative benchmark. See Treuren and Schinkel (2018) for details.

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Summary

This dissertation bundles three essays in industrial economics in which market imperfections and their consequences are studied.

In the first essay, I measure, in the Netherlands over the years 2007 to 2018, the marginal contribution to firm-level revenue of employees relative to their compensation. This exercise is motivated by a large and rapidly expanding literature documenting oligopsony power in U.S. labor markets. To identify the firm-level ratio of the marginal revenue product of labor to the wage – the labor wedge – a method is put forward that relates the labor wedge to the revenue elasticity of labor and the labor share of revenue. This method improves upon existing approaches in that it allows for market imperfections in all input and output markets, and requires no assumptions on firm conduct.

The median firm in the Netherlands is found to pays a wage *above* its marginal revenue product of labor, suggesting that U.S. based oligopsony findings do not transfer to the European context. A potential explanation is that the Dutch institutional setting of collective bargaining agreements and strong employment protection benefits employees at the expense of employers. In addition, a strong positive relation between a firm's buyer power in the materials market and the wage it pays its employees is documented, while between-firm wage differences explain the large cross-sectional dispersion of the labor wedge. These results suggest that compensation of employees depends on rents generated in other input markets, and hint at firms subsidizing employees with rents obtained due to buyer power in materials markets.

The second essay deals with cartel stability in experimental first-price sealed-bid and English auctions, and is joint work with Jeroen Hinloopen and Sander Onderstal. The received wisdom is that in settings where bidders are likely to form a bidding ring, auctioneers are well-advised to use the first-price sealed-bid auction rather than the English auction. The reason is that cartels are thought to be stable more often in the English auction (a cartel is said to be stable if all parties involved in the agreement stick to it). The intuition, formalized by Robinson (1985), is that stable cartel agreements can never emerge as a Nash-equilibrium in the first-price auction as, absent side-payments

and repeated play, at least one agreement member always faces an incentive to defect by undercutting the designated winner.

However, the experimental literature finds little evidence of cartel stability differing between the two auction formats. One potential explanation is that the setting of existing experimental work does not correspond exactly to the setting of Robinson (1985). Another explanation is equilibrium selection, as even in the English auction, an infinite number of equilibria exist where cartel agreements are not stable. To separate these explanations, we conduct a lab experiment closely following the set-up of Robinson (1985). We find that bidding rings are more often stable in the English auction than in the first-price sealed-bid auction, regardless of matching protocol. Our findings suggest that the observed differences between empirical studies and the received wisdom are to be explained by other aspects of bidding rings than cartel stability.

The third essay investigates whether allowing firms to collaborate on their strategic decisions can foster corporate social responsibility (CSR), and is joint work with Maarten Pieter Schinkel. Industry-wide voluntary agreements are touted as a means for corporations to increase CSR where governments fail. We study which type of joint CSR agreement induces firms to increase CSR efforts in a model of oligopolistic competition with differentiated products. Consumers have a willingness to pay for more responsibly manufactured products. Firms are driven by profit, and possibly by intrinsic motivation, to invest in costly CSR efforts.

We find that cooperative agreements directly on the level of CSR *reduce* CSR efforts compared to competition. Such agreements throttle both for-profit and intrinsic motivation for CSR. CSR efforts only increase if agreements are permitted *solely* on output. Such production agreements, however, reduce total welfare in the market and raise antitrust concerns. Taking negative production externalities into account may help to justify a production agreement under a wider welfare standard, but not agreements on CSR directly. Moreover, simply requiring a higher CSR level by regulation while preserving competition always leads to higher within-market welfare. While voluntary collective agreements have their merits in other contexts, for example in reaping R&D synergies, we contribute that agreements on CSR weaken competition as an important driver of corporate social efforts.

Samenvatting

Dit proefschrift bundelt drie essays in de industriële economie. Deze essays bespreken marktimperfecties en hun consequenties.

In het eerste essay meet ik, voor de jaren 2007 tot 2018 in Nederland, de marginale bijdrage aan bedrijfsomzet van werknemers in verhouding tot hun compensatie. Deze exercitie wordt gemotiveerd door een omvangrijke en snel groeiende literatuur die arbeidsmarktmacht voor bedrijven in Amerika documenteert. In dit essay wordt een methode voorgedragen om de bedrijfsspecifieke ratio van het marginale product van arbeid en de compensatie van een werknemer – de zogenaamde "labor wedge" – te identificeren. Deze methode heeft ten opzichte van bestaande methoden als voordeel dat geen aannames vereist zijn over zowel marktimperfecties op input- of output-markten, als over het gedrag van bedrijven.

