ESSAYS ON MANAGERIAL INCENTIVES AND PRODUCT-MARKET COMPETITION

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Essays on Managerial Incentives and Product-Market Competition

Giancarlo Spagnolo

STOCKHOLM SCHOOL OF ECONOMICS
EFI, THE ECONOMIC RESEARCH INSTITUTE

A Dissertation for the
Degree of Doctor of Philosophy
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ABSTRACT: *Essays on Managerial Incentives and Product-Market Competition* consists of four self-contained essays primarily concerned with incorporating the objectives of real world top managers, as shown by available empirical evidence, in supergame-theoretic analyses of long-term competition between oligopolistic firms.

The first essay, "Ownership, Control, and Collusion," considers how the separation between ownership and control affects firms' competitive attitudes when top managers have the preference for smooth profit streams revealed by the evidence on "income smoothing," and when managerial compensation has the low pay-performance sensitivity found in many empirical studies.

In a similar fashion, the second essay, "Stock-Related Compensation and Product-Market Competition," deals with the effects of the apparently more aggressive managerial incentives linked to stock price (e.g. stock options), which have become increasingly common in the U.S., on long-term oligopolistic competition.

In the third paper, "Debt as a (Credible) Collusive Device," shareholders' commitments to reduce conflicts with debtholders by choosing a top manager with a highly valuable reputation or with "conservative" incentives are considered. These forms of commitment have been shown to reduce the (agency) cost of debt finance; this paper characterizes their effects on the relation between firms' capital structure and product market competition.

The fourth paper, "Multimarket Contact, Concavity, and Collusion," addresses the relation between multimarket contact and firms' ability to sustain collusive behavior in repeated oligopolies. It explores how this relation is affected by the strict concavity of firms' objective function induced by managerial objectives and by other features of reality, discusses the effects of conglomeration and horizontal mergers, and extends the results to non-oligopolistic supergames.

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Keywords: Oligopoly, tacit collusion, delegation, managerial incentives, repeated games, ownership and control, financial market - product market interactions, corporate governance, conglomeration, mergers.

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Contents

Preface

All the material in this thesis has been written during my "stay" at the Stockholm School of Economics, first as a visiting graduate student from Cambridge, then as a member of the Stockholm Ph.D. program. I begin with thanking Lars Bergman for accepting me at the School and Partha Dasgupta for sending me here.

The quotation marks around the word stay are needed since in this period, for a number of different reasons, I have always been "commuting," first between Stockholm, Cambridge, and Rome, and more recently between Stockholm, Muenchen, and Rome. On average, over these three and a half years I have spent about half of my time in Stockholm. And although I always bring my work with me when I travel (even on holidays with a camping-bus, to the great disappointment of my girlfriend), almost all the work for this thesis was done in Stockholm. The stimulating-but-cool working atmosphere at the Stockholm School of Economics and the extremely high standard of teaching, research, seminars, guests, and advanced mini-courses of the School and of the Stockholm doctoral program have made new research ideas pop up continuously in my mind. The town of Stockholm helped my work a lot too, with its superb organization, pleasant setting, and "fresh" weather (perfect for studying). Unfortunately, these same aspects that helped me to concentrate on my work also had their drawbacks. The most important one was that, by working a lot, I could not penetrate and enjoy the social and cultural life of Stockholm as much as I would have liked to. I will try to do better on this ground in the forthcoming months.

If I managed to restrict the focus on some of the many ideas dancing in my mind, to explore them with some success and relatively few (?) mistakes, and to curb my "Latin" temptation to write lengthy so that I could keep the thesis shorter than an encyclopedia, this is all due to Jörgen W. Weibull who supervised my work since my arrival in Stockholm. Jörgen, thank you for teaching me that doing economic theory is not just having potentially interesting ideas and providing their loose description; that one has to focus and work hard on each single idea, make it as clear as possible in its simplest form, and rigorously derive its consequences within a well specified model (yes, I know that my degree of rigor is still far from how you would like it...).

Considering that my interests were driving me more and more into the fields of Industrial Organization and Corporate Finance, about one year ago Jörgen decided to ask Tore Ellingsen to join him as a co-advisor for my Thesis. What can I say – the combination Jörgen-Tore is clearly unimprovable! Tore, thank you very much for accepting to step in, and for all the useful advice, criticism, and encouragement you managed to give me both before and during this last year.

My life at the Stockholm School of Economics, both as a doktorand and as a frequent flyer, has been made much easier by the always ready, gentle, and efficient help of Carin Blomkvist, Britt-Marie Eisler, Ritva Kiviharju, and especially of Pirjo

Furtenbach and Kerstin Niklasson (both of whom are probably looking forward to the day I will do the job-market).

I never joined the lunches – here in Sweden you have lunch one hour after my breakfast – and I am a very loud researcher, often talking with an assistant who is helping me. This means that those who had to bear the worst consequences of my work were probably my roommates Björn, David, Chloé, and Fredrick (who continued to say he didn't mind the noise, but started wearing professional ears-covers for pneumatic-hammer operators). Thank you my friends!

I had the luck to share my apartment with uncle Esben... Sven: David was right, it was a big deal to have you at home. I already miss our balcony cigarettes and the evening chats, even though we will probably have them for one more year. Many thanks also to Gianluigi and Kasper, who in quite different ways introduced me to the life of the elite-invandrare in Stockholm.

Finally, I am grateful to my parents, who have always backed me up, whatever I have done, and I acknowledge an enormous debt to my two wonderful ladies, Martina and Emily, who I had to leave alone for many long, and sometimes hard periods of time.

In the end, money matters: funding for my research has been provided, during these three and a half years, by the Italian Consiglio Nazionale delle Ricerche, the University of Rome "La Sapienza," the Swedish Competition Authority, and the Stockholm School of Economics.

Stockholm, December 1998.

P.S.: Davide, the young son of my closest neighbors in Rome, continued asking over the years, "Dad, is Giancarlo still studying? But when will he finish school and find a job?" I think he was terrorized by the idea that he might also have to study until over thirty. In any case, he stopped asking, left school, and found a job while I was still a student, a doktorand. But now it is finished, I'll really have to find a job...

Chapter 1

Introduction and Summary

Introduction and Summary

1 Introduction

The superiority of free market economies has been demonstrated by the inefficiency and recent collapse of centrally planned ones. However, the *optimality* of decentralized exchange is guaranteed by the fundamental theorems of welfare economics only in the case of perfect competition. Unfortunately, few real world industries are even somewhat close to the definition of perfect competition. Most industries are oligopolistic, and many of them are subject to sophisticated strategic behavior that may lead firms to curb competition and monopolize markets, that is, to maximize industry profits while reducing social welfare.

That this is a fundamental problem of market economies was clear to the founding fathers of economic science from the beginning. The classical reference is from Adam Smith:

> "People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the publick, or in some contrivance to raise prices." (*The Wealth of Nations,* Book I, Ch. X, Part II.)

A sound competition policy is therefore necessary to avoid the potentially large social welfare losses linked to collusive behavior. And, as any other public policy, to be effective competition policy must be implemented by well informed regulators. Antitrust authorities need to know which factors signal the presence of, or facilitate, such costly market failures.

To this aim, the phenomenon of long term competition in mature oligopolistic industries, and in particular that of tacit collusion between rival firms, has been analyzed in the last thirty years within models of repeated oligopoly games. Supergames are among the best understood parts of game theory, and this led to a very good understanding of many of the factors that enhance firms' ability to support tacit collusive agreements by the credible threat of future retaliation.[1]

[1] Classical references include James Friedman (1971); Robert Aumann and Lloyd Shapley (1976); Ariel Rubinstein (1979); Ed Green and Robert Porter (1984); Drew Fudenberg and Eric Maskin (1986); Julio Rotemberg and Garth Saloner (1986); Dilip Abreu (1986, 1988).

To our knowledge, however, all classical supergame-theoretic analyses of tacit collusion confined themselves to the standard assumption of firms' objective function being linear in profits. In the real world many interacting factors determine the final shape of firms' objective function, and the most important among these factors surely is managerial incentives. The managerial theories of the firm stressed early that when ownership is separated from control, firms tend to pursue objectives different from profit-maximization.[2] Also, the work of Thomas Schelling (1960) made clear that contracts with third parties, such as managerial incentive schemes, may have important strategic effects. Therefore, understanding how commonly adopted managerial incentive schemes affect oligopolistic firms' competitive attitudes, and thereby social welfare, may be interesting both from a positive and a policy perspective.

By now there is a considerable amount of empirical evidence on managerial incentives available in economics, accounting, and management science journals. Several important studies on the subject were made in the '80s, and the empirical literature on managerial incentives really exploded after Michael Jensen and Kevin Murphy's (1990) famous paper.[3] In addition, empirical evidence on other phenomena can be used to derive top managers' revealed preferences, for example the robust evidence on "income smoothing."[4]

Because we want to understand how the objectives of real world top managers influence firms' competitive attitudes, our modelling approach will be "empirical." We will consider the effects of top managers' incentives schemes, as found in the empirical studies, in supergame-theoretic models of long-term competition and tacit collusion. As you will see, this approach will also provide an explanation for a theoretical puzzle brought up by some recent empirical results on the relation between firms' capital structure and product market competition.

To conclude this introduction, we note that the work in this thesis is closely related to a line of research initiated by John Vickers (1985) and Chaim Fershtman (1985), that explores the strategic effects of delegating control to managers with preferences or incentives different from those of the owners in oligopolies.[5] Most contributions to this literature model strategic delegation as a two-stage game, where a first stage in which principals (owners) choose delegates' preferences (managers' incentive schemes) is followed by a second-stage static market interaction. Because of this modelling approach, these contributions could not deal with the phenomenon of tacit collusion. The present work extends this literature by letting firms interact repeatedly in time,

[2]For example, Herbert Simon (1957); William Baumol (1958); Richard Cyert and James March (1963); Robin Marris (1964); Oliver Williamson (1964); Michael Jensen and William Meckling (1976).

[3]For example, Sherwin Rosen (1992); Steven Kaplan (1994, 1998); Charles Hadlock and Gerald Lumer (1997); Stacey Kole (1997); Brian Hall and Jeffrey Liebman (1998).

[4]See, e.g. Craig Lewis (1998); Mark De Fond and Chul Park (1997); Eero Kasanen *et. al.* (1996); Robert Holthausen *et al.* (1995); Jennifer Gaver *et al.* (1995); Kenneth Merchant (1989); Paul Healy (1985).

[5]See, e.g. Fershtman and Kenneth Judd (1987); Steven Sklivas (1987); Fershtman, Judd, and Ehud Kalai (1991); Michael Katz (1991); Michele Polo and Piero Tedeschi (1992); David Reitman (1993).

so that the effects of delegation on long-term competition and tacit collusion can be analyzed with the tools of repeated games.

2 Summary of the Essays

2.1 Essay I: Ownership, Control, and Collusion

This paper characterizes the effects of the separation between ownership and control on firms' ability to collude in long-run oligopolies, when top managers have the preference for smooth profit streams revealed by empirical work on "income smoothing," and when managerial incentives are low-powered, as found in many empirical studies on the subject.

In a simple repeated oligopoly model, it is first demonstrated that managers' preference for smooth profit streams entails a preference for collusive behavior. Firms led by "income smoothing managers" can support in equilibrium any tacit collusive agreement at lower discount factors than owners or profit-maximizing managers.

Next, Paul Healy's (1985) hypothesis that income smoothing is driven by the common and low-powered "bonus contracts" is considered. It is found that such contracts, whether long-term or short-term, are able to make even the joint monopoly collusive agreement supportable in equilibrium at any level of the discount factor.

Then, the product market effects of a simple "reduced form" of Drew Fudenberg and Jean Tirole's (1995) model of income smoothing are derived. When incumbent managers enjoy private benefits and have short-term wage contracts, and owners follow a replacement rule by which the manager is not reappointed if profit falls below a certain cut-off level, the joint monopoly agreement again becomes supportable at any level of the discount factor.

The results provide a joint explanation for the puzzling questions raised by the empirical findings on income smoothing and managerial compensation: Why is it that shareholders choose to tolerate the real costs linked to income smoothing practices, and choose not to realize the potential gains from high-powered incentives stressed by agency theory? This paper's answer is that in mature oligopolistic industries the same low-powered incentives that induce income smoothing also allow shareholders to enjoy higher collusive profits.

Finally, the paper shows that when top managers are in control, Rotemberg and Saloner's (1986) "price wars during booms" need not occur. When managers have a strong enough preference for smooth profit streams or are under bonus contracts, the collusive price tends to be pro-cyclical.

2.2 Essay II: Stock-Related Compensation and Product-Market Competition

In the last decade the pay-performance sensitivity of top-managers' compensation has increased in the U.S. because of the widespread adoption of stock-related incentives, such as stock options plans, share-performance plans, or bonuses linked to stock price. This paper tries to answer the following question: Does this trend towards stock-based incentives induce a more competitive attitude in managers, so that concerns about tacit collusion and social welfare can be abandoned at least in the U.S.?

The focus is on stock-based compensation plans as they are commonly designed in the real world: relatively liquid plans awarding stock-based bonuses for several consecutive years. These kind of incentives are introduced in a classical model of repeated oligopoly.

It is found that as long as the stock market has perfect foresight, some dividends are distributed, and incentives are paid more than once or are deferred, compensation packages related to stock price greatly facilitate tacit collusion in long-run oligopolies.

Stock-related incentives link managers' *present* compensation to the stock market's expectations about the firms' *future* profitability. When a breach from a tacit collusive agreement occurs, the stock market anticipates the negative effect of the breach on firms' future profitability linked to the forthcoming punishment phase, and immediately discounts it on the stock price, reducing managers' short-run gains from any deviation.

When stock-based incentives are deferred, the first pro-collusive effect is reinforced by the fact that the already limited beneficial effect of short-run gains from deviation on the stock price may be completely passed at the time the manager receives the bonus. Delegation of control to managers under deferred stock-related compensation is shown to allow owners to support the joint monopoly collusive agreement at any level of the discount factor.

The results are independent of whether managerial contracts are long or short term.

2.3 Essay III: Debt as a (Credible) Collusive Device

The natural implication of the two more established theories on the effects of financial structure on product market competition – the "long purse" or "predation" theory, and the "limited liability" theory – is that debt should lead either the leveraged firms or their competitors to behave more aggressively. Though, recent empirical work has shown that in concentrated industries high leverage tends to have anti-competitive effects on product markets. This paper proposes a theoretical explanation for this evidence based on the interaction between capital structure, managerial incentives, and firms' ability to sustain collusive behavior. It starts from many authors' observation that by committing to a prudent behavior through "conservative" managers, shareholders can limit the "asset substitution" problem and reduce the ex ante (agency) cost of debt finance. Such commitment opportunity is introduced in Maksimovic's (1988) model of leveraged oligopoly. It is found that if owners commit against strategic default by hiring a manager with an established reputation – with much to lose from bankruptcy – debt enhances firms' ability to collude with respect to unleveraged firms. Analogous commitments to debtholder-friendly behavior through low-powered managerial incentive schemes have even stronger pro-collusive effects, which add to the effect of managers' reputation. It is then shown that when credit markets are concentrated, colluding lenders can increase their rents by controlling the choice of managers and their incentives in oligopolies. They can make the choice of prudent managers or of conservative managerial incentives *renegotiation-proof* through high levels of debt, thereby making commitments to conservative (collusive) product market strategies credible even when secret renegotiation is possible and costless. And even when credit markets are perfectly competitive and firms have multiple lenders, choosing at least one lender in common (or, equivalently, at least two distinct but "allied" lenders) is shown to remain a feasible way by which oligopolistic firms can credibly implement tacit collusive agreements.

2.4 Essay IV: Multimarket Contact, Concavity, and Collusion

The traditional view that multimarket contact facilitates collusion in general was not supported by Bernheim and Whinston's (1990) rigorous supergame-theoretic analysis. Although these authors conclude that in a wide range of circumstances multimarket contact facilitates collusive behavior, they also begin with an irrelevance result: when firms and markets are identical and there are constant returns to scale, multimarket contact does not strengthen firms' ability to collude.

This paper notes that when ownership is separated from control, so that managerial objectives become relevant, but also when corporate taxes are non-linear or financial markets are imperfect, firms' objective functions tend to display decreasing marginal utility for profits within each time period. Strictly concave static objective functions make the repeated strategic interactions *interdependent*: firms' evaluation of profits from one market depends on profits realized in other markets. Then, the irrelevance result goes away and multimarket contact is shown to *always* facilitate tacit collusion.

The wealth effect induced by a strictly concave static objective function is also shown to generate "scale economies" in collusion; with multimarket contact collusion can be viable in a set of markets even when, absent multimarket contact, it couldn't be supported in *any* of these markets.

The effects of horizontal mergers without multimarket contact on the minimum discount factor at which collusion is supportable are ambiguous. However, horizontal mergers are found always to facilitate collusion when the discount factor is relatively low, and conversely to hinder collusion when the discount factor is relatively high.

Finally, "multi-game" contact is shown to always facilitate cooperation in any repeated strategic interaction other than oligopolistic ones – e.g., implicit contracts, reciprocal exchange, Prisoners's Dilemmas – as long as agents' static objective function is strictly *submodular* in stage-games' material payoffs.

2.5 Concluding Remarks

At this point the reader will think that when I sleep I just dream about bunches of firm owners and managers meeting in smoke-filled rooms to split collusive rents... Well, I don't (at least not every night). Still, to me the correspondence between empirical findings and theoretical results appears striking... Do directors really take into account the need to curb product market competition when choosing top managers' compensation? It will be hard to answer this question. Managerial incentives, though, are institutions – behavioral regularities – and I am prone to consider investors and directors (as well as academic consultants) boundedly rational. The pro-collusive managerial incentives one finds in the real world can therefore be thought of as "cooperative institutions" selected in time by the evolutionary process of strategic interaction in oligopolies.

Chapter 2

Essay I

Ownership, Control, and Collusion

Ownership, Control, and Collusion*

GIANCARLO SPAGNOLO[†]

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Abstract

This paper considers how the separation between ownership and control affects firms' ability to collude in long-run oligopolies. It finds that as long as managers have a preference for smooth time paths of profits, as revealed by the empirical evidence on "income smoothing," by delegating control owners can sustain any tacit collusive agreement at lower discount factors. Common "low-powered" managerial incentives with monetary bonuses or incumbency rents are found to make the joint monopoly collusive agreement supportable at any discount factor. Low pay-performance sensitivity in top managers' compensation – as found by Jensen and Murphy (1990) – is therefore "optimal" in the sense of maximizing firms' (collusive) profits.

JEL CLASSIFICATION: D43, G30, J33, L13, L21.

KEYWORDS: Oligopoly, CEO compensation, tacit collusion, delegation, managerial incentives, income smoothing, incumbency rents, ownership and control, governance.

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1 Introduction

A highly debated contribution by Michael Jensen and Kevin Murphy (1990) revealed that, at least until the mid '80s when the "stock-options wave" began, the compensation of U.S. top managers has typically had a very low pay-performance sensitivity.[1] Analogously, Steven Kaplan (1994, 1998) found that low-powered incentives are the norm for top executives of other developed countries, where no stock-options wave has taken place yet. Agency theory teaches us that high-powered managerial incentives should be highly beneficial for firm owners (Bengt Holmström, 1979). Why is it that, for such a long period of time and in many different countries, shareholders have chosen to forgo these benefits and face the agency costs linked to low-powered managerial incentives?

Three decades of empirical research on "income smoothing" have revealed that managers invest time, effort and firms' resources, and even use barely legal accounting tricks, in order to smooth accounting profits in time. That is, real world managers show a strong (revealed) preference for smooth temporal paths of firm profits.[2] In a recent paper on the subject, Drew Fudenberg and Jean Tirole (1995) note that income smoothing involves substantial real costs, among which are:

> "...poor timing of sales, overtime incurred to accelerate shipments, disruption of the suppliers' and customers' delivery schedules, time spent to learn the accounting system and tinker with it..." (p. 76).

Why is it that shareholders continue to face the costs of income smoothing practices, instead of suitably modifying their managers' incentive schemes?

This paper proposes a new, joint explanation for these two strands of empirical findings. It shows that when managers are left with the kinds of low-powered incentives that induce income smoothing, the separation between ownership and control *greatly* enhances the ability of firms to sustain highly profitable tacit collusive agreements.

The phenomenon of tacit collusion among oligopolistic firms has been well understood thanks to three decades of research on repeated games.[3] However, most previous supergame-theoretic analyses of tacit collusion confined themselves to the standard assumption that firms' objective function is linear in profits. Since in the real world many interacting factors determine the shape of firms' objective function,

[1] See, also, Sherwin Rosen (1992); and Charles Hadlock and Gerald Lumer (1997).

[2] Restricting attention to more recent studies, see Paul Chaney and Craig Lewis (1998); Mark De Fond and Chul Park (1997); Eero Kasanen *et. al.* (1996); Robert Holthausen *et al.* (1995); Jennifer Gaver *et al.* (1995); Kenneth Merchant (1989); and Paul Healy (1985).

[3] Classical references include James Friedman (1971); Robert Aumann and Lloyd Shapley (1976); Ariel Rubinstein (1979); Ed Green and Robert Porter (1984); Drew Fudenberg and Eric Maskin (1986); Julio Rotemberg and Garth Saloner (1986); and Dilip Abreu (1986, 1988).

it is interesting to understand how these factors affect firms' ability to collude. In particular, economists have realized for a long time that when ownership is separated from control, firms tend to pursue objectives different from profit maximization.[4] Also, the work of Thomas Schelling (1960) made it clear that contracts with third parties may have important strategic effects.

A recent line of research started by John Vickers (1985) and Chaim Fershtman (1985) builds on these ideas to explore the strategic effects of delegating control to managers with preferences or incentives different from those of the owners in oligopolies (for example, see Fershtman and Kenneth Judd, 1987; Steven Sklivas, 1987; Fershtman, Judd and Ehud Kalai, 1991; and Michael Katz, 1991). Most contributions to this literature model strategic delegation as a two-stage game, where a first stage in which principals (owners) choose simultaneously their delegates' preferences (managers' incentive schemes) is followed by a second-stage simultaneous market interaction between delegates.

To analyze the effects of delegation on tacit collusion we build on this literature by letting firms interact repeatedly in time. On the one hand, the appointment of a CEO and the design of his compensation package are decisions taken relatively infrequently in the life of a firm, compared to ordinary pricing and quantity-setting decisions. Consequently, a better approximation for some real-world oligopolistic interactions may be a one-shot delegation game followed by a second-stage oligopoly supergame between delegates under long-term contracts. On the other hand, the owners of oligopolistic firms are likely to interact repeatedly in time through the choice of their managers' incentives. Therefore, an infinitely repeated game whose stage game is a "classical" two-stage delegation game should shed further light on the effects of the separation of ownership and control on tacit collusion.

We take an "empirical approach" by starting from what we know about real-world managers' objectives, that is, from the empirical evidence cited at the beginning. To analyze the product-market implication of income-smoothing managers and low-powered incentives, we follow the bulk of the previous work on delegation in oligopoly by assuming managerial incentives to be binding and publicly observable.[5]

[4]For example, see Herbert Simon (1957); William Baumol (1958); Richard Cyert and James March (1963); Robin Marris (1964); Oliver Williamson (1964); and Jensen and William Meckling (1976).

[5]This takes us closer to the world of large publicly traded corporations, where ownership is spread and for which the appointment of a new CEO and the revision of his compensation package may become almost public issues. Even in such cases, when the costs of renegotiation are low the credibility of commitment through delegation may be undermined by the possibility of secret renegotiation (Mathias Dewatripont, 1988; Katz, 1991). We postpone the discussion of contract renegotiation until the end of the paper (Section 5.2), where we argue that rules for changing incentives and composition of the boards of directors, top managers' and directors "communities," and other features of the real world provide complementary mechanisms that turn managerial incentives into credible commitment devices.

In a classical repeated oligopoly model we show that – whatever the reason behind it – managers' preference for "smooth profit streams" revealed by studies on income smoothing carries with it a preference for "collusive behavior." Firms led by managers who prefer smooth time paths for firm profits can support any collusive agreement at lower discount factors than the minimum at which owner-led firms can. This is so because the preference for smooth income paths both reduces managers' appreciation of the short-run profits from unilaterally breaking a collusive agreement, and increases their sensitivity to losses from the punishment phase that follows such a breach.[6]

Several theoretical explanations have already been offered for managers' attempts to smooth firms' profits. We explore the product market implications of two of the most debated among these explanations.

We first consider Paul Healy's (1985) hypothesis that income smoothing practices are driven by the commonly used "bonus contracts" that pay managers in each period a fixed salary, plus an additional monetary bonus only awarded if a predetermined target level of profits is achieved. We find that such contracts, whether long-term or short-term, act as powerful incentives for collusion. Bonus contracts are able to make even the joint monopoly collusive agreement supportable in equilibrium at any level of the discount factor.

More recently, Drew Fudenberg and Jean Tirole (1995) have proposed an explanation of income smoothing based on incumbent managers' rents (e.g. private benefits of control), owners' inability to commit to long-term contracts, and "information decay" (the higher informational content of more recent performance indicators). We consider a simple "reduced form" of their optimal contracting model, a short-term wage contract with private benefits for the incumbent manager, and a replacement rule by which the manager is not reappointed if the firm's profits fall below a certain cut-off level. We find that the fear of losing future rents by being replaced during the low-profits punishment phase that follows a deviation deters managers from breaking any collusive agreement which delivers per-period profits higher than the cut-off level. As with short-term bonus contracts, the joint monopoly collusive agreement becomes supportable at any level of the discount factor.

As we wrote, these results provide another reason why shareholders may be willing to tolerate the mismanagement costs linked to income smoothing. In oligopolistic environments, the same kinds of incentives that induce such costly managerial practices also allow shareholders to enjoy high collusive profits. Moreover, the results make Jensen and Murphy's (1990) findings appear a bit less surprising, at least for mature oligopolistic industries. In such industries highly powered incentives are "subopti-

[6]Note that this result does not depend on any imperfection in credit markets. The evidence on income smoothing reveals that managers prefer smooth streams of firms' profits. With perfect credit markets, managers can freely smooth the time profile of their own income or that of the firm's cash flow, but they cannot affect (at least legally) that of the firm's profits.

mal," as they lead to aggressive managerial behavior and low profits. Low-powered incentives – such as bonus contracts and wage contracts with private benefits or other incumbency rents – are "optimal" in the sense that they induce the kind of "satisfying" managerial behavior that eventually maximizes firms' (collusive) profits. Our results also seem consistent with Hadlock and Lumer's (1997) finding that the pay-performance sensitivity of managers' compensation, although low, has been gradually increasing in the last half-century. In the last decades reduced transport costs, more efficient financial markets, faster information circulation, and other changes linked to "globalization" have increased the competitiveness of many industries and reduced the collusive rents that "conservative" managerial incentives may help to capture.[7]

The other results of the paper deal with the cyclical behavior of collusive prices. We find that when managers are under the incentive schemes described above or, for any other reason, have a preference for smooth time paths of firms' profits, Rotemberg and Saloner's (1986) "price wars during booms" need not occur. This is because in "good" states of demand income-smoothing managers have a lower marginal valuation of short-run gains from deviations than in "bad" states of demand. This effect works against the "size" effect identified by Rotemberg and Saloner, and dominates it when managers are sufficiently averse to intertemporal substitution in firm profits.

Finally, it is worth noting that the findings in this paper are distinct from those in the related work of Fershtman, Judd, and Kalai (1991), Michele Polo and Piero Tedeschi (1992), and Rajesh Aggarwal and Andrew Samwick (1996). Fershtman, Judd, and Kalai (1991) obtain a full "folk theorem" for classical two-stage observable delegation games by using target compensation functions that guarantee delegates a fixed prize as long as they keep principal's utility above a certain level. Polo and Tedeschi (1992) and Aggarwal and Samwick (1996) obtain a pro-collusive effect of delegation by allowing each manager's contract to be conditioned on the performance of the competing firms. We work instead with repeated oligopoly models, and we obtain full collusion at any level of the discount factor with the simple types of low-powered managerial incentives observed in empirical studies. These contracts are not target compensation functions (e.g. managers under bonus contracts lose future bonuses when they increase the owner's payoffs by deviating from collusion), and are conditional only on the firm's own profits.

The rest of the paper is organized as follows. Section 2 introduces the model and discusses the general pro-collusive effect of the separation of ownership and control when managers smooth profits. Section 3 considers the effects of long-term bonus

[7] Brian Hall and Jeffrey Liebmann (1998) have documented how the widespread adoption of stock-related incentive plans has greatly increased U.S. top managers' pay-performance sensitivity in the last fifteen years. Interestingly, and much in the same spirit as this paper, Giancarlo Spagnolo (1998a) has recently shown that, far from dissipating social welfare concerns, these highly powered stock-related incentives are also usually designed so that they greatly facilitate tacit collusion in product markets.

contracts. Section 4 analyzes short-term bonus contracts, incumbency rents, and replacement rules. Section 5 discusses the assumptions behind the results. Section 6 briefly concludes. With a few exceptions, proofs are in the appendix.

2 "Income smoothing" and collusion

2.1 A simple model

Consider a homogeneous good oligopolistic industry in which N identical firms compete in price. Time is discrete and trade occurs simultaneously in each period $t = 1, 2, \ldots$. At the beginning of each period each firm announces its current price. Let c denote the firms' constant and identical marginal cost, δ owners' and managers' common intertemporal discount factor, and p_i^t the price that firm i announces in period t. Demand is a decreasing and continuous function $Q(p^{mt})$ of price, where $p^{mt} = \min_i\{p_i^t\}$. When the N firms announce identical prices, demand is shared equally. When the quoted prices differ, all the consumers buy from the subset of firms which quoted the lowest price. These firms must meet all the demand at the announced price and allocate it equally among them. It is also assumed that total industry profits are concave in price and reach a maximum at $p^{mt} = p^M$, where $p^M = \arg\max_p (p - c)Q(p)$ is the monopoly price.

An equilibrium outcome in this market will be an infinite path of prices and associated profits vectors $\langle p^t, \pi^t \rangle_{t=0}^{\infty}$. As long as no collusive agreement is implemented, firms earn zero profits as they are caught in the unique Nash equilibrium of the static Bertrand game, with $p_i^{mt} = c$ and $\pi_i^t = 0$, for every i and t.

We focus first on stationary collusive agreements supported by trigger strategies, that is, by the threat of reverting forever to the Nash equilibrium of the static game (James Friedman, 1971). This greatly simplifies the analysis and the exposition, while it does not restrict the scope of the results.[8] Moreover, real-world tacit collusive agreements seldom consist of complex non-stationary equilibrium paths supported by sophisticated enforcing mechanisms.[9] Extensions to different market structures and more sophisticated punishment strategies are discussed in Section 5.1.

A stationary collusive agreement to set $p_i^t = p^* > c$, $\forall i, t$ can be supported by trigger strategies if and only if for every firm i, the expected gains from respecting

[8]With repeated Bertrand competition the most collusive market equilibria are stationary with colluding firms behaving as a monopolist in each period, while unrelenting trigger strategies are "optimal punishments." They keep players at their security levels, so that no complex punishment mechanism can enlarge the set of supportable equilibria (Abreu, 1986).

[9]Firms are dealing with forbidden implicit contracts on which exchanges of information and other forms of communication are risky. In a world where information is typically imperfect and costly and coordination difficult, the simplicity of stationary equilibria and trigger strategies may be important for tacit collusive agreements to be implementable.

the agreement outweigh the short-run gains from deviating from it. Formally, the condition is as follows:

$$\frac{1}{1-\delta}\frac{1}{N}(p^* - c)Q(p^*) \geq (p^* - c)Q(p^*) \Leftrightarrow \delta \geq 1 - \frac{1}{N}. \tag{1}$$

If condition 1 is not satisfied, tacit collusion is not supportable. To simplify notation, in the rest of the paper we will sometimes let π_i^* denote the per-period collusive profits of a firm i, $\frac{1}{N}(p^* - c)Q(p^*)$, and $\widehat{\pi}_i^*$ denote short-run profits from deviating unilaterally from that collusive agreement $(p^* - c)Q(p^*)$. The superscripts ^{M} and ^{N} will indicate the value of a variable at the joint monopoly and at the static Nash equilibrium outcomes respectively.

Previous work on delegation showed that leaving control to a manager with preferences/incentives different from the owners' has significant strategic effects in oligopoly. In our infinitely repeated oligopoly framework the first obvious consideration that would follow is that owners would like to choose managers with a higher intertemporal discount factor in order to facilitate collusion and enjoy higher profits. Because this is straightforward, we assume throughout the paper that managers' and owners' discount factors are identical and constant in time.

2.2 "Income-smoothing managers" and tacit collusion

The evidence on income smoothing discussed in the introduction reveals that real-world managers have a robust preference for smooth time paths of firms' profits. The preference for smooth profits, that is, the aversion to intertemporal substitution in firm profits, implies decreasing marginal utility of profits within each period, and therefore a strictly concave static objective function. When managers are in control, firms' objective functions should incorporate this preference. In our model, an owner-led firm i should therefore maximize, in each period τ, the objective function $\sum_{t=\tau}^{\infty} \delta^t U(\pi_i^t)$, with U strictly concave. On the other hand, to our knowledge, there is no evidence of income smoothing practices for owner-led firms. This allows us to state the first result.

Proposition 1 *Suppose owners maximize expected profits, while managers have a preference for smooth profit time-paths. Then, the separation between ownership and control facilitates collusion by allowing firms to support in subgame-perfect equilibrium any tacit collusive agreement at a lower minimum discount factor.*

As mentioned in the introduction, the intuition is that managers' strictly concave objective function relaxes the necessary and sufficient conditions for any collusive agreement to be supported in equilibrium for two reasons: (1) it reduces the relative value of one-shot gains from unilateral deviations from the agreement (they are now evaluated at relatively lower marginal utility); and (2) it increases the relative value of the losses from the punishment phase which follows a deviation (they are now evaluated at relatively higher marginal utility).

The necessary conditions for any given collusive agreement to be supportable in equilibrium are linear in three parameters: the discount factor δ; the equilibrium profit stream $\{\pi_i^t = \pi_i^*\}_{t=\tau}^{\infty}$; and the stage-game's payoff structure, parametrized here by $\hat{\pi}_i^*$. The concavity of the instantaneous utility function makes such conditions less stringent and therefore, given two of the parameters, it enlarges the set of values of the third parameter which satisfy the relation. This leads to the following remark.

Remark 1 *Proposition 1 implies that, given the discount factor δ, managers' preference for smooth profit streams (i) (weakly) enlarges the set of collusive agreements that firms can support in any given market, and (ii) it enlarges the set of markets (parametrized here by $\hat{\pi}_i^*$) in which firms are able to support any given collusive profit stream.*

2.3 Extensions

2.3.1 Other reasons to "smooth-and-collude"

The results of this section may appear to best fit the explanation of income smoothing offered by Richard Lambert (1984) and Ronald Dye (1988), by which financially constrained managers under share contracts smooth their own income in time by smoothing firms' profits. However, the results apply to whatever is the specific factor that leads managers to have a preference for smooth streams of firms' profits. For example, managers' preference for discretion in the form of "free cash flow" identified by Jensen (1986) should also induce a preference for smooth time paths of profits when information asymmetries make external finance costly and dividend policy rigid. An alternative explanation for income smoothing, provided by Joshua Ronen and Samcha Sadan (1981) and Brett Trueman and Sheridan Titman (1988), assumes that managers act in the interests of shareholders, and that shareholders (and capital markets in general) have a preference for assets delivering smooth returns. In this case it would be factors behind shareholders' preferences – for example financial constraints – that facilitate collusion. More generally, any factor (internal or external to the firm) that makes smoothing profits a profitable policy also makes firms more prone to collude. Therefore, many of the arguments brought up in the finance literature for why firms should smooth profits by "hedging" – such as reducing the tax bill (because the corporate tax is generally not perfectly linear in profits), or limiting the extra cost of external finance (due to information asymmetries) – also identify factors that tend to increase firms' willingness to collude (e.g. Kenneth Froot *et al.*, 1993).

The pro-collusive effect of a strictly concave objective function behind Proposition 1, and the converse pro-competitive effect of strictly convex objective functions it implies, permit a comparison with the work of Voijslav Maksimovic (1988) on the relation between leverage and collusion. In Maksimovic's model, long-term debt with a per-period repayment coupon has a pro-competitive effect because shareholders enjoy all short-run gains from breaking a collusive agreement, while limited liability protects them from part of the losses in the following punishment phase. In light of the proof of Proposition 1, we can say that Maksimovic's result is due to the strict convexity of firms' objective function induced by the long-term debt with a repayment coupon.

Because our focus is on managerial incentives, in the remainder of this paper we abstract from tax issues and stick to the assumption of perfect capital markets and profit-maximizing investors (owners).[10]

2.3.2 Demand uncertainty

Rotemberg and Saloner (1986) have noted that when demand is subject to stochastic shocks, short-run gains from breaking a collusive agreement change together with the realization of the state of the world. High demand implies larger short-run profits obtained by deviating unilaterally from a collusive agreement and capturing the whole market. Instead, the expected losses from the punishment phase, the threat that disciplines the collusive agreement, are constant across states of the world. Then, when the discount factor binds, the more profitable collusive agreements between profit-maximizing firms need to be conditioned on each period's realization of the shock. When the realized state of demand is high, the agreement must indicate a lower collusive price in order to restrain the temptation to break the agreement below the constant expected gains from sticking to it. These kinds of agreements would appear to outside observers as "price wars during booms."

What is, instead, the cyclical behavior of collusive prices when firms are led by income-smoothing managers?

Let θ denote the stochastic shock that affects demand, so that in our model the demand function becomes $Q = Q(p, \theta)$, with $Q(p, \theta)$ increasing in θ. For simplicity, assume θ to be *i.i.d.* so that in each period $\theta \in \{\theta^L, \theta^H\}$, with $\Pr(\theta = \theta^H) = q$ and $0 < q < 1$. Then we can state the following result.

Proposition 2 *Suppose firms are led by managers with a preference for smooth profit streams. Then price wars during booms need not occur: when managers are sufficiently averse to intertemporal substitution in firms' profits, collusive prices are pro-cyclical.*

[10] For the relation between market imperfections and cooperation/collusion see Giancarlo Spagnolo (1998c).

The intuition is, again, quite straightforward. When managers are averse to intertemporal substitution their objective function is strictly concave, therefore they have a lower marginal valuation of profits at higher levels of realized profits, that is, when demand is high. This means that in good states of the world firms' marginal valuation of short-run gains from deviation is lower than in bad states of the world. This "wealth" effect works in the opposite direction to the "size" effect identified by Rotemberg and Saloner, and dominates it when managers' preference for smooth profits is sufficiently strong.[11]

3 Long-term "bonus contracts"

In a highly debated contribution, Healy (1985) argued that income smoothing may be driven by managers' monetary incentive schemes, and provided empirical support for his view. He noted that most common managerial incentive schemes had fixed monetary bonuses paid only when profits reached a certain positive target level. These "capped" incentives would lead managers to transfer profits from periods in which they are far above or below the level that triggers the bonus, to periods in which they are close but below such a target. More recently, Paul Joskow and Nancy Rose (1994) found evidence that Boards discount extreme profit realization from managers' compensation, so that managerial incentives tend to be "capped." How do these incentive schemes influence firms' ability to sustain collusive agreements?

In this section we focus on long-term managerial contracts, so the delegation game will be a two-stage game where a first-stage static interaction in which owners choose their delegates' incentives is followed by a second-stage infinitely repeated market game. This strategic structure is analogous to Jean Pierre Benoit and Vijay Krishna's (1987) and Carl Davidson and Raymond Denekere's (1990) analyses of excess capacity and tacit collusion in Bertrand supergames, and to Maksimovic's (1988) work on

[11] It is well known that von Neumann-Morgenstern utility functions do not allow separation of agents' risk aversion from their aversion to intertemporal substitution. It is easy to check that, with Bertrand competition and demand uncertainty, risk aversion unambiguously reduces players' evaluation of (uncertain) net expected gains from collusion relative to (certain) short-run gains from deviation. This effect would work against the pro-collusive effect of managers' aversion to intertemporal substitution identified by Proposition 1, so that with demand uncertainty, the overall effect of managerial control on collusion would depend on the variance of the shock (pro-collusive with high variance, pro-competitive with low variance). We have chosen not to pursue this extension here because the pro-competitive effect of risk aversion is strictly dependent on homogeneous Bertrand competition, while all other results in this paper are not (see Section 5.1.1). With most alternative market structures, players' evaluation of net expected gains from cooperation depends on how the degree of risk aversion changes with wealth (for example, with non-increasing absolute risk aversion, demand uncertainty with constant variance tends to increase players' evaluation of expected gains from collusion in repeated oligopolies where firms earn positive profits at the static Nash equilibrium).

capital structure in oligopoly. In Section 4 we will consider the case of short-term managerial contracts.

We adopt the standard assumption that when managers are indifferent with respect to two or more actions they choose the one that maximizes their firm's profits.[12] Also, to make the pro-collusive effect more evident, we assume that inequality (1) – owners' incentive compatibility condition for any collusive agreement to be supportable – is not satisfied. Finally, to skip straightforward comparisons between costs (managers' compensation) and benefits (additional collusive profits) of delegation, we assume that owners' disutility of running the firm personally is larger than, or equal to managers' reservation wage R.

3.1 Long-term bonus contracts and tacit collusion

Because condition (1) is not satisfied, owner-led firms are stuck at the static Bertrand-Nash equilibrium earning zero profits. However, firm owners may decide – at the foundation of the industry or in a following period – to hire managers under the commonly used bonus contracts, to try to improve on their miserable situation. We define a long-term bonus contract as a stationary sequence of values for the triple of parameters $\left\{W_i, B_i, \pi_i^B\right\}$, where W_i denotes the manager's salary, B_i denotes a positive monetary bonus, and π_i^B denotes the minimum level of the firm's profits that triggers its payment to the manager.[13] Suppose owners can choose between keeping control, hiring a profit-maximizing manager, and hiring a manager under a bonus contract (in which case the owners must also choose the target π_i^B). With long-term contracts the timing of the delegation game is as follows.

- Stage 1: Owners simultaneously decide whether to delegate and choose the parameters of managers' incentive contract.
- Stage 2: Managers (if delegation takes place) or owners play the market supergame.

In the second-stage market supergame a manager i under bonus contract with $\pi_i^B > 0$ finds it convenient to respect any tacitly agreed sequence of collusive prices

[12]This makes exposition easier and ensures that the reversion to the static Nash equilibrium remains a credible threat under manager-control. Alternatively, one could let managers' compensation contain a small profit-sharing component, or assume that managers own a small amount of firms' shares.

[13]Regarding managers' participation constraint, we can follow Fershtman and Judd (1987) by assuming that managers' real compensation is some function $A(W + B) \geq R$. The parameter A can then be set freely to reflect conditions on the managerial labor market, as managerial behavior is only driven by the step at the target profit level π_i^B, which does not depend on A.

$\{p^t = p^*\}_{t=0}^{\infty}$ such that

$$\pi_i^B \leq \frac{1}{N}(p^* - c)Q(p^*), \forall i, \tag{2}$$

whatever the discount rate is. This is so because by sticking to the agreement, he receives, together with the wage, a stationary flow of bonuses with total discounted expected payoffs $\frac{W_i+B_i}{1-\delta}$. A unilateral deviation from any such collusive agreement leaves the manager's wage unaffected and allows him to get the bonus in the period of the deviation, but triggers a punishment phase during which profits are zero and the bonus is not paid. Discounted expected payoffs from the unilateral deviation are therefore $B_i - \frac{W_i}{1-\delta}$, that is, a net loss of $\delta\frac{B_i}{1-\delta}$.

If all managers are under bonus contracts, the set of collusive prices supportable in subgame-perfect equilibrium in the market supergame P^* is non-empty as long as $\sum_{i=1}^{N} \pi_i^B \leq (p^M - c)Q(p^M)$. This is so because if condition (2) does not hold for one (or more) manager(s), then that manager would deviate from any collusive price (either to try to obtain the bonus at least once or, when this is impossible, because he is indifferent and therefore maximizes the firm's profits). Therefore, as long as $\sum_{i=1}^{N} \pi_i^B \leq (p^M - c)Q(p^M)$ managers can support collusion in the second stage. Furthermore, if all managers have $\pi_i^B = \pi_i^M$, where $\pi_i^M = \frac{(p^M-c)Q(p^M)}{N}$, the joint monopoly agreement is the only stationary collusive agreement managers can support in equilibrium in the second-stage supergame, whatever the discount factor is.

Consider now the first stage of the delegation game. Can an owner profit by deviating unilaterally from a strategy profile that in the first stage prescribes each owner to delegate control to a manager under a bonus contract with $B > 0$ and $\pi_i^B = \pi_i^M$? If an owner deviates by choosing to keep control or to delegate to a profit-maximizing manager (e.g. setting $B = 0$) collusion cannot be supported and he expects zero profits forever. If an owner deviates by setting $\pi_i^B > \pi_i^M$ the condition $\sum_{i=1}^{N} \pi_i^B \leq (p^M - c)Q(p^M)$ is violated, collusion cannot be supported and, again, all owners (including the deviating one) get zero profits forever. Finally, if an owner deviates by choosing $\pi_i^B < \pi_i^M$ he cannot gain, but he can lose since even though managers can support collusion in the second stage, his manager may settle with a collusive agreement delivering profits π_i^* with $\pi_i^B \leq \pi_i^* < \pi_i^M$.

This simple reasoning is summarized by the following proposition.

Proposition 3 *By delegating control to managers under long-term bonus contracts with $\pi_i^B = \pi_i^M$, owners can support the joint monopoly collusive agreement as a subgame-perfect equilibrium of the delegation game at any level of the discount factor.*

3.2 Extensions

3.2.1 Richer contract space

We focused on bonus contracts because of their empirical relevance, but the results above remain valid when owners can choose from a larger set of managerial incentive contracts. For example, owners may think of making a manager's compensation a continuous function of firm profits, or a function of sales revenue, which we denote by S_i. Suppose owners can choose the parameters of the following compensation function:

$$W_i + \gamma_i g_i(\pi_i) + \beta_i f_i(S_i) + B_i \cdot 1_{\{\pi_i \geq \pi_i^B\}},$$

where $\gamma_i \geq 0$ and $\beta_i \geq 0$ are coefficients, $g_i(.)$ and $f_i(.)$ are continuous increasing functions, and 1_A is the indicator function on a set A. When $\beta_i > 0$, we assume owners forbid (contractually) managers to choose prices lower than marginal cost, so that owners avoid negative profits if collusion breaks down.[14] Owner i's choice variables in the first-stage delegation game are now $\{\gamma_i, \beta_i, g_i, f_i, B_i, \pi_i^B\}$, and we can state the following lemma.

Lemma 1 *The minimum discount factor at which any collusive agreement (or, given the discount factor, the set of agreements that) can be supported in subgame-perfect equilibrium in the delegation game is increasing (or, decreasing) with γ_i and β_i.*

The point is that under bonus contracts managers have no incentive whatsoever to deviate from a collusive agreement that permits them to obtain the bonuses. Incentive components increasing in profits generate short-run gains from deviation for managers, while leaving their wage during punishment phases unaffected. Incentive components increasing with sales also generate managerial short-run gains from deviation, and they even increase managers' wage during punishments. A simple result follows from Lemma 1.

Proposition 4 *By delegating control to managers under long-term bonus contracts with $\gamma_i = 0$, $\beta_i = 0$, $B_i > 0$, and $\pi_i^B = \pi_i^M$, owners can still support the joint monopoly collusive agreement in subgame-perfect equilibrium at any level of the discount factor.*

A formal proof is not required, as it is straightforward to check that each owner cannot gain by deviating from this strategy profile. By choosing $\gamma_i > 0$ or $\beta_i > 0$ an owner cannot affect collusive profits or the static Bertrand outcome, while he makes his manager's incentive constraint more stringent and therefore destabilizes collusion. On the other hand, as before, the choice of $\pi_i^B < \pi_i^M$ may lead the managers to support a less profitable agreement, while choosing $\pi_i^B > \pi_i^M$ or $B_i = 0$ leads managers to maximize per-period profits, and therefore to the repeated play of the static Bertrand equilibrium.

[14] This also ensures the existence of the static Nash equilibrium in the market game when incentives for sales are chosen.

3.2.2 Demand uncertainty

For the effects of demand uncertainty, we consider the two extreme cases of fully contractable and non-contractable shocks.

Suppose first that shock θ is contractable, that is, the shock can be observed ex post by owners and third parties, with or without delay. For example, if there exist independent agencies monitoring the state of demand, a contract could be made contingent on the state of demand reported by one of these agencies. Then we easily obtain the following result.

Proposition 5 *With contractible demand uncertainty, by delegating control to managers under long-term bonus contracts owners can implement the joint monopoly outcome in all states of demand at any level of the discount factor.*

That is, with contractible demand uncertainty and long-term bonus contracts there will be no price wars during booms.

Consider now the case in which third parties can never observe any reliable signal of past realizations of demand. Now owners cannot condition incentive contracts on (a verifiable signal of) the state of demand, and the bonus contract is as in Section 3.1. For simplicity we continue assuming that θ is *i.i.d.* and that each period $\theta \in \left\{\theta^L, \theta^H\right\}$, with $\Pr(\theta = \theta^H) = q$ and $0 < q < 1$. The outcome of the delegation game may depend now on managers' ability to coordinate. Let us restrict attention to symmetric agreements, and let φ, with $0 \leq \varphi \leq 1$, parametrize managers' coordination ability so that, when managers are indifferent between several supportable collusive prices, when $\varphi = 1$ they choose the collusive price delivering the highest profit stream, when $\varphi = 0$ they choose the collusive price delivering the lowest profit stream, and so on. Then we can state the following result.

Proposition 6 *When the demand shock is not contractable:*

(i) Owners setting $\pi_i^B = \pi_i^M(\theta^H) = \frac{(p^M - c)Q(p^M, \theta^H)}{N}$ and managers sustaining collusion is a subgame-perfect equilibrium of the delegation game whatever is the discount factor. Furthermore, as long as $(p^M - c)Q(p^M, \theta^L) \geq \frac{(p^M - c)Q(p^M, \theta^H)}{N}$ and $\delta \leq \frac{1}{1-q}$, the monopoly price can be sustained only in high states of demand and the collusive price will be counter-cyclical.

(ii) When $\frac{1-q}{q} > \frac{(N-1)\left[(p^M - c)Q(p^M, \theta^H) - (p^M - c)Q(p^M, \theta^L)\right]}{(p^M - c)Q(p^M, \theta^L)}$, there exist a $\widetilde{\varphi}$, with $0 < \widetilde{\varphi} < 1$, such that for any $\varphi \geq \widetilde{\varphi}$ there also exist subgame-perfect equilibria of the delegation game in which owners set $\pi_i^B = \pi_i^M(\theta^L)$ in the first stage and managers sustain collusion in all states in the second stage supergame. As long as $1 > \varphi \geq \widetilde{\varphi}$, in this equilibria the collusive price will be pro-cyclical.

Therefore, with non-contractable uncertainty price wars during booms can, but need not occur; the collusive price may be counter-cyclical.

4 Short-term contracts, incumbency rents, and replacement rules

4.1 Short-term bonus contracts

With long-term contracts, delegation under bonus contracts emerges as a powerful collusive device. How is this finding affected by owners' or managers' inability or unwillingness to commit to long-term contracts?

We continue to assume that condition (1) is not satisfied, and modify the model by considering managerial contracts that last one period only. Now the two-stage delegation game with an infinitely repeated second stage which we had in Section 3 is replaced by an infinitely repeated oligopoly game with a two-stage delegation game as its stage game. At the beginning of each time period owners simultaneously choose whether or not to delegate control to managers and, if they decide to, the parameters of the compensation function. At the end of the same time period delegates or owners interact in a one-shot Bertrand oligopoly game. The timing of period t stage game is now:

Stage game t

- Step 1: Owners simultaneously decide whether to delegate and choose managers' incentive contracts.
- Step 2: All players observe the outcome of Step 1, then players in control simultaneously choose prices for period t only.

As in standard repeated games with perfect information, we assume that at the end of each period prices and profits are observed by all players. We can state a result analogous to Proposition 3.

Proposition 7 *By delegating control to managers under short-term bonus contracts, owners can still sustain the joint monopoly collusive agreement in subgame-perfect equilibrium at any level of the discount factor.*

The result is due to the fact that, even though explicit managerial contracts last one period only, owners and managers are free to agree on *implicit* employment contracts with each other, which are long-term by definition (Bentley MacLeod and James Malcomson, 1989; Lorne Carmichael, 1989). Then, owners have no incentive to deviate from an implicit long-term contract that leads the manager to sustain collusion in the product market, since owners' deviations (changes of the contract, replacement of the manager) are observed by competing firms' managers who can react before any gain from deviation in the product market can be realized. On the other hand, managers always find it convenient to respect the collusive agreement, since their incentive contract is such that they gain nothing by deviating, while after the deviation they are fired and/or kept at their reservation wage forever.[15]

It is straightforward to check that a fully analogous argument applies when managerial contracts last any finite number of periods other than one. The only difference is that in that case owners choose once every T periods, rather than at the beginning of each period.

4.2 Incumbency rents and replacement rules

In the case of short-term bonus contracts, the managers' collusive behavior is driven by the "capped" incentive scheme together with the fear of losing future rents. An analogous pro-collusive effect should therefore be linked to managers' fear of losing other common kinds of incumbency rents, such as private benefits of control. As already mentioned, Fudenberg and Tirole (1995) proposed an explanation of income smoothing based on managers' fear of losing incumbency rents. In their optimal contracting model, managers enjoy private benefits of control (the incumbency rents), owners cannot commit to long-term contracts, and performance measures are subject to "information decay" so that new performance measurements are better signals than old ones. In equilibrium, managers under wage contracts incur positive costs in order to smooth reported profits and dividends because, given information decay, some periods of low profits may lead shareholders to replace the manager even if profits have been high in the past.

To characterize the product-market effects of the "aversion to low profits" drawn by Fudenberg and Tirole, we consider a very stylized reduced form of their model. Suppose that managerial contracts last one period, that per-period compensation is composed of a flat wage plus some private benefits of control, and that owners use a replacement rule by which the manager is not reconfirmed if profits fall below some lower cut-off level. As in the previous section, each period t stage game is composed of two steps:

[15] The equilibrium set with short-term contracts differs from that with long-term contracts only with regard to the case in which managers are kept at their reservation wage R. The results in Section 3 apply for any level of managerial compensation $W_i + B_i \geq R$, while Proposition 7 holds for $W_i + B_i > R$ only. This is because now a fraction (however small) of the collusive rent must be left to the manager to generate the expected gains from compliance necessary to enforce any implicit contract. In MacLeod and Malcomson's (1989) characterization implicit contracts can also be supported when employees are indifferent. Here the strict inequality is needed because of our assumption that, when indifferent, managers maximize firms' profits.

Stage game t

- Step 1: Owners simultaneously decide whether to delegate and choose the parameters of managers' compensation.
- Step 2: All players observe the outcome of Step 1, then players in control simultaneously choose prices.

One can state the following proposition.

Proposition 8 *Suppose managers in control enjoy private benefits (or any other kind of incumbency rents independent of profits). Then, by delegating control to managers under short-term wage contracts, owners can still sustain the joint monopoly collusive agreement in subgame-perfect equilibrium at any level of the discount factor.*

Private benefits of control and other incumbency rents coupled with the termination threat have a pro-collusive effect analogous to that of short-term bonus contracts. Again, each owner has no incentive to deviate from an implicit long-term contract that in equilibrium leads the manager to sustain collusion in the product market, since the owner's deviations (a change of the contract or the replacement of the manager) is observed by competing firms' managers who react before any gain from deviation can be realized. On the other hand, as long as managers under wage contract enjoy incumbency rents, they find it strictly convenient to respect any collusive agreement that allows them to be reappointed and enjoy rents in future periods.

4.3 Extensions

4.3.1 Richer contract space

Suppose that managerial contracts last one period only, managers enjoy per-period private benefits of control B_i, and owners reconfirm the manager for the next period only if profits are above some lower cut-off level π_i^B (or, equivalently, suppose that managers have a bonus component in the short-term compensation function). Further, suppose that owners can also choose the parameters of the following per-period monetary compensation function:

$$W_i + \gamma_i g_i(\pi_i) + \beta_i f_i(S_i),$$

where as before W_i is a flat salary, $\gamma_i \geq 0$ and $\beta_i \geq 0$ are coefficients, and $g_i(.)$ and $f_i(.)$ are continuous increasing functions. Again, we assume that owners forbid managers contractually to choose prices lower than the marginal cost when $\beta_i > 0$. Now (provided that $W_i + B_i > R$) in Step 1 of each time period, owners' strategically relevant choice variables are $\{\gamma_i, \beta_i, g_i, f_i, \pi_i^B\}$. The logic behind the results in the previous subsections still applies. We can state a lemma analogous to Lemma 1.

Lemma 2 *When managers are under short-term bonus contracts or wage contracts with incumbency rents, the minimum discount factor at which any collusive agreement can be supported in subgame-perfect equilibrium in the infinitely repeated delegation game increases with* γ_i *and* β_i.

Again, managers who are paid a flat wage and enjoy private benefits of control have no incentive whatsoever to deviate from a collusive agreement that permits them to be reconfirmed every period. Instead, incentive components increasing in profits generate short-run gains from deviation for managers, while incentive components increasing with sales also increase managers' wage during punishments. Therefore we can write a result analogous to Proposition 4.

Proposition 9 *By delegating control to managers under short-term bonus contracts or wage contracts with incumbency rents, with* $\gamma_i = 0$, $\beta_i = 0$, $B_i > 0$, *and* $\pi_i^B = \pi_i^M$, *owners can still support the joint monopoly collusive agreement in subgame-perfect equilibrium at any level of the discount factor.*

Again, a formal proof is not required as it is straightforward to check that each owner cannot gain by deviating from this strategy profile. By choosing $\gamma_i > 0$ or $\beta_i > 0$ an owner cannot affect collusive profits, while he makes his manager's incentive constraint more stringent and therefore destabilizes collusion. On the other hand, as before, the choice of $\pi_i^B < \pi_i^M$ may lead the managers to accept a less profitable agreement, while choosing $\pi_i^B > \pi_i^M$ or $B_i = 0$ leads managers to maximize per-period profits, and therefore to the repeated play of the static Bertrand equilibrium.

4.3.2 Demand uncertainty

Suppose the demand shock θ, or a reliable proxy of it, can be observed ex post by third parties, with or without delay. Then, even when contracts are short-term, bonuses or replacement can be made contingent on the (proxy of the) state of demand, so that statements analogous to Proposition 5 can be proved along the lines of the proofs of Propositions 7 and 8. Then no price wars during booms should be expected. Suppose, instead, that no reliable proxy of θ can ever be observed by courts. Then contracts cannot be conditioned on the shock, and only statements analogous to Proposition 6 can be proved along the lines of the proof of Propositions 7 and 8. Then price wars during booms may, but need not occur; the collusive price may again be pro-cyclical.

5 Discussion

5.1 Alternative specifications of the model

5.1.1 *Market structure*

We have been working with a repeated Bertrand oligopoly, but most of the results we obtained hold with other market structures, such as repeated Cournot competition, repeated price competition with differentiated products or capacity constraints. A more general result showing the relation between intertemporal substitution and cooperation in supergames – the mechanism behind Proposition 1 – can be found in Spagnolo (1998c). For all other results it is straightforward to verify that they apply to other market structures. The only modification to the proofs that support the results is the addition of a stream of positive profits during the punishment phase that does not affect the logic of the proofs. For example, consider Proposition 3, and let $\pi_i^N > 0$ denote the static Nash equilibrium profits which firms earn during the punishment phase when the stage-game oligopoly is not homogeneous-good Bertrand. In the second stage of the game of Section 3.1 each manager under a bonus contract will now find it convenient to stick to any collusive agreement delivering per-period profits π_i^A such that

$$0 < \pi_i^N < \pi_i^B \leq \pi_i^A, \forall i,$$

and all the following reasoning holds unchanged. As long as $\pi_i^B > \pi_i^N$, the reasoning regarding the first-stage delegation game also holds unchanged, and owners lose by setting $\pi_i^B \leq \pi_i^N$. Analogous arguments apply to the other results regarding long-term contracts.

The check is even more straightforward in the case of short-term contracts. Then managers are not reappointed after a deviation has driven firms into a market war; therefore firm profits during punishment phases – and therefore market structure – are irrelevant for managers' behavior.

5.1.2 *Incentives for sales with Cournot competition*

When firms compete in output, because Stackelberg profits, denoted by π_i^S, are typically lower than profits at the joint monopoly equilibrium, owners who expect other owners to choose bonus contracts with $\pi_i^B = \pi_i^M$ lose strictly by deviating and choosing aggressive managerial incentives linked to sales revenue, such as those in Fershtman and Judd (1987) and Sklivas (1987) (FJS from now on).[16] However, with Cournot competition, if collusion is not sustained or breaks down, and managers start playing

[16] We are not aware of any general study on the relation between Stackelberg profits and profits with the symmetric joint monopoly agreement, but in all the simple explicit examples we solved, we always obtained $\pi_i^S < \pi_i^M$.

the static Nash equilibrium, each owner would be better off if he had unilaterally chosen incentives linked to sales ($\beta > 0$). Because of this, when firms compete in output owners may wish to coordinate on a more robust equilibrium of the delegation game, both in the case of long and short term contracts. In this alternative equilibrium owners give managers a mixed incentive contract with a pro-collusive bonus together with an aggressive FJS-type sales-related incentive component. To see this, consider a Cournot duopoly where a manager's per-period compensation can be composed of an incentive scheme linear in per-period profits and in sales revenue, plus an additional bonus:

$$\rho_i \left(\alpha_i \pi_i + (1 - \alpha_i) S_i\right) + (1 - \rho_i) B_i \cdot 1_{\left\{\pi_i \geq \pi_i^B\right\}}.$$

Now each owner i's relevant strategy space in the first stage of the delegation game is the set of parameters $\left\{\rho_i, B_i, \alpha_i, \pi_i^B\right\}$. Let α^{FJS} denote the equilibrium level of the parameter α obtained in the FJS two-stage duopoly models. We get immediately a result analogous to Proposition 4.

Proposition 10 *When incentives linked to sales are feasible and firms compete in output, by delegating control under a mixed managerial contract with $\alpha = \alpha^{FJS}$, $\pi_i^B = \pi_i^M$, $B_i > 0$, and $\rho_i > 0$ but small enough to satisfy managers' incentive compatibility constraint at the joint monopoly agreement, owners can support the joint monopoly agreement as a subgame-perfect equilibrium of the delegation game at any level of the discount factor.*

The point is that the pro-collusive effects of capped bonuses and of private benefits of control remain when these are only part of a more complex managerial compensation package. Furthermore, when owners use the mixed contract described above, if an owner deviates optimally by choosing $\rho_i = 1$, the competing firm's manager reacts by maximizing only the FJS-type part of his incentive scheme, since whatever he does he cannot get his bonus. Therefore, when an owner deviates, instead of π_i^S he obtains the low equilibrium profits of the FJS model $\pi_i^{FJS} < \pi_i^N$, both in the period of the deviation and in the following periods. This mechanism ensures that deviating owners incur a direct loss in the same period of the deviation, and that if one owner deviates by choosing aggressive FJS-type incentives other owners lose less, as their managers will have as aggressive incentives as those of the deviating owner's manager. Note that this applies independently of whether π_i^S is $>, =,$ or $<$ than π_i^M.

5.1.3 *Renegotiation-proof punishment strategies*

We wrote that in repeated Bertrand oligopolies unrelenting trigger strategies keep firms at their security levels and therefore they are an "optimal punishment" in the sense of Abreu (1986). However, these strategies are not renegotiation-proof, and indeed no renegotiation-proof punishment can be built in a repeated Bertrand game if renegotiation is costless.[17] As persuasively argued by Barbara McCutcheon (1997), in the case of collusive agreements renegotiation costs tend to be positive but small, because of the risk of being caught renegotiating and fined by the competition authority. In this case the optimal renegotiation-proof punishment is to price competitively for a finite number of periods such that the loss of gains from cooperation is just below the cost of renegotiation (see also Andreas Blume, 1994). It is easy to show that all the results hold unchanged when players use these alternative punishment strategies. In fact, Proposition 1 is strengthened in this framework because the cost of renegotiation is concentrated in time (e.g. in the period of the fine), and is therefore relatively larger for income-smoothing managers whose marginal utility is higher at low levels of profits. So, for any given cost of renegotiation, managers can use the tougher threat of a longer period of market war, which adds to the other two pro-collusive effects behind Proposition 1.[18] Regarding the other results with long-term contracts, it is straightforward to check that Propositions 3 to 6 hold for any finite length of the punishment phase.

For the case of short-term managerial contracts we can say something more general: the results regarding short-term contracts hold whatever punishment strategies owners use. This follows from the fact that, with short-term contracts, owners are free to break the implicit contract and fire the manager after a deviation from a tacit collusive agreement occurs. And after they take back control, owners can personally implement any (optimal or renegotiation-proof) punishment available. On the other hand – whatever the punishment phase looks like – short-term delegation maintains its pro-collusive effect linked to the low (zero) gains from deviations obtained by managers under capped incentive contracts.

5.2 Renegotiation of managerial contracts

Throughout the paper we have assumed that managerial incentives are observable and binding, as in most previous work on strategic delegation in oligopolies. As pointed out by Mathias Dewatripont (1988), Katz (1991) and others, in the case of contracts with third parties the credibility of the commitment can be undermined by agents' ability to *secretly* renegotiate them. If shareholders could costlessly and secretly renegotiate the incentive contract with their manager and induce him to deviate from a collusive agreement, then the separation of ownership and control could affect firms' ability to collude. There are several arguments that lead us to think that the case of managerial incentive contracts that can be costlessly and secretly renegotiated is not a common one in our world.

[17] Unless one introduces randomized punishments; see Joseph Farrell and Maskin (1989).

[18] Contact the author for a formal proof.

5.2.1 Renegotiation secrecy

In most large public companies, top managers' compensation is in the hands of the Board of Directors within the (often restrictive) limits set by shareholders. These limits cannot be secretly renegotiated, as they are set and can be modified only during *public* shareholders' meetings. Sometimes Boards are left with sufficient freedom for a secret renegotiation that may induce a CEO to break a cartel. However, Joskow and Rose (1994) found that Boards themselves discount extreme performance realizations from managers' compensation, making it "capped." So the question is: Why do Boards give managers the low-powered incentives that lead to income smoothing? The first, obvious answer that comes to mind is that this is what Boards want. That is, Boards of Directors leave top managers with low-powered incentives and let them smooth firm profits in time because directors themselves have those kinds of incentives. Directors usually enjoy firm perquisites and have generous compensation with even more low-powered incentives than managers, so they tend to be interested in a continuous flow of "satisfactory" (collusive) profits that ensure reappointment (future incumbency rents). Then, *all of what we have written in the previous sections can be restated after replacing the word "managers" with the word "directors."* However, we wrote above that directors' compensation contract can be renegotiated or renewed only in public shareholders' meetings, which means that they cannot be *secretly* renegotiated. It follows that if a firm's shareholders choose "prudent" (incentives for) directors, who then choose a "prudent" (incentive contract for) the CEO, that firm is credibly committed to "prudent," collusive product-market behavior.

5.2.2 Renegotiation costs

Direct bargaining costs. Even if we assume concentrated ownership, so that public shareholders' meetings are not required to renegotiate directors' compensation, the costs of renegotiation may be substantial for owners. There will typically be direct costs linked to the bilateral bargaining process between managers and owners, even in the absence of information asymmetries (e.g. Luca Anderlini and Leonardo Felli, 1998). When third parties (e.g. debtholders) have seats on the board the bargaining process becomes trilateral, and direct renegotiation costs increase.

Interlocked directors. Besides direct renegotiation costs, there may be indirect renegotiation costs which increase the commitment power to "conservative" managerial incentives. One of these kinds of costs is linked to interlocked directors. Kevin Hallock (1997) finds that 20 to 30% of U.S. firms have interlocked boards of directors, in the sense that they have a manager or a director sitting on each other's board. Note that this figure does not include interlocks realized through different directors who represent a single interest (say, the same large bank). One would expect interlocks between competing firms to be forbidden, as it is too obvious that common directors would facilitate collusion, for example through information sharing and coordination activities. However, in many countries this is not the case.[19] Consider a duopoly with interlocked boards of directors. Interlocked directors enjoy generous salaries and private benefits from both firms, so their objective is a satisfactory (collusive) profitability of both firms that ensures reappointment. Even if secret renegotiation of directors' compensation were possible and no direct or indirect costs of renegotiation were there, any director could unilaterally veto the secret renegotiation of managerial contract by threatening to make it public. Therefore, all directors must be fully compensated for the expected losses (of bonuses, wage, private benefits) which they incur after renegotiation because of firms' bad performance in the non-cooperative phase that follows a breach of the collusive agreement. This means that, to obtain (secret) renegotiation, interlocked directors must also be compensated for the losses which they incur because of the competing firm's low performance caused by a deviation. This extra cost of renegotiation, due to common directors' partial internalization of competing firms' market externalities, makes managers'/directors' incentives a credible commitment device.

The community of managers and directors. Another kind of indirect renegotiation cost has to do with the ability of the "top-managers' community" to enforce cooperative behavior between their members. The "top-managers' community," particularly in smaller countries, is a network whose members interact in various kinds of "cooperative" activities. One is wage-busting. For example, Kevin Hallock (1997) shows that when firms are interlocked managerial compensation goes up. That is, managers treat each other well. Another is unemployment insurance. CEOs fired from a firm are often hired as managers or directors of competing firms. One reason for this is, of course, the inside knowledge about the competitor that the fired manager brings along. Another reason, however, is the "mutual non-market insurance" against unemployment which the managers' community provides for its members. A breach of a collusive agreement by one manager induced by the secret renegotiation of his contract damages other managers in the industry, and may be punished by the "managers' community" through the interruption of wage-busting and unemployment insurance provisions. The loss of colleagues' support can reduce the deviating manager's expected wage after the deviation. Then the manager would require compensation for this additional loss at the renegotiation stage. These extra costs, by reducing overall

[19] Giovanni Ferri and Sandro Trento (1997) find that interlocking directors between large banks is a very common and rapidly increasing phenomenon in Italy. They give the example of Ugo Tabanelli, director and vice-chairman of Banco di Santo Spirito between 1960 and 1985, who in the same period of time had been simultaneously sitting on the boards of 4 of its main competitors: Banca di Roma, Credit, Comit, and Mediobanca.

gains from deviation, give commitment value to managerial incentives.[20]

5.2.3 Free secret renegotiation

Even if secret and costless renegotiation were possible, there are other arguments in support of a "collusion" explanation for the diffusion of low-powered managerial incentives and of income-smoothing practices.

Coordination and stabilization. Many economists believe that the incentive compatibility conditions for tacit collusion (inequality (1) in our model) are easily satisfied in most real-world oligopolistic industries (e.g. Carl Shapiro, 1989). If this is true, then if tacit collusion is not sustained in all mature oligopolistic industries it is only because of coordination failures.[21] Then, the pro-collusive functions of the separation of ownership and control with low-powered incentives that lead to income smoothing are (a) to facilitate coordination and (b) to stabilize the collusive agreement. As seen in previous sections, target profit levels for bonuses and replacement rules are powerful coordination instruments which enable owners to eliminate less profitable collusive agreements from the equilibrium set. Also, CEOs have typically a more homogeneous background than shareholders, they are professionals with similar educations and careers, and this may further facilitate coordination. On the other hand, even when the owners' discount factor is such that (1) is satisfied there exist positive short-run gains from deviating. Delegation of control to managers with capped incentives removes all short-run gains from deviations, making the profitable agreement more stable. Then renegotiation has no bite, as owners themselves are not interested in unilaterally breaking the collusive agreement.

Bounded rationality and evolution. Even if secret and costless renegotiation were available to investors and condition (1) were not satisfied, the pro-collusive effect of low-power incentive schemes might still have driven their diffusion. The idea of fully rational economic agents is nowadays considered a myth by many economists. Of course, even though agents are not fully rational, efficient institutions, such as "as if"

[20]The effect of the loss of reputation within the managers' community is stronger the shorter the length of managers' contracts is. In the case of short-term contracts the manager can be fired – and therefore suffers the reservation wage loss right from the period after the deviation. With long-term contracts the owner is committed to keeping the manager at the pre-deviation reservation wage, so that unemployment insurance is less valuable to managers. But even very long-term contracts are normally of limited length compared to the length of a manager's career. Bankruptcy, takeovers, and other unforeseen events may interrupt the long-term contract between an owner and the manager, in which case colleagues' support becomes important. Knowing this, the manager will always require some extra compensation to "betray" his colleagues, which gives commitment value to delegation of control.

[21]Fines from antitrust authorities seem way too small to deter collusion (e.g. McCutcheon, 1997).

rational behavioral rules, may be selected by the evolutionary process of competition... or by that of collusion in oligopolies! Consider boundedly rational investors who select directors' and CEOs' incentives on the basis of their past success in a world dominated by oligopolistic industries. Such investors would not be aware of exactly why choosing "conservative" or "prudent" incentives for managers pays more than choosing aggressive incentives, and will be even less aware that secretly renegotiating incentive contracts might pay more. In the many supergames they have played over time, investors have tried different incentives for top managers, and because of the oligopolistic structure of most real world industries the "conservative" low-powered incentives which Jensen and Murphy observed are those that performed better and survived.[22]

6 Concluding remarks

We are not arguing here that firms' attempts to internalize market externalities is the only force that drives real world economic institutions. For example, as in most previous work on the strategic effects of delegation, we had to abstract from the important issue of managerial moral hazard (just as most of the literature on moral hazard abstracts from the strategic effects of incentive contracts). When moral hazard is brought into the picture, a demand for highly-powered incentives emerges and too low-powered incentives become suboptimal. However, we do believe that the pro-collusive effect of "conservative" managers is one important reason why low-powered incentive schemes and income smoothing have been so widespread in the last decades.

Of course, this theory will be more convincing after being tested on the empirical ground. The two main testable predictions of the model are the following: (1) low-powered managerial incentives, managerial rents, and income smoothing should all be more common in mature oligopolistic industries than in dynamic and competitive ones; (2) within mature oligopolistic industries, markups should be relatively higher in industries where top managers have low-powered incentives or enjoy substantial private benefits of control (or other incumbency rents).

[22] Indeed, managers in our delegation supergame can be seen as automata chosen by owners/players in a "metagame" to play a subsequent supergame, as in the work of Abreu and Rubinstein (1988). Under such an interpretation the capped incentive schemes discussed in Sections 3 and 4 would correspond to automata instructed not to deviate first, to play "nice" strategies. The work of Robert Axelrod (1984) has shown that in the repeated Prisoner's Dilemma, which is isomorphic to repeated oligopoly games, only automata with nice strategies would survive. Ken Binmore and Larry Samuelson (1992) found that if a group of invading automatas could recognize each other with a "secret handshake," then any evolutionary stable outcome must contain a fraction of "nasty" automata who deviate first; however, in the case of managerial incentives group play and "secret handshakes" make no sense, so that Axelrod's original results apply).

7 Appendix

Proof of Proposition 1 To prove the proposition we must show that when – because of managerial control – firms' instantaneous objective function is subject to any strictly concave monotone transformation $U(\pi_i)$ of the profit function $\pi_i(p) = \frac{1}{N}(p-c)Q(p)$, the incentive constraints to support any collusive agreements are relaxed. We first need a simple lemma.

Lemma 3 *The Bertrand equilibrium remains the unique static Nash equilibrium of the stage game when this is played by agents with a strictly concave objective function.*

Proof A strictly concave objective function is a monotone transformation of the profit function. The set of Nash equilibria of a game is not affected by monotone transformations of payoff functions, as these generate ordinally equivalent games. **Q.E.D.**

The lemma makes sure that reversion to the static Bertrand equilibrium remains a credible punishment strategy when managers are running the firms. Now, for any strictly concave increasing objective function $U(\pi_i)$, $U' > 0$, $U'' < 0$, a stationary collusive agreement on price p^* will be supported by firm i if

$$\frac{1}{1-\delta}U[\frac{1}{N}(p^*-c)Q(p^*)] \geq U[(p^*-c)Q(p^*)] + \frac{\delta}{1-\delta}U(0),$$

or, equivalently, if

$$\delta \geq \frac{U[(p^*-c)Q(p^*)] - U[\frac{1}{N}(p^*-c)Q(p^*)]}{U[(p^*-c)Q(p^*)] - U(0)}. \tag{A.1}$$

The concave transformation will always make collusion easier to sustain if the RHS of condition (A.1) is smaller than the RHS of condition (1), i.e. when

$$\frac{U[(p^*-c)Q(p^*)] - U[\frac{1}{N}(p^*-c)Q(p^*)]}{U[(p^*-c)Q(p^*)] - U(0)} < (1-\frac{1}{N}).$$

After a few algebraic manipulations this last inequality leads to

$$U[\frac{1}{N}(p^*-c)Q(p^*)] > U(0) - \frac{1}{N}U(0) + \frac{1}{N}U[(p^*-c)Q(p^*)],$$

and then to

$$U[\frac{1}{N}(p^*-c)Q(p^*) + (1-\frac{1}{N})0] > \frac{1}{N}U[(p^*-c)Q(p^*)] + (1-\frac{1}{N})U(0),$$

which is Jensen inequality, the definition of strict concavity, a property assumed for U. **Q.E.D.**

Proof of Proposition 2 Demand is now an increasing function of the stochastic shock θ, $Q(p,\theta)$. When profit-maximizing owners run the firms, the no-deviation conditions for a collusive agreement to choose a price p^* are

$$\frac{1}{N}(p^* - c)Q(p^*,\theta^H) + \frac{\delta}{1-\delta}\frac{1}{N}(p^* - c)E_\theta\ [Q(p^*,\theta)] \geq (p^* - c)Q(p^*,\theta^H)$$

in periods in which demand is high, and

$$\frac{1}{N}(p^* - c)Q(p^*,\theta^L) + \frac{\delta}{1-\delta}\frac{1}{N}(p^* - c)E_\theta\ [Q(p^*,\theta)] \geq (p^* - c)Q(p^*,\theta^L)$$

in periods in which demand is low, where E is the expectation operator. The conditions can be rewritten as

$$\begin{cases} (1-\frac{1}{N})(p^* - c)Q(p^*,\theta^H) \leq \Pi \\ (1-\frac{1}{N})(p^* - c)Q(p^*,\theta^L) \leq \Pi \end{cases},$$

where $\Pi = \frac{\delta}{1-\delta}\frac{1}{N}(p^* - c)E_\theta\ [Q(p^*,\theta)]$. Given that the two conditions differ only in the demand factors on the LHS, and that $Q(p^*,\theta^H) > Q(p^*,\theta^L)$, the condition is more easily satisfied in low states of demand, and when the discount factor is binding and firms maximize collusive profits, Rotemberg and Saloner's result follows.

Consider instead firms led by income-smoothing managers, with static objective function $U(\pi_i)$, $U'() > 0, U''() < 0$. The conditions now become

$$\begin{cases} U\left[(p^* - c)Q(p^*,\theta^H)\right] - U\left[\frac{1}{N}(p^* - c)Q(p^*,\theta^H)\right] \leq \Pi^U \\ U\left[(p^* - c)Q(p^*,\theta^L)\right] - U\left[\frac{1}{N}(p^* - c)Q(p^*,\theta^L)\right] \leq \Pi^U \end{cases},$$

where $\Pi^U = \frac{\delta}{1-\delta}E_\theta\ \left[U\left[\frac{1}{N}(p^* - c)Q(p^*,\theta)\right]\right]$. When the discount factor is binding and firms maximize collusive profits, price wars during booms do not occur and prices are pro-cyclical when

$$U\left[(p^* - c)Q(p^*,\theta^H)\right] - U\left[\frac{1}{N}(p^* - c)Q(p^*,\theta^H)\right] <$$

$$< U\left[(p^* - c)Q(p^*,\theta^L)\right] - U\left[\frac{1}{N}(p^* - c)Q(p^*,\theta^L)\right]$$

or, equivalently, when

$$U\left[\pi_i^*(\theta^H)\right] - U\left[\pi_i^*(\theta^L)\right] > U\left[N\pi_i^*(\theta^H)\right] - U\left[N\pi_i^*(\theta^L)\right].$$

If we approximate the RHS of this inequality with the Taylor expansion of U around $N\pi_i^*(\theta^L)$ and simplify, we get

$$U\left[\pi_i^*(\theta^H)\right] - U\left[\pi_i^*(\theta^L)\right] > U'\left[N\pi_i^*(\theta^L)\right] N\left[\pi_i^*(\theta^H) - \pi_i^*(\theta^L)\right] - \Delta,$$

with $\Delta > 0$. By inspection, U can always be chosen concave enough to make $U'\left[N\pi_i^*(\theta^L)\right] < \frac{U\left[\pi_i^*(\theta^H)\right]-U\left[\pi_i^*(\theta^L)\right]+\Delta}{N\left[\pi_i^*(\theta^H)-\pi_i^*(\theta^L)\right]}$ and satisfy the inequality. **Q.E.D.**

Proof of Lemma 1 Suppose owner i chooses $B_i, \pi_i^B, \gamma_i > 0$. Then, if the manager of firm i respects a collusive agreement delivering per-period profits $\pi_i^* \geq \pi_i^B$ he receives the discounted future income flow $\frac{\gamma_i g_i(\pi_i^*)+B_i}{1-\delta}$, while if he deviates he obtains $\gamma_i g_i(\widehat{\pi}_i^*)+B_i$ immediately and zero afterwards. It follows that the manager will respect the collusive agreement if

$$\frac{\gamma_i g_i(\pi_i^*) + B_i}{1-\delta} \geq \gamma_i g_i(\widehat{\pi}_i^*) + B_i, \quad \Leftrightarrow \quad \delta \geq \delta^\gamma = \frac{\gamma_i\left[g_i(\widehat{\pi}_i^*) - g_i(\pi_i^*)\right]}{\gamma_i g_i(\widehat{\pi}_i^*) + B_i}.$$

By inspection, when $\gamma_i > 0$, δ^γ is positive and increasing in γ_i. When an owner chooses $B_i, \pi_i^B, \beta_i > 0$, and managers are restricted to choosing $p \geq c$, the static Nash equilibrium of the market game is unchanged and the manager of firm i respects a collusive agreement delivering per-period profits π_i^* if

$$\frac{\beta_i f_i(\frac{p^*Q(p^*)}{N}) + B_i}{1-\delta} \geq \beta_i f_i(cQ(p=c)) + B_i + \frac{\delta\beta_i f_i(\frac{cQ(p=c)}{N})}{1-\delta},$$

or, equivalently, if

$$\delta \geq \delta^\beta = \frac{\beta_i\left[f_i(cQ(p=c)) - f_i(\frac{p^*Q(p^*)}{N})\right]}{\beta_i\left[f_i(cQ(p=c)) - f_i(\frac{cQ(p=c)}{N})\right] + B_i}.$$

Again, by inspection, when $\beta_i > 0$ the minimum discount factor δ^β is positive and increasing in β_i. When an owner chooses both $\gamma_i, \beta_i > 0$ these two effects cumulate and the pro-collusive effect of the bonus is further diluted. The statement follows from this together with Proposition 3. **Q.E.D.**

Proof of Proposition 5. Suppose the realization of θ can be observed by owners with T^O periods of delay, and by courts with T^C periods of delay, where $T^C \geq T^O$ (when θ is the report of an independent agency, T^C is the lag with which the reports are made). Consider the following compensation contract: in each period the manager gets a wage plus a bonus $B_i > 0$ if $\pi_i(\theta) \geq \pi_i^B(\theta)$, but the bonus is paid to the manager with T^C periods of delay and increased market interests to compensate for it. If owners break the contract managers can go to court $T^C - T^O$ periods afterwards and be compensated (therefore owners will respect the agreement). Then the rest of the proof is identical to that of Proposition 3 (in Section 3.1) after having replaced π_i^B by $\pi_i^B(\theta)$, π_i^* by $\pi_i^*(\theta)$, $\widehat{\pi}_i^*$ by $\widehat{\pi}_i^*(\theta)$, π_i^M by $\pi_i^M(\theta)$, $\widehat{\pi}_i^M$ by $\widehat{\pi}_i^M(\theta)$, and interpreting B_i as the present value of the payment obtained T^C periods later. **Q.E.D.**

Proof of Proposition 6 (i) Consider first the second stage. Suppose all managers have been hired under bonus contracts, with $B > 0$ and $\pi_i^B = \pi_i^M(\theta^H)$. Then by the proof of Proposition 3 follows that whatever the discount factor managers can support any price rule $\pi_i^*(\theta)$ such that $\pi_i^*(\theta^H) = \pi_i^M(\theta^H)$ and $\pi_i^*(\theta^L)$ is such that $\widehat{\pi}_i^*(\theta^L) < \pi_i^M(\theta^H)$. This is because in equilibrium managers receive bonuses in all high states, while a deviating managers gains nothing in the period of the deviation but looses the stream of future bonuses $\frac{\delta q B}{1-\delta}$. When the price rule has $\pi_i^*(\theta^L)$ such that $\widehat{\pi}_i^*(\theta^L) \geq \pi_i^M(\theta^H)$, a manager gains B by deviating from the joint monolpoly price in low states. These kind of unilateral deviations can be deterred only if $B < \frac{\delta q B}{1-\delta} \Leftrightarrow \delta > \frac{1}{1+q}$. It follows that when

$$\widehat{\pi}_i^M(\theta^L) = (p^M - c)Q(p^M, \theta^L) > \frac{(p^M - c)Q(p^M, \theta^H)}{N} = \pi_i^M(\theta^H) = \pi_i^B$$

managers can support the joint monopoly price also in low states of demand only if $\delta > \frac{1}{1+q}$.

Consider now the first stage. An owner can deviate unilaterally from the equilibrium profile by choosing not to delegate control (e.g. setting $B = 0$) or by setting $\pi_i^B \neq \pi_i^M(\theta^H)$. In the first case no collusive agreement can be supported in the second stage, whatever the state of demand is. In the second case, when the owner sets $\pi_i^B > \pi_i^M(\theta^H)$ again no collusive agreement can be supported in the second stage, and when the owner sets $\pi_i^B < \pi_i^M(\theta^H)$ he gains nothing, while he may lose because his manager may settle with a collusive agreement delivering lower profits than $\pi_i^M(\theta^H)$. In all these cases the owner cannot gain by deviating unilaterally.

(ii) Consider first the second stage. Suppose all managers have been hired under bonus contracts, with $B > 0$ and $\pi_i^B = \pi_i^M(\theta^L)$. Then by the proof of Proposition 3 managers can support any collusive agreement A by which in low states firms set the monopoly price so that $\pi_i^A(\theta^L) = \pi_i^M(\theta^L)$, and in high states set any price such that $\pi_i^A(\theta^H) \geq \pi_i^M(\theta^L)$. The exact collusive price that managers will support in high states depends then on φ.

Consider now the first stage, and let us check whether $\pi_i^B = \pi_i^M(\theta^L)$ is a Nash equilibrium for owners. The best that an owner can get by deviating from such a strategy profile, is by setting $\pi_i^B = (p^M - c)Q(p^M, \theta^H) - \frac{N-1}{N}(p^M - c)Q(p^M, \theta^L)$, so that in low profit states collusion cannot be supported but in high states it is, and the only agreement the manager of the deviating owners will set for delivers to the deviating owners per-period profits $(p^M - c)Q(p^M, \theta^H) - \frac{N-1}{N}(p^M - c)Q(p^M, \theta^L)$, where

$$(p^M - c)Q(p^M, \theta^H) - \frac{N-1}{N}(p^M - c)Q(p^M, \theta^L) > \frac{(p^M - c)Q(p^M, \theta^H)}{N} > \frac{(p^M - c)Q(p^M, \theta^L)}{N}.$$

If this deviation is not profitable, no other deviation is. This unilateral deviation is profitable only if

$$\frac{q\left[N\pi_i^M(\theta^H)-(N-1)\pi_i^M(\theta^L)\right]}{1-\delta}>\frac{q\varphi\pi_i^M(\theta^H)+(1-q)\pi_i^M(\theta^L)}{1-\delta}$$

or, equivalently, if

$$\varphi<\frac{q\left[N\pi_i^M(\theta^H)-(N-1)\pi_i^M(\theta^L)\right]-(1-q)\pi_i^M(\theta^L)}{q\pi_i^M(\theta^H)}.$$

When $\frac{1-q}{q}>\frac{(N-1)\left[(p^M-c)Q(p^M,\theta^H)-(p^M-c)Q(p^M,\theta^L)\right]}{(p^M-c)Q(p^M,\theta^L)}$ the RHS of this inequality is smaller than one. Then, for any φ such that

$$1\geq\varphi\geq\widetilde{\varphi}=\frac{q\left[N\pi_i^M(\theta^H)-(N-1)\pi_i^M(\theta^L)\right]-(1-q)\pi_i^M(\theta^L)}{q\pi_i^M(\theta^H)}$$

the owners' deviation is not profitable and all owners setting $\pi_i^B=\pi_i^M(\theta^H)$ is a Nash equilibrium of the first stage game between owners. Furthermore, as long as $1>\varphi\geq\widetilde{\varphi}$ managers can support collusion all states, but they can support the monopoly price only in low states. The statement follows. **Q.E.D.**

Proof of Proposition 7 Consider the following strategy profile for N owners and N managers.

Each owner's strategy: "Delegate to a manager under short-term bonus contract with total compensation above his reservation wage and $\pi_i^B=\pi_i^M$; in Step 1 of each following period reconfirm the manager and contract for one more period if in all previous periods all owners delegated and $\pi_i\geq\pi_i^B$; take back control or hire a profit-maximizing manager at his reservation wage forever otherwise."

Each manager's strategy: "In Step 2 of each period t, stick to any agreed collusive price delivering per-period profits $\pi_i\geq\pi_i^B$ for every firm i if *(a)* all owners delegated followed equilibrium strategies in Step 1 of all past periods and in t, and if (b) no manager ever deviated from the agreed collusive price; maximize firm profits otherwise."

To save on notation, set $W_i=R$ so that the bonus $B_i>0$ also denotes the amount of collusive rent left to the manager (the relative sizes of W_i and B_i are strategically irrelevant), and consider the joint monopoly price p^M delivering per-period profits $\pi_i^M=\pi_i^B$ to each firm i. Let us check for unilateral deviations in any period t.

Owners: If an owner sticks to equilibrium strategies he expects net profits $\frac{\pi_i^M-B_i}{1-\delta}$, which are always positive (to satisfy his individual rationality constraint he must have set $B_i\leq\pi_i^B\leq\pi_i^M$). An owner can deviate in Step 1 by choosing $\pi^B>\pi^M$, $\pi^B<\pi^M$, by hiring a profit-maximizing manager (e.g. setting $B=0$), or (equivalently) by not delegating control. When $\pi_i^B > \pi_i^M$ the only way the manager can get the bonus is by deviating unilaterally from a collusive agreement, and because this is common knowledge no agreement can be sustained. If an owner deviates by choosing $\pi_i^B < \pi_i^M$ he cannot gain, but he can lose since even though managers can support collusion in the second stage, his manager may settle with a collusive agreement delivering profits π_i^* with $\pi_i^B \leq \pi_i^* < \pi_i^M$. When the owner deviates by choosing $\pi^B < \pi_i^M$ the manager always gets the bonus and, being indifferent, always deviates to maximize owner's profits. When an owner deviates by retaining control or hiring a profit-maximizing manager, he or his manager deviates in Step 2 because condition (1) is not satisfied. However he deviates in Step 1, other players learn that in Step 2 he (or his manager) will deviate from the collusive agreement, so that in the period of the deviation all managers maximize profits and the Bertrand outcome occurs. Because we always have $\frac{\pi_i^M - B_i}{1-\delta} \geq 0$, no owner will find it convenient to deviate unilaterally, whatever the discount rate is.

Managers: As for long-term contracts, if a manager deviates he gains nothing, but he loses the stream of future bonuses $\frac{B_i}{1-\delta}$. It follows that as long as $B_i > 0$ owners will not deviate unilaterally, whatever the discount rate is. **Q.E.D.**

Proof of Proposition 8 The proof is analogous to the proof of Proposition 7 above, after reinterpreting variables by letting B_i denote a manager's private benefits of control and π_i^B the cut-off level of profit below which the manager is replaced. The only (strategically irrelevant) difference is – when checking for unilateral deviations on the side of the managers – that here when a manager deviates he loses the stream of future bonuses $\frac{\delta B_i}{1-\delta}$ instead of $\frac{B_i}{1-\delta}$, as the deviating manager is retained – and enjoys private benefits – for one more period after the deviation occurs. **Q.E.D.**

Proof of Lemma 2 For the case of a short-term bonus contract the proof is identical to the proof of Lemma 1. Consider instead the case of incumbency rents with replacement rules. Suppose the equilibrium selected by owners and supported by the equilibrium strategy profile described in the proof of Proposition 7 has ($W_i = R = 0$ and) $B_i, \pi_i^B, \gamma_i > 0$. Then, if the manager of a firm i respects a collusive agreement delivering per-period profits $\pi_i^* \geq \pi_i^B$ he receives the discounted future income flow $\frac{\gamma_i g_i(\pi_i^*)+B_i}{1-\delta}$, while if he deviates he obtains $\gamma_i g_i(\widehat{\pi}_i^*)+B_i$ immediately, B_i the next period ($\widehat{\pi}_i^* > \pi_i^* \geq \pi_i^B$, therefore the manager is reappointed for one more period after the deviation), and zero afterwards. It follows that the manager will respect the collusive agreement if

$$\frac{\gamma_i g_i(\pi_i^*) + B_i}{1-\delta} \geq \gamma_i g_i(\widehat{\pi}_i^*) + B_i + \delta B_i \Leftrightarrow \delta \geq \frac{\gamma_i \left[g_i(\widehat{\pi}_i^*) - g_i(\pi_i^*)\right]}{\gamma_i g_i(\widehat{\pi}_i^*) + \delta B_i}.$$

As in the proof of Lemma 1, for $\gamma_i > 0$ the RHS is positive and increasing in γ_i, as when differentiating the RHS and rearranging we obtain

$$\frac{\partial RHS}{\partial \gamma_i} = \frac{\left[g_i(\widehat{\pi}_i^*) - g_i(\pi_i^*)\right] \delta B_i}{\left[\gamma_i g_i(\widehat{\pi}_i^*) + \delta B_i\right]^2} > 0.$$

When an owner chooses $B_i, \pi_i^B, \beta_i > 0$, his manager respects a collusive agreement delivering per-period profits π_i^* if

$$\frac{\beta_i f_i(\frac{p^* Q(p^*)}{N}) + B_i}{1-\delta} \geq \beta_i f_i(cQ(p=c)) + B_i + \delta B_i,$$

or, equivalently, if

$$\delta \geq \frac{\beta_i \left[f_i(cQ(c)) - f_i(\frac{p^* Q(p^*)}{N})\right]}{\beta_i f_i(cQ(c)) + \delta B_i}.$$

When $\beta_i > 0$ the RHS of this inequality is positive and increasing in β_i. Again, when (at least) one owner chooses both $\gamma_i, \beta_i > 0$, these two effects cumulate and the pro-collusive effect of private benefits is further diluted. The statement follows from this together with Proposition 8. **Q.E.D.**

Proof of Proposition 10: With long-term contracts in the second-stage market supergame, managers under the mixed incentive contract sustain the joint monopoly collusive agreement if

$$\frac{\rho_i \left(\alpha_i^{FJS} \pi_i^M + (1-\alpha_i^{FJS}) S_i(q_i^M)\right) + (1-\rho_i) B}{1-\delta} \geq \rho_i \left(\alpha_i^{FJS} \widehat{\pi}_i^M + (1-\alpha_i^{FJS}) S_i(\widehat{q}_i(q_{-i}^M))\right) +$$

$$+ (1-\rho_i) B + \frac{\delta}{1-\delta}\left[\rho_i \left(\alpha_i^{FJS} \pi_i^{FJS} + (1-\alpha_i^{FJS}) S_i^{FJS}\right)\right],$$

which reduces to

$$\delta \frac{(1-\rho_i) B}{1-\delta} \geq \rho_i \left(\alpha_i^{FJS} \widehat{\pi}_i^M + (1-\alpha_i^{FJS}) S_i(\widehat{q}_i(q_{-i}^M))\right) - \rho_i \left(\alpha_i^{FJS} \pi_i^M + (1-\alpha_i^{FJS}) S_i(q_i^M)\right).$$

By inspection, for any $\left(\alpha_i \widehat{\pi}_i^M + (1-\alpha_i) S_i(\widehat{q}_i(q_{-i}^M))\right) - \left(\alpha_i \pi_i^M + (1-\alpha_i) S_i(q_i^M)\right)$ and for any δ there is a level $\underline{\rho}$ such that when $\rho_i, \rho_j \leq \underline{\rho}$ the incentive constraint is satisfied and managers sustain the joint monopoly collusive agreement.

Consider now the first-stage delegation game among owners, and let us check whether the mixed contract is an equilibrium strategy. If both owners choose the prescribed mixed contracts, managers sustain collusion and owners share monopoly profits. If owner i deviates by choosing a managerial contract that leads manager i to deviate from the collusive agreement (that is, chooses $\rho_i > \underline{\rho}$) manager j observes the choice, realizes that whatever he does he will never get his bonus (or that he will be replaced anyway) and maximizes the FJS-type part of his compensation $\alpha_j^{FJS}\pi_j + (1-\alpha_j^{FJS})S_j$ only. This leads both managers to maximize the FJS part objective function in the second stage, so both firms obtain $\pi_i^{FJS} = \pi_j^{FJS}$ in the period of the deviation. It follows that deviating is not profitable, and that even when owner i deviates by choosing parameters that lead manager i to deviate, sticking to the equilibrium contract is an optimal strategy for owner j. If owner i deviates by choosing a managerial contract that does not lead to a deviation (for example chooses $\rho_i = 0$) collusion is sustained and owner j still loses nothing by sticking to the equilibrium contract.

The case of short-term contract is analogous. When collusion is supported by the strategy profile described in the proof of Proposition 7, each owner cannot gain unilaterally deviating from by delegating control to the manager under a short-term mixed incentive contract. And such a contract allows the manager to sustain the joint monopoly collusive agreement while, as shown above, it protects the owner from the competing owner's deviation with FJS-type managerial incentives. **Q.E.D.**

Chapter 3

Essay II

Stock-Related Compensation and Product-Market Competition

Stock-Related Compensation and Product-Market Competition*

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Abstract

This paper shows that as long as the stock market has perfect foresight, some dividends are distributed, and incentives are paid more than once or are deferred, stock-related compensation packages are strong incentives for managers to support tacit collusive agreements in repeated oligopolies. The stock market anticipates the losses from punishment phases and discounts them on stock prices, reducing managers' short-run gains from any deviation. When deferred, stock-related incentives may remove all managers' short-run gains from deviation making collusion supportable at any discount factor. The results hold with managerial contracts of any length.

JEL CLASSIFICATION: D43, G30, J33, L13, L21.

KEYWORDS: CEO compensation, tacit collusion, oligopoly, delegation, managerial incentives, ownership and control, corporate governance.

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1 Introduction

In a highly discussed empirical study, Michael Jensen and Kevin Murphy (1990) showed that until the end of the '80s, and contrary to the predictions of agency theory, U.S. top-managers' compensation had on average a very low pay-performance sensitivity. Steven Kaplan (1994, 1998) found analogous results for other developed countries, such as Germany and Japan. These surprising findings led to concerns about the welfare implications of most common governance practices, since low-powered managerial incentives tend to soften product-market competition (e.g. Rajesh Aggarwal and Andrew Samwick, 1996; Giancarlo Spagnolo, 1996b).

More recently, Brian Hall and Jeffrey Liebman (1998) have shown that the pay-performance sensitivity of U.S. top-managers' compensation has increased substantially in the last decade, mainly because of a widespread adoption of stock-related incentives, such as stock options plans. Stock-based managerial incentives are believed to be a powerful tool by which owners can motivate managers to work hard, to take risks, and to take into account the long-run effects of their choices (e.g. investments) on firms' profitability.[1] What about their effects on product markets? Does this trend towards stock-based incentives imply a more competitive attitude on the part of managers, so that concerns about tacit collusion and social welfare can be abandoned at least in the U.S.?

The results of this paper suggest that, unfortunately, this is not quite the case. Our model shows that as long as agents in financial markets have rational expectations and firms pay out dividends, most common stock-based managerial compensation plans greatly facilitate tacit collusion in long-run oligopolies. We find that stock-related compensation reduces managers' incentives to break any tacit agreement in any repeated oligopoly, and may make the joint monopoly agreement supportable at any level of the discount factor.

The phenomenon of tacit collusion in long-run oligopolies has been fruitfully studied in the last three decades within a discounted repeated games framework.[2] However, most classical supergame-theoretic analyses of collusion confined themselves to the standard assumption that firms maximize the discounted sum of expected per-period profits. In the real world many interacting factors affect firms' objective function, and consequently firms' ability to collude. Among these factors the most important are probably managerial incentives.[3]

[1] See, for example, Sanjai Bhagat *et al.* (1985); Kevin Murphy (1985); Matthew Jackson and Edward Lazear (1991); Myron Scholes (1991); Bengt Holmström and Jean Tirole (1993).

[2] Classical references include James Friedman (1971); Robert Aumann and Lloyd Shapley (1976); Ariel Rubinstein (1979); Edward Green and Robert Porter (1984); Drew Fudenberg and Eric Maskin (1986); Julio Rotemberg and Garth Saloner (1986); Dilip Abreu (1986, 1988).

[3] This was recognized early by scholars interested in firm behavior. See Herbert Simon (1957); William Baumol (1958); Richard Cyert and James March (1963); Robin Marris (1964); Oliver

A number of authors have already explored the strategic effects of delegating decision power to managers with preferences/incentives different from those of owners in oligopolies (e.g. John Vickers, 1985; Chaim Fershtman, 1985; Fershtman and Kenneth Judd, 1987; Steven Sklivas, 1987; Fershtman, Judd and Ehud Kalai, 1991; Michael Katz, 1991; David Reitman, 1993). Most contributions to this literature focus on the strategic effects of managerial incentives in two-stages models, where owners simultaneously choose their managers' incentive schemes before a one-shot oligopolistic market interaction between manager-led firms. In Fershtman and Judd (1987) and Sklivas (1987) (FJS from now on), firm owners can precommit to a more aggressive market behavior by choosing the parameters of a managerial contract that is linear in profits and sales revenue. In the case of quantity competition, the simultaneous attempts to gain a strategic advantage by precommitting through managerial incentives offset one another and lead to higher output and lower profits than in the standard Cournot-Nash equilibrium.

In probably the closest paper in spirit to the present one, Reitman (1993) has shown that if one lets owners introduce stock options in an FJS-type model, these may curb managers' overly aggressive behavior and bring back the original Cournot-Nash equilibrium. This result is due to the non-linearity of stock options in stock price, which induces a discontinuity in managers' best response function and generates other equilibria than the FJS one. The Pareto-dominant among the symmetric equilibria corresponds to the no-delegation Cournot-Nash equilibrium, so that if managers coordinate on this equilibrium the "delegation Prisoner's Dilemma" identified by FJS disappears and, eventually, the ability to precommit through managerial incentives does not affect the outcome of the Cournot game.

We depart from previous work on strategic delegation in oligopolies by allowing for repeated interaction, so that tacit collusion can be analyzed with the tools of repeated games. One could say, therefore, that the results of this paper originate from the repetition of the FJS-Reitman model.

We focus on stock-based compensation plans as usually designed in the real world according to Stacey Kole's (1997) empirical findings. These plans are typically quite liquid (when not in cash, they have few restrictions on resale or transfers of shares) and pay managers stock-based bonuses for several consecutive years.

The pro-collusive effect that we identify is linked to the fact – forcefully stressed by Bengt Holmström and Jean Tirole (1993) – that the stock price incorporates additional information with respect to a firm's profits, information strictly related to the firm's future profitability. Incentive schemes based on stock price link managers' *present* compensation to the stock market's expectations about *future* firms' profitability. When a breach of a tacit collusive agreement occurs, a stock market with rational expectations anticipates the negative effect of the breach on firms' future

Williamson (1964); Michael Jensen and William Meckling (1976).

profitability linked to the forthcoming price-quantity war, and immediately discounts it on stock price (for a real world example see e.g. Jonathan Laing, 1997). Because this effect occurs in the very same period in which a manager deviates from a collusive agreement, incentives linked to stock price directly reduce managers' short-run gains from deviation.

Furthermore, we find that when stock-based incentives are deferred, as they often are in reality, the first pro-collusive effect is reinforced by the fact that the already limited beneficial effect on the stock price of short-run profits from a unilateral deviation may be completely gone at the time when the manager receives the bonus. Then, the manager is left with no incentive whatsoever to deviate, which further stabilizes collusive agreements.

Interestingly, we also find that these pro-collusive effects of stock-based managerial incentives are not reduced, and may even be increased when managerial contracts are short-term.

Although this paper is close in spirit to Reitman (1993), the effects identified here are very different from the effect discussed there. Both the "expectations effect" and the "deferred incentives effect" are not linked to the non-linearity of stock options; they apply to any form of managerial compensation that is positively related to stock price. Further, the effects of managerial incentives discussed here have a strong impact on the equilibrium outcome of the oligopoly game. For example, in our model when owners delegate control to managers under deferred stock-related incentives, the joint monopoly outcome becomes supportable even when, without delegation, owners could not support any collusive agreement. Moreover, the results in this paper are not specific to Cournot competition; they extend to any other kind of repeated oligopoly.

We follow the literature on strategic delegation in assuming observable and binding managerial incentives. This assumption has been criticized on the ground of its robustness with respect to *secret* renegotiation (Mathias Dewatripont, 1988; Michael Katz, 1991). However, as is also made clear by Reitman (1993), for the case that we are focusing on this assumption is close to reality. The adoption of stock-based managerial incentive plans, such as stock options, normally requires shareholders' approval. Shareholders' approval must be obtained in open shareholders' meetings, and these make stock-based incentives and their renegotiation almost public information.[4]

Finally, the results of this paper are related to, but well distinct from those in Fershtman, Judd, and Kalai (1991), Michele Polo and Piero Tedeschi (1992), and Aggarwal and Samwick (1996). Fershtman, Judd, and Kalai (1991) obtain a full "folk theorem" for two-stage observable delegation games by using "target compensation

[4]Consider, for example, the recent world-wide discussions on the stock-option plan in Walt Disney's management's new compensation package. The results of this paper would be of interest even if secret renegotiation were possible, as the *costs* typically linked to contract renegotiation would still give commitment value to managerial incentives (see the discussion in Section 6.7).

functions" that award agents a fixed prize as long as managers keep principal's utility above a certain level. Michele Polo and Piero Tedeschi (1992) and Aggarwal and Samwick (1996) obtain cooperative outcomes in two-stage delegation games by allowing managerial contracts to be related to competing firms' profits. Here we work with repeated oligopoly models, instead, and we obtain full collusion at any discount factor with the empirically observed stock-related managerial incentive plans, which are not target compensation functions and which are conditional on the firm's own stock price only.

The rest of the paper is organized as follows: Section 2 presents the model; Section 3 discusses the pro-collusive effect linked to stock-market expectations; Section 4 considers deferred stock-based incentives; Section 5 discusses the length of managerial contracts; Section 6 extends and discusses the results; and Section 7 briefly concludes. All proofs are in the appendix.

2 The model

2.1 Product market

There are N symmetric firms, indexed by the subscript i. Market structure is a standard Cournot oligopoly (stage game) infinitely repeated in discrete time under complete and perfect information.

Let $\pi_i(q_i, q_{-i}) = P(q_i + q_{-i})q_i - c(q_i)$ denote firm i's static (stage-game's) profit function, where q_i represents firm i's output, q_{-i} the quantity produced by the other N-1 firms, $P(.)$ the inverse demand function and $c(.)$ firms' cost function.

We assume that the inverse demand function satisfies $P' < 0$ and $P'' \geq 0$, that profits are concave in firms' own output, and that marginal profits are decreasing in rivals' output, so that static reaction functions are continuous and downward sloping.

Let $\pi_i^N = \pi_i(q_i^N, q_{-i}^N)$ denote firm i's static (stage-game's) profits when firms produce the Cournot-Nash equilibrium output vector $q^N = (q_1^N, ..., q_n^N)$, $\pi_i^A = \pi_i(q_i^A, q_{-i}^A)$ denote owner i's static payoff from a stationary tacit agreement A to restrict production to the vector $q^A = (q_1^A, ..., q_n^A)$, and $\widehat{\pi}_i^A = \pi_i(\widehat{q}_i(q_{-i}^A), q_{-i}^A)$ denote his static payoffs from unilaterally deviating from A by producing the static best response output $\widehat{q}_i(q_{-i}^A)$. Analogously, $\pi_i^M = \pi_i(q_i^M, q_{-i}^M)$ will denote firm i's profits at the joint monopoly market outcome q^M, and $\widehat{\pi}_i^M = \pi_i(\widehat{q}_i(q_{-i}^M), q_{-i}^M)$ will denote static payoffs from unilaterally deviating from the joint monopoly collusive agreement.

Time is indexed by the superscript $t = 1, 2, 3...$ (the time superscript is absent when we refer to a representative period) and δ denotes the intertemporal discount factor common to all agents, owners and managers. We assume that at each point in time t each agent maximizes the discounted sum of expected monetary gains. So each owner i maximizes the discounted sum of firm i's expected profits $U_i^t = \sum_{\tau=1}^{\infty} \delta^{\tau} \pi_i^{t+\tau}$.

To simplify exposition we focus on stationary collusive agreements enforced by "unrelenting" trigger strategies, that is, by the threat of reverting to the non-cooperative Cournot-Nash equilibrium forever (Friedman, 1971).[5] Also, to make things more interesting, we assume throughout that the discount factor is too low for owners to support the joint monopoly collusive agreement in subgame-perfect equilibrium.

2.2 Financial market

We assume the following.

1. The stock market is perfectly informed, rational, and skilled in game theory: it fully understands equilibria selected in the product market.
2. The value of a firm (of its shares) in one period depends positively upon the discounted profit stream it is expected to generate and on the realized profits which have not yet been distributed as dividends (we assume no physical assets to simplify exposition).
3. At the end of each period realized profits are paid out to shareholders as dividends (but see Section 5.1).

Under these assumptions the price of one share of firm i, P_i^t, at the end of period t before period t's dividends are paid out is

$$P_i^t = V\left[\pi_i^t + E_t\left(\sum_{\tau=1}^{\infty}\delta^\tau\,\pi_i^{t+\tau}\right)\right],$$

where E_t is the expectation operator and V is a continuous and increasing function.

2.3 Managerial contracts

According to Kole (1997), most common stock-based managerial incentive plans are relatively liquid, such as stock options with stock appreciation rights (SARs) or share-performance cash bonuses. In most cases the effect of these incentive plans is deferred and distributed in time, probably to reduce the much advertised risk of costly managerial "short-termism" in investment choices.[6] For example, for stock options the

[5]In Section 6.5 and Appendix 2 we show that the choice of more sophisticated strategies (e.g. finite length, "optimal," or renegotiation-proof punishment strategies) does not affect our conclusions. Also, at the cost of a more cumbersome exposition the results can easily be extended to encompass non-stationary collusive agreements.

[6]See, e.g. MC Narayanan (1985); Jeremy Stein (1989); Lucian Bebchuck and Lars Stole (1993); and John Bizjak *et al.* (1993).

typical vesting schedule includes a "wait to exercise" of 12 months for the first quarter of the award, after which the remainder of the award becomes available in equal installments over the next three years. We will focus mainly on the product-market effects of these more common stock-related incentive plans.[7] We assume the following:

1. Owners can delegate decision power (to profit-maximizing managers or) to managers under observable incentive contracts such that in each period managers receive a wage equal to their reservation wage – both of which we normalize to zero without loss of generality – plus an incentive payment linked to stock price, such as stock options or a cash bonus positively related to stock price.[8]

2. Managers are not required to keep firms' shares; the instant in which they receive their compensation they sell their shares or options in order to diversify their portfolio.

3. In periods in which the manager has no way of gaining from the stock-based part of the compensation, he is indifferent about available actions since they all lead to the same wage. We adopt the standard assumption that in such cases managers choose the action that maximizes the owner's objective function.

4. To skip straightforward comparisons between direct cost (managers' compensation) and benefits (higher collusive profits) of delegation, we assume that managers' reservation wage is smaller than or equal to owners' disutility of running the firm personally.

2.4 Useful benchmarks

Given the common discount factor, any collusive agreement A is sustainable in subgame-perfect equilibrium by owners or profit-maximizing managers as long as discounted expected profits from sticking to the agreement exceed expected profits from deviating, that is,

$$\frac{\pi_i^A}{1-\delta} \geq \widehat{\pi}_i^A + \frac{\delta \pi_i^N}{1-\delta}. \tag{1}$$

[7]Restricted stock awards and stock options plans with restrictions on resale/transfer of the shares are used by a minority of firms. We discuss the product-market effects of these other incentives in Section 6.2 (managerial ownership).

[8]Alternatively, we could have followed Fershtman and Judd (1987) and Reitman (1993) in completely abstracting from the issue of managers' individual rationality constraint by assuming that managers' final compensation is some function $A(W+f(P))$, where W is a wage component and f an incentive component function of stock price. The parameter A can be freely set to reflect conditions on managers' labor market, as managerial behavior is driven by the marginal incentive component $f(P)$ only. The two assumptions are fully equivalent: they lead to identical results and they both simplify exposition by allowing us to focus exclusively on the incentive part of the compensation.

Let $\overline{A}$ denote the "most collusive" symmetric agreement that owners or profit-maximizing managers can support at the given discount factor, the one which makes (1) hold as an equality. We assumed that owners cannot support the joint monopoly collusive equilibrium, so that $\pi_i^{\overline{A}} < \pi_i^M$. Alternatively, one can rephrase (1) in terms of the minimum level of the discount factor $\underline{\delta}^A$ at which owners or profit-maximizing managers can support a given agreement A, that is,

$$\delta \geq \underline{\delta}^A = \frac{\widehat{\pi}_i^A - \pi_i^A}{\widehat{\pi}_i^A - \pi_i^N}. \tag{1'}$$

It is useful to state a simple lemma:

Lemma 1 *The Cournot-Nash equilibrium outcome (the equilibrium outcome of the stage game played by owners or profit-maximizing managers) is also a Nash equilibrium outcome of the stage game played by managers under incentive contracts positively related to stock price.*

The statement follows straightforwardly from the assumptions. In the static interaction, if all other managers choose the Cournot-Nash production level then a manager paid as a function of stock price cannot gain by choosing a different production level: any other choice will reduce the firm's profits, the stock price, and therefore the manager's compensation. This lemma makes sure that the reversion to the static Cournot-Nash equilibrium remains a credible punishment strategy when managers under stock-based compensation are running the firms, and allows us to study the effects of these incentives on firms' ability to collude by plugging managers' compensation function into condition (1).

3 Stock-related compensation, expectations, and collusion

3.1 The general case

Consider the following class of managerial incentive contracts linked to stock price:

Definition 1 ***Incentive contracts class A (ICA):*** *In each period t the manager of firm i receives a compensation positively related to the stock price $f_i(P_i^t)$ – where f_i is* any *monotone and strictly increasing function* – before *period t profits are paid out as dividends.*

Because under ICA-type contracts managers get paid before the distribution of dividends, the value of a share at the time when they receive their compensation is as in the example in Section 2.2. Then, the incentive compatibility condition for a stationary collusive agreement A to be supportable by the manager of firm i under a compensation package of the ICA type is

$$\frac{1}{1-\delta} f_i \left[V \left(\frac{\pi_i^A}{1-\delta} \right) \right] > f_i \left[V \left(\widehat{\pi}_i^A + \frac{\delta \pi_i^N}{1-\delta} \right) \right] + \frac{\delta}{1-\delta} f_i \left[V \left(\frac{\pi_i^N}{1-\delta} \right) \right], \quad (2)$$

where the inequality is strict because of assumption 3 in Section 2.3. We can now state the first result.

Proposition 1 *Suppose firms are led by managers under incentive contracts in the class ICA. Then, the minimum discount factor at which any collusive agreement can be supported in subgame-perfect equilibrium is strictly lower than when firms are led by owners or profit-maximizing managers. Conversely, for a given discount factor more profitable collusive agreements become supportable when firms are led by managers under incentive contracts in the class ICA.*

The intuition behind this result is the following. The short-run incentive to deviate from any collusive agreement is lower for a manager under an ICA-type contract than for a profit-maximizing one because the value of the shares of a firm that deviates from a collusive agreement does not increase as much as short-run profits in the period in which the deviation occurs. This is because, as noted by Holmström and Tirole (1993), the stock price contains more information than accounting profits, and in the case of a deviation the additional information is about the forthcoming punishment phase, that is, bad news. The stock market forecasts that the deviation will be followed by a production war leading to a period of low profits and adjusts firms' stock prices accordingly. Therefore a negative effect of the punishment phase occurs on (deviating and non-deviating) managers' compensation already in the *same* period in which the deviation occurs. In addition, expected stock price and related bonuses in the periods that follow the deviation are low because gains from deviation are distributed and per-period profits are depressed by the punishment phase. These effects make managers under stock-related compensation more prone to collude than owners or profit-maximizing managers.

3.2 Stock options

To make our result more concrete, we consider the case of the most popular type of managerial incentives related to stock price, namely stock option plans. Also, stock options are not strictly increasing functions of the stock-price, since for all strike prices above the stock price the value of the option is constant and equal to zero. Therefore we could not simply apply Proposition 1 to this case.

Definition 2 ***Incentive contracts class $A_{\underline{P}}$ ($ICA_{\underline{P}}$):*** *In each period t the manager receives the right to buy a number γ_i of shares at a predetermined price $\underline{P}_i$, both of which are constant across time periods,* before *period t profits are paid out as dividends.*

Again, because under these contracts managers get paid before the distribution of dividends, the value of a share at the time when they can cash their stock options includes that period's profits. Then the incentive compatibility condition for a stationary collusive agreement A to be supportable by the manager of firm i under a compensation package of the ICA$_{\underline{P}}$ type is

$$\begin{aligned}\frac{1}{1-\delta}\max\left\{\gamma_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i\right],0\right\} \;>\; & \max\left\{\gamma_i\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\} + \\ & +\frac{\delta}{1-\delta}\max\left\{\gamma_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\},\end{aligned} \quad (3)$$

where the inequality is strict because of assumption 3 in Section 2.3. In each period the stock options are "in the money" (valuable) if the price of the shares P_i^t at the end of the period is higher than $\underline{P}_i$. Then we can state a result analogous to Proposition 1.

Corollary 1 *Suppose firms are led by managers under incentive contracts in the class $ICA_{\underline{P}}$, with $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$, $\forall i$. Then, the minimum discount factor at which any collusive agreement delivering per-period profits π_i^A can be supported in subgame-perfect equilibrium is strictly lower (and, for a given discount factor, more profitable collusive agreements become supportable,) than when firms are led by owners or by profit-maximizing managers.*

Again, the intuition is that the short-run incentive to deviate from any collusive agreement is lower for a manager under an ICA$_{\underline{P}}$-type contract because the stock market forecasts the production war that follows a deviation and adjusts firms' stock price accordingly, anticipating the negative effects of the punishment during the same period in which the deviation occurs. One can also state the following corollary.

Corollary 2 *Suppose the repeated oligopoly game is played by managers under $ICA_{\underline{P}}$-type contracts. Then, the minimum discount factors at which any collusive agreement can be supported in subgame-perfect equilibrium is independent of γ_i and is maximized when $\underline{P}_i \leq V\left(\frac{\pi_i^N}{1-\delta}\right)$, $\forall i$.*

As before, a corresponding statement holds for the most profitable agreement supportable at a given discount factor. The corollary implies that the pro-collusive effect is stronger when the strike price is so generous that stock options are valuable whatever collusive equilibrium is chosen. It is easier to understand the intuition behind this conclusion by looking at condition (3). By increasing the strike price over $\underline{P}_i = V\left(\frac{\pi_i^N}{1-\delta}\right)$ owners reduce the value of stock options in periods in which they are "in the money," therefore they reduce managers' expected gains from cooperation (LHS of (3)) and one-period gains from deviation (first member of the RHS of (3)). However, managers' payoffs from the punishment phase (second member of the RHS of (3)) are not affected by such a change. Because the fall of gains from cooperation is protracted in time, it dominates the fall of one-period gains from deviation, making collusion harder to sustain. Instead, reductions of the strike price below $\underline{P}_i = V\left(\frac{\pi_i^N}{1-\delta}\right)$ increase both sides of condition (3) at the same rate and leave managers' incentive constraint unaffected.

4 Deferred stock-related compensation

4.1 The general case

Consider now a slightly different class of contracts, by which in each period managers receive their stock-related bonuses only after having distributed that period's profits as dividends.

Definition 3 ***Incentive contract class B (ICB):*** *In each period t the manager receives a compensation positively related to stock price $f_i(P_i^t)$ – where f_i is any monotone and strictly increasing function –* after *period t profits are paid out as dividends.*

Because managers get paid after the distribution of dividends, the value of the shares when they cash their options does not incorporate present profits π_i^t. When managers under ICB-type contract cash their bonuses the stock price is therefore:

$$P_i^t = V\left[E_t\left(\sum_{\tau=1}^{\infty}\delta^\tau\,\pi_i^{t+\tau}\right)\right].$$

Also, consider stock-related incentive plans such that managers can cash the bonuses only some time after having left the firm. This form of compensation is often introduced to avoid managers (who may be planning to leave the firm) taking actions against the long-run interest of shareholders in order to improve their short-run market valuation, and to maintain an incentive for managers close to retirement to work hard. To keep things simple we assume that managers face a constant per-period probability $(1-\eta)$ of leaving the firm (because of a take-over, say, or because they find a better job).

Definition 4 ***Incentive contract class C (ICC):*** *In each period the manager receives a wage, which we normalize to zero, and in the period after he stops working for the firm, say τ periods after he started, he receives additional compensation positively related to stock price $(1+r)_i^\tau f_i(P_i^\tau)$ – where f_i is any monotone increasing function and $\frac{1}{1+r} = \delta$.*

Then one can state the following result.

Proposition 2 *Suppose firms are led by managers under incentive contracts in the class ICB or ICC. Then, the joint monopoly collusive agreement can be supported in subgame-perfect equilibrium at any level of the discount factor.*

The intuition behind the proposition is somewhat analogous to that behind Proposition 1, but here the mechanism is taken at its extreme consequences. For a manager under contracts in class ICB or ICC there is no incentive whatsoever to deviate from collusion. After short-run profits from a deviation from a collusive agreement are paid out as dividends, the price of the shares of the deviating firm (and therefore its manager's compensation) depends *only* on stock market expectations about the firm's future profitability, and therefore it falls. Managers under contracts in the classes ICB and ICC incur a net loss when they deviate from a collusive agreement without ever being able to capture any of the short-run gains from deviating.[9]

4.2 Stock options

Consider now stock option plans with deferred realization.

Definition 5 ***Incentive contract class $B_{\underline{P}}$ (ICB$_{\underline{P}}$):*** *In each period t the manager receives the right to buy a number γ_i of shares at a predetermined price $\underline{P}_i$, both of which are constant across time periods,* after *period t profits are paid out as dividends.*

Because managers get paid after the distribution of dividends, the value of the shares when they cash their stock options does not incorporate present profits π_i^t. Also, consider stock option plans such that managers can exercise the options only some time after retirement. Again, we assume that in every period the manager faces a constant probability $(1-\eta)$ of leaving the firm.

[9]Note that nothing changes if managers under ICC-type contracts know exactly when they will stop working for their firms. What is important is that, after managers have left, firms go on producing so that stock market expectations about future firms' profitability can influence the leaving managers' compensation through stock prices.

Definition 6 ***Incentive contract class $C_{\underline{P}}$ ($ICC_{\underline{P}}$):*** *In each period the manager receives a flat wage, which we normalized to zero, and in the period after he stops working for the firm, say τ periods after he started, the manager receives a number of stock options $\gamma_i(1+r)^\tau$ - where $\frac{1}{1+r} = \delta$ - with a strike price $\underline{P}_i$, with γ_i and $\underline{P}_i$ constant across time periods.*

Then one can state what follows.

Corollary 3 *Suppose the repeated oligopoly game is played by managers under incentive contracts in the class $ICB_{\underline{P}}$ or $ICC_{\underline{P}}$, with $\underline{P}_i < V\left(\frac{\pi_i^M}{1-\delta}\right)$, $\forall i$. Then, the joint monopoly collusive agreement can be supported in subgame-perfect equilibrium at any level of the discount factor.*

The intuition behind this result is fully analogous to that behind Proposition 2.

5 On the length of managerial contracts

In the previous sections managers where implicitly assumed to have an infinite horizon, as the firm. Although managers do tend to stay with one firm for long periods, in reality managerial contracts are seldom life-long. In this section we want to show that the results in the previous sections hold independently of the length of the explicit managerial contract. To do this, we assume here that managerial contracts last a finite number of periods T. In this case every T periods owners must decide whether to reconfirm the current manager and his incentive contract or to replace them. This situation can be modelled as a repeated game whose stage game is composed of several consecutive steps. To simplify exposition we assume that all managers' contracts last the same number of periods T and are signed (and expire) simultaneously. It will become clear below that the results of this section are not dependent on these simplifying assumptions. To make the model treatable and the results more clear-cut, we also assume that when owners or profit-maximizing managers are in control no collusive agreement can be supported.

Assumption δ : *For any collusive agreement A, it holds that $\delta < \underline{\delta}^A = \frac{\widehat{\pi}_i^A - \pi_i^A}{\widehat{\pi}_i^A - \pi_i^N}$.*

The stage game of the oligopoly supergame will now be composed of $T+1$ steps. The timing of a stage game beginning in a period t will be as follows.

Stage game t

- Step 1: Owners choose whether to delegate control and managers' incentive contracts.
- Steps 2 to $T+1$: All players observe the outcome of the previous step, then players in control choose output levels.

In other words, in Step 1 of each stage game each of the owners simultaneously decides whether to delegate or reconfirm control to a manager, and if he does it he also chooses the manager's incentive contract for the T following periods. If delegation occurs in Step 1, then starting from Step 2 the manager chooses output in T consecutive static Cournot market interactions; otherwise, the owner does it. This means that a new stage game will only begin every $T+1$ periods.

We can now state the following result.

Proposition 3 *Any collusive agreement supportable in subgame-perfect equilibrium by managers under life-long stock-related incentive contracts can be supported in equilibrium by managers under stock-related incentive contracts of any finite length T.*

That is, the pro-collusive effects linked to stock-market expectations and deferred incentives identified in Sections 3 and 4 apply independently of the length of managerial contracts. This is because, even when explicit managerial contracts last a finite number of periods, owners and managers are free to agree on *implicit* employment contracts with each other, which are long-term by definition (Bentley MacLeod and James Malcomson, 1989; Lorne Carmichael, 1989). On the side of managers, the negative effects of stock-based incentives on short-run gains from deviations highlighted in Sections 3 and 4 remain when managerial contracts are short-term. Regarding owners, they have no incentive to renege on implicit contracts that lead their manager to sustain collusion, since changes of management or incentives are observable and other firms' managers can react before any short-run gain from deviation can be realized. This is also why the proposition can easily be proved to hold when explicit contracts are not signed (do not expire) simultaneously or have different duration.

Note that the converse of the proposition is not true. In fact, the incentive compatibility conditions for the self-enforcing implicit contracts that replicate the results in the previous sections with short-term explicit managerial contracts can be less stringent than the incentive compatibility conditions with long-term explicit contracts. More formally:

Corollary 4 *If managers have stock-related incentives in the class ICA or in the class* $ICA^{\underline{P}}$ *with* $\underline{P}_i < V\left(\frac{\pi_i^N}{1-\delta}\right)$ $\forall i$*, then the shorter is the length T of the explicit managerial contracts, the smaller is the discount factor at which any collusive agreement can be supported (and, for a given discount factor, more profitable agreements become sustainable) in subgame-perfect equilibrium in the delegation supergame.*

Again, owners have no incentives to renege on the implicit managerial contracts, while the negative effect of stock-based incentives on managers' short-run gains from deviations highlighted in Sections 3 does not depend on the length of explicit managerial contracts. Moreover, with short-term contracts at the end of the stage in which a manager deviates he is fired and kept at his reservation wage forever. The threat of termination, with the loss of future stock-related bonuses it implies, has an additional pro-collusive effect that adds to that identified in Section 3. Because termination is closer in time the shorter is the length of explicit managerial contracts, the smaller is T the stronger is the pro-collusive effect.

6 Extensions and discussion

6.1 Alternative specifications of the model

6.1.1 *Dividend policy*

The pro-collusive effects identified in Sections 3 and 4 are driven by the fact that the stock-based incentives are paid to managers in several consecutive periods (ICA, ICB) or are deferred (ICB, ICC), and by assumption 3 in Section 2.2 by which all realized profits are paid out as dividends (so that the stock price at time t depends mostly (or only) on market expectations about firms' profitability in periods *after* t). While the time structure of stock-related incentives in our model reflects the evidence on most common real-world arrangements (Kole, 1997), the assumption that all profits are distributed as dividends is extreme; it has been made to simplify exposition and make results more clear-cut. In fact, this last assumption is not necessary for any of the pro-collusive effects of stock-based compensation identified above. It is easy to check that analogous results obtain as long as *some* profits are paid out as dividends *sometimes* (once is enough) after a deviation occurs. In a perfect information world profits distributed in past periods (distributed gains from deviation) do not enter the present firm's value, therefore future profits have a relatively larger weight than past profits in the determination of a firm's present stock price. This is enough for stock-related incentives to be pro-collusive: by substituting in conditions (2) and (3) one can immediately see that the *only* case in which the behavior of managers under stock-based incentives corresponds to that of profit-maximizing managers or owners, so that the pro-collusive effects disappear, is when firms *never* pay out any dividend *and* investors value a firm's retained profits as much as distributed ones. Both these conditions are generally not met in reality: most firms do pay out dividends, and any announcement of dividend cuts generates strong negative stock-price reactions (e.g. Franklin Allen and Roni Michaely, 1995). Of course, the less dividends are paid out, the closer are managers' and owners' objectives, and the weaker are the pro-collusive effects of stock-related compensation.

6.1.2 *Market structure*

The results above are robust to changes in modelling assumptions about market structure. It is straightforward to check that they apply to repeated oligopolies other than the Cournot type. All results and proofs are stated using only profit streams π_i^N, π_i^M, $\widehat{\pi}_i^M$, etc., with no direct reference to the specific strategic variables used in the product market. We can reinterpret the profit stream as deriving from any other repeated oligopoly (for example, setting $\pi_i^N = 0$ in the case of homogeneous good Bertrand competition), and note that all proofs continue to hold.

6.2 Profit sharing and managerial ownership

We have focused on liquid incentives related to stock price. What if we allow owners to choose managerial contracts that also incorporate a profit-sharing component or a requirement to retain for a minimum number of periods firm's shares received as a bonus?

Incentive contracts of the classes ICA, ICB, and ICC, whether continuous or discontinuous, make managers more prone to collude than owners. It is straightforward to check that any additional profit-sharing component leads managers to behave more like owners; it dilutes the pro-collusive commitment effect of stock-based incentives without bringing any countervailing benefit. Because of this, it is easy to show that in our model the choice to have a profit-sharing incentive component besides stock-related incentives is always dominated (see the section "Profit Sharing" in the appendix).

Analogous reasoning applies when managers are required to keep in their portfolios the shares they get as bonuses for a minimum amount of time (as in "stock-ownership plans"). If managers under contracts in the classes ICA or ICB keep the shares they receive each period, they will in time own an increasing fraction of the firm. This leads them to receive a larger and larger share of the profits realized in each period as dividends, with an effect on product-market behavior identical to that of a profit-sharing component increasing in time in the compensation package. The more shares the manager owns, the more dividends he gets, the more he behaves like an owner, the smaller is the set of collusive agreements he is willing to support, and the higher is the minimum discount rate at which he is willing to stick to any given collusive agreement. Summarizing:

Remark 1 *Profit-sharing incentives, restrictions on the resale or transfer of firm shares received as bonus, and, more generally, managerial ownership dilute the pro-collusive effects of stock-related compensation plans.*

6.3 Incentives linked to sales

In our oligopoly supergame owners can enforce tacit agreements to restrict output. Because in collusive equilibria output is given by the tacit agreement, colluding owners cannot gain strategic advantages (such as reductions in competing firms' output) by delegating control to managers under aggressive FJS-type incentives linked to sales revenue. Incentives linked to sales, though, may still play a role since they may affect owners' gains from deviations and payoffs in the punishment phase.

Consider the case analyzed in Section 5.1, with explicit managerial contracts of any time-length T, and suppose owners can also choose FJS-type incentive schemes linear in profits and sales. Then, in step 1 of any stage game an owner who expects other owners to choose pro-collusive stock-based managerial incentives may wish to deviate by choosing an aggressive FJS-type managerial contract increasing with sales. In the remainder of the supergame collusion would not be sustained, but the deviating owner would enjoy Stackelberg profits π_i^S for the first T periods after the deviation, and of course $\pi_i^S > \pi_i^N$. Normally it holds that $\pi_i^S < \pi_i^M$,[10] therefore if owners expect other owners to stick to a strategy profile prescribing the use of stock-related incentives that lead managers to support the joint monopoly agreement, they would lose strictly by deviating and choosing aggressive FJS-type incentives, whatever T and δ are. More generally (whether π_i^S is $>$, $=$, or $<$ than π_i^M), even when owners can choose FJS-type incentive schemes, any agreement to delegate control to managers under stock-related incentives leading to a collusive market price with per-period profits π_i^A remains supportable as long as $\pi_i^A > (1-\delta^T)\pi_i^S + \delta^T \pi_i^{FJS}$, where π_i^{FJS} denotes profits at Nash equilibrium of the FJS delegation game and $\pi_i^{FJS} < \pi_i^N$.[11] Of course, this is so because at the end of the stage game in which the owner deviates, T periods after the deviation, other owners can react and also optimally choose FJS-type incentives. Therefore, an owner's unilateral deviation is not profitable and collusion

[10] We are not aware of any general study on the relation between Stackelberg profits and profits at the symmetric joint monopoly agreement, but in the simple examples we worked out we always obtained $\pi_i^S < \pi_i^M$.

[11] It is $\pi_i^{FJS} < \pi_i^N$ because with quantity competition, attempts to gain a strategic advantage through precommitment offset one another (e.g. Fershtmann and Judd, 1987; Sklivas, 1987).

is supportable as long as

$$\frac{\pi_i^A}{1-\delta} > \frac{(1-\delta^T)}{1-\delta}\pi_i^S + \frac{\delta^T}{1-\delta}\pi_i^{FJS}.$$

Note that for small enough T this condition will be satisfied even for less profitable agreements, since the owners' positive short-run gains from deviation generated by the opportunity to choose FJS-type incentives (first member at the RHS) are outweighted by the lower profits they induce during the subsequent non-cooperative phase (second member on the RHS).

Finally, if owners can choose both "collusive" stock-based incentives and "aggressive" FJS-type incentives simultaneously, collusion can be further stabilized. To see this, consider a duopoly and the possibility of such "mixed" compensation contracts. Suppose the incentive part I_i of managers' per-period compensation can be composed of a FJS-type incentive scheme linear in per-period profits and in sales revenue (denoted by S_i), plus an additional stock-related bonus plan as in the previous sections. That is,

$$I_i = \rho_i\left(\alpha_i\pi_i + (1-\alpha_i)S_i\right) + (1-\rho_i)IC_i(P_i),$$

where $\mathrm{IC}_i(\mathrm{P}_i)$ can be chosen from the classes defined in Sections 3 and 4. Let α^{FJS} denote the equilibrium level of the parameter α of the classical FJS two-stage duopoly model. We get immediately the following result.

Proposition 4 *Even when $\pi_i^S > \pi_i^M$, and whatever T and δ are, any collusive agreement A delivering per-period profits π_i^A can be implemented by a mixed managerial contract with $\alpha = \alpha^{FJS}$, $IC_i(P_i) = ICA^{\underline{P}}$, $\underline{P}_i > \pi^{FJS}$, and $\rho > 0$ but small enough to satisfy the managers' incentive compatibility condition.*

A formal proof (which would be analogous to that of Proposition 3) is not needed, since the logic behind the proposition is straightforward. The point is that the pro-collusive effect of stock options identified in Section 3.2 remains when these are a part of a more complex managerial incentive scheme. In addition, when owners use the mixed contract described above, if in step 1 of a stage game an owner deviates optimally (sets $\rho_i = 1$), the competing manager reacts already in step 2 by maximizing the FJS-type part of his incentive scheme only, as his options are valueless whatever he does. Then, already from the step 2, instead of π_i^S the deviating manager obtains π_i^{FJS}. Therefore this mechanism, which is reminding of the one in Reitman (1993), further stabilizes collusion by ensuring that even an owner who deviates using FJS-type contracts incurs a direct loss in the same period in which he deviates.

6.4 Demand uncertainty

Many contributions to the literature on managerial incentives in oligopoly emphasize results obtained with demand uncertainty, both because uncertainty makes the model more realistic and because it leaves room for a function for managers. The managers' task is then to observe the realization of demand, which occurs after the delegation phase, and choose output using that information (e.g. Fershtman and Judd, 1987; Reitman, 1993).

Let θ denote the stochastic component of demand, and assume θ to be independently and identically distributed in time and its distribution to be common knowledge among agents. As in Julio Rotemberg and Garth Saloner's (1986) model, with demand uncertainty the expected losses from the punishment phase that disciplines the collusive agreement are constant in time, while short-run gains from deviation change together with the realization of the state of the world θ. Then, when the discount factor binds, most profitable collusive agreements must be conditioned on the per-period realization of the shock θ. Whether the supergame is played by owners or by managers, players can agree on a "collusive rule" $q^A(\theta) = (q_1^A(\theta), ..., q_n^A(\theta))$ mapping states of the world into firms' collusive output levels, and eventually into profits. The rule is chosen in order to ensure, given agents' discount factor and the expected punishment for deviations, that for each realization of θ the prescribed collusive output levels are such that the incentive constraint is satisfied for all players. The rule will therefore prescribe larger collusive output levels in good states of the world, when gains from deviations are larger. It is simple to check that in our model the introduction of demand uncertainty leaves the results unchanged. Of course, demand uncertainty adds to strategic uncertainty from the ex-ante point of view, so that we must substitute π_i^N, π_i^A, $\widehat{\pi}_i^A$, π_i^M,...etc., with the corresponding expected values $\pi_i^N(\theta)$, $\pi_i^A(\theta)$, $\widehat{\pi}_i^A(\theta), \pi_i^M(\theta)$,...etc., in agents' incentive constraints. Also, when owners use stock options they will now choose a strike price conditional on the state of demand $\underline{P}_i(\theta)$, if θ can be contracted upon, or otherwise keep $\underline{P}_i$ below $\min_\theta \left\{\pi_i^M(\theta)\right\}$ in order to make collusion supportable in all states of demand. However, the logic behind our results goes through.

6.5 Alternative punishment strategies

We assumed that firms sustain collusive agreements by the threat of reverting to the static Nash equilibrium of the oligopoly game forever. Unrelenting trigger strategies are widely used in the literature because they satisfy the requirement of subgame perfection and they are easy to handle (both for researchers in models and for firms in markets). However, this kind of punishment is not optimal in repeated Cournot oligopolies (Abreu, 1986), and may be subject to ex-post renegotiation, which would undermine their credibility (e.g. Joseph Farrell and Maskin, 1989; Douglas Bernheim and Debraj Ray, 1989).

It is easy to check that all the results continue to hold when the threat used to enforce collusion is to revert to the static Nash equilibrium only for a finite number of periods, for example because the strength of the punishment is bounded by the finite costs of renegotiation (as in Andreas Blume, 1994, and Barbara McCutcheon, 1997).

More generally, the results concerning deferred stock-related incentives depend on managers being unable to capture any short-run gains from deviation. Therefore, all the results in Section 4 apply independent of what punishment strategies are used.[12]

What if managers have contracts in the class ICA or $ICA^{\underline{P}}$ and there are no renegotiation costs? In Appendix 2 we analyze the case of long-term stock-option plans and find that the results in Section 3 can be extended both to the case of Abreu's (1986) two-phase optimal punishments and to that of Eric van Damme's (1989) "repentance" renegotiation-proof strategies.

6.6 Renegotiation of managerial contracts

In the introduction we explained that stock-related incentives are less subject than other types of incentive to secret renegotiation, because they require shareholders' approval which is given in public shareholders' meetings. If this were not the case, the results of the model would still be of interest for several reasons.

Even if we assume concentrated ownership, so that public shareholders' meetings are not required to renegotiate managers' compensation, the cost of renegotiation may be substantial for owners; and renegotiation costs give commitment value to managerial incentives. There will typically be direct costs of the bilateral bargaining process between managers and owners, even if there are no information asymmetries (Luca Anderlini and Leonardo Felli, 1998). When third parties (for example debtholders) have seats on the board, the bargaining process becomes trilateral and bargaining costs increase. Moreover, interlocked directors and large finance-providers with industry-wide interests will oppose any renegotiation of managerial contract that leads to a market war (Spagnolo, 1996b, 1998b).

Finally, suppose secret renegotiation were possible and costless. The results would still be of substantial interest. Many economists believe that the incentive compatibility conditions for tacit collusion, inequality (1) in our model, are easily satisfied in most real-world oligopolistic industries (e.g. Carl Shapiro, 1989). If this is true, then if tacit collusion is not present in *all* oligopolistic industries it is only because of coor-

[12] Even in the case of ICC-type incentives, for which there is the chance that a punishment phase of finite length has passed at the time when the incentives are paid, the pro-collusive effect is independent of the shape of the punishment phase as long as the date at which the manager leaves the firm is uncertain. Of course if the punishment phase lasts one period only, as in Abreu's (1986) two-phase optimal punishments, and the ICC-type incentive is deferred for more than one period with certainty, then neither a deviation nor the punishment affect manager's compensation, and we are led to owners' incentive compatibility condition (condition (1), amended for the new punishment) by assumption 3 in Section 2.3. However, in this case owners can simply restrict the choice of incentives to the classes ICA and ICB.

dination failures.[13] Then, owners would not have incentives to renegotiate managers' contracts, and the pro-collusive effects of incentives related to stock price would be to further stabilize tacit collusion and to facilitate coordination.[14]

7 Concluding remarks

We are not arguing here that the effect on tacit collusion is the only force driving firms' adoption of managerial compensation plans related to stock price. As in most previous work on the strategic effects of delegation, to make the model treatable we had to abstract from many important issues, particularly from that of managerial moral hazard (just as most of the literature on moral hazard abstracts from the strategic effects of incentive contracts). When managers' moral hazard is brought into the picture many other beneficial effects of these incentives emerge.

However, we believe that in the imperfectly competitive real world, the pro-collusive effect of these incentives is one important reason behind their success. In the end, shareholders are satisfied when their managers' incentive schemes lead to higher stock prices, regardless of whether this is achieved through higher effort or through more effective collusion.

[13]Fines from competition authorities seem much too small to deter collusion (e.g. McCutcheon, 1997).

[14]CEOs have typically a more homogeneous background than shareholders, they are professionals with similar educations and careers, and a common background is the best known among the factors that facilitate coordination.

8 Appendices

8.1 Appendix 1: Proofs

Proof of Lemma 1 When profits increase (decrease) in one period and everything else remains equal, the stock price increases (decreases) too. Therefore – with regard to the stage game – the stock price function is a monotone transformation of the profit function. A managerial compensation function increasing with stock price is a further monotone transformation of the profit function; consequently, managers' objective function is a monotone transformation of owners' objective function. The set of Nash equilibria of a game is not affected by monotone transformations of payoff functions, as these generate ordinally equivalent games. The statement follows. **Q.E.D.**

Proof of Proposition 1 At $\delta = \underline{\delta}^A$ condition (1) is satisfied as an equality so

$$\frac{\pi_i^A}{1-\underline{\delta}^A} = \widehat{\pi}_i^A + \frac{\underline{\delta}^A}{1-\underline{\delta}^A}\pi_i^N, \Longrightarrow V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right) = V\left(\widehat{\pi}_i^A + \frac{\underline{\delta}^A}{1-\underline{\delta}^A}\pi_i^N\right),$$

by definition (1′). Substituting into condition (2) we obtain

$$\frac{1}{1-\underline{\delta}^A} f_i\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)\right] > f_i\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)\right] + \frac{\underline{\delta}^A}{1-\underline{\delta}^A} f_i\left[V\left(\frac{\pi_i^N}{1-\underline{\delta}^A}\right)\right],$$

which after a few algebraic manipulations becomes

$$\underline{\delta}^A f_i\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)\right] > \underline{\delta}^A f_i\left[V\left(\frac{\pi_i^N}{1-\underline{\delta}^A}\right)\right],$$

which is always satisfied. Because the inequality is strict, by continuity, perturbing the discount factor around $\underline{\delta}^A$ we can find a continuum of discount factors lower than $\underline{\delta}^A$ at which such a condition is satisfied but (1) is not. This reasoning applies to any stationary collusive agreement A and to each firm i. This proves the statement regarding the discount factor.

Conversely, given agents' discount factor, at the most collusive agreement that owners can support, delivering $\pi_i^{\overline{A}}$, we have $V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right) = V\left(\widehat{\pi}_i^{\overline{A}} + \frac{\delta}{1-\delta}\pi_i^N\right)$, and substituting into condition (2) we obtain

$$\frac{1}{1-\delta} f_i\left[V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right)\right] > f_i\left[V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right)\right] + \frac{\delta}{1-\delta} f_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)\right],$$

that leads to

$$f_i\left[V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right)\right] > f_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)\right],$$

which is always true. By continuity, perturbing profits around $\pi_i^{\overline{A}}$ we can find a continuum of higher collusive profit streams which satisfy this condition but not condition (1). This reasoning applies to any stationary collusive agreement and to each firm i. The statement regarding the equilibrium set follows. **Q.E.D.**

Proof of Corollary 1 In the non-trivial case in which $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$, manager i's incentive compatibility constraint (2) becomes

$$\begin{aligned}\frac{1}{1-\delta}\gamma_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i\right] &> \gamma_i\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right]+\\ &+\frac{\delta}{1-\delta}\max\left\{\gamma_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\}.\end{aligned}$$

Evaluating (1) at $\delta=\underline{\delta}^A$ we obtain

$$\frac{\pi_i^A}{1-\underline{\delta}^A}=\widehat{\pi}_i^A+\frac{\underline{\delta}^A}{1-\underline{\delta}^A}\pi_i^N, \Longrightarrow V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)=V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}^A}{1-\underline{\delta}^A}\pi_i^N\right).$$

Substituting from this equality into the previous inequality and simplifying we obtain

$$\gamma_i\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)-\underline{P}_i\right]>\max\left\{\gamma_i\left[V\left(\frac{\pi_i^N}{1-\underline{\delta}^A}\right)-\underline{P}_i\right],0\right\}.$$

By inspection, for any strike price $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)$ and number of options $\gamma_i \neq 0$ this condition holds as a *strict* inequality. By continuity, perturbing the discount factor around $\underline{\delta}^A$ we can find a continuum of discount factors lower than $\underline{\delta}^A$ (of more collusive agreement, i.e., $\pi_i \geq \pi_i^A$) at which such a condition is satisfied but (1) is not. This reasoning applies to any stationary collusive agreement A and to each firm i.

Conversely, given the discount factor, at the most collusive agreement owners can support, delivering firm profits $\pi_i^{\overline{A}}$, we have $V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right) = V\left(\widehat{\pi}_i^{\overline{A}}+\frac{\delta}{1-\delta}\pi_i^N\right)$, and substituting in the condition above we obtain

$$\gamma_i\left[V\left(\frac{\pi_i^{\overline{A}}}{1-\delta}\right)-\underline{P}_i\right]>\max\left\{\gamma_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\},$$

which holds as a strict inequality for any $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\underline{\delta}^A}\right)$ and $\gamma_i \neq 0$. By continuity, perturbing profits around $\pi_i^{\overline{A}}$ we can find a continuum of collusive profit streams which satisfy this condition but not condition (1). This line of reasoning applies to any stationary collusive agreement and to each firm i. The statement follows. **Q.E.D.**

Proof of Corollary 2: Consider first the case $V\left(\frac{\pi_i^N}{1-\delta}\right) \leq \underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$. Condition