In de meeste gevallen betalen bedrijven in Nederland een compensatie aan hun werknemers die *hoger* is dan de marginale bedrijfsomzet gegenereerd door arbeid. Dit resultaat suggereert dat de oligopsonie-resultaten uit de VS niet zonder meer gelden voor de Europese context. Eén mogelijke verklaring voor dit resultaat is de institutionele setting in Nederland, waar collectieve arbeidsafspraken en sterke contractuele bescherming van werknemers bijdragen aan een sterke positie van werknemers ten opzichte van werkgevers. Een andere bevinding is een sterk positieve relatie tussen de marges van bedrijven in de markt voor intermediaire goederen en de compensatie van hun werknemers, alsmede dat verschillen in de labor wedge voornamelijk verklaard lijken te worden door verschillen in de compensatie van werknemers. Deze resultaten suggereren dat beloning van werknemers afhangt van de onderhandelingspositie van hun werkgevers in andere input-markten, bijvoorbeeld omdat bedrijven winsten die gegenereerd zijn in de markt voor intermediare goederen deels uitkeren aan werknemers.

Het tweede essay bespreekt kartelstabiliteit in experimentele eerste-prijs gesloten bod en Engelse veilingen, en is gezamenlijk werk met Jeroen Hinloopen en Sander Onderstal. De heersende opvatting is dat veilingmeesters beter eerste-prijs gesloten bod veilingen dan Engelse veilingen kunnen gebruiken indien samenzwering tussen bieders waarschijnlijk is.

De oorzaak is dat kartels vaker stabiel worden geacht in Engelse veilingen dan in eerste-prijs gesloten bod veilingen (een kartel is stabiel als alle deelnemende bieders zich houden aan de kartelafspraak). De intuitie voor dit vermoeden, formeel gemaakt in Robinson (1985), is dat stabiele kartelafspraken nooit een Nash-evenwicht zijn in een eerste-prijs gesloten bod veiling zonder herhaalde interactie of bijbetalingen, omdat ten minste één bieder altijd de prikkel heeft om een lager bod uit te brengen dan de aangewezen winnaar.

Desondanks geeft de experimentele literatuur weinig blijk van verschillen in kartelstabiliteit tussen de twee veilingmechanismen. Eén mogelijke verklaring is dat de setting van bestaande experimenten niet exact overeenkomt met die van Robinson (1985). Een andere verklaring komt voort uit de selectie van Nash-evenwichten, daar óók de Engelse veiling een oneindig aantal Nash-evenwichten bezit waarin kartelafspraken niet stabiel zijn. Om deze verklaringen te onderscheiden voerden wij een labexperiment uit dat nauwgezet de setting van Robinson (1985) volgt. Kartelafspraken blijken inderdaad vaker stabiel te zijn in Engelse veilingen dan in eerste-prijs gesloten bod veilingen, ongeacht hoe deelnemers aan elkaar gekoppeld worden in opeenvolgende veilingen. Onze bevindingen suggereren dat de geobserveerde verschillen tussen de empirische studies en de heersende opvattingen te wijten zijn aan andere aspecten van kartelafspraken dan kartelstabiliteit.

Het derde essay bekijkt of het toestaan van afspraken tussen bedrijven over strategische keuzevariabelen bij kan dragen aan een toename van maatschappelijk verantwoord ondernemen (MVO), en is samen met Maarten Pieter Schinkel geschreven. Industriebrede, vrijwillige afspraken worden aangeprezen als een manier om MVO te stimuleren, daar waar overheden tekort schieten. Wij onderzoeken welke gezamenlijke afspraken bedrijven prikkelen om hun investeringen in MVO te verhogen in een model van oligopolistische concurrentie met gedifferentiëerde goederen. Consumenten hebben betalingsbereidheid voor meer verantwoord geproduceerde goederen. Bedrijven worden gedreven door winstmotieven, en mogelijk óók door intrinsieke motivatie, om te investeren in MVO.

Wij laten zien dat gezamenlijke afspraken over MVO zelf, leiden tot een *reductie* van MVO in vergelijking met de situatie zonder afspraken. Zulke afspraken remmen zowel winstmotieven als intrinsieke motivatie voor MVO. MVO wordt alleen gestimuleerd als afspraken over enkel productiehoeveelheden toegestaan zijn. Dergelijke productieafspraken verminderen echter de totale welvaart in de markt en zijn doorgaans in strijd met mededingingswetten. Wanneer negatieve productie-externaliteiten in acht worden genomen, kunnen productieafspraken wellicht gerechtvaardigd worden met behulp van een bredere welvaart norm. Dit geldt echter niet voor afspraken over MVO zelf. Bovendien leidt het reguleren van een hogere MVO-standaard zonder het toestaan van afspraken altijd tot een hogere welvaart in de relevante markt. Hoewel collectieve afspraken voordelen kunnen opleveren in een andere context, bijvoorbeeld als middel om R&D synergiën te genereren, laat het derde essay zien dat afspraken over MVO zelf averechts werken door een belangrijke drijfveer van MVO, onderlinge concurrentie, te verzwakken.

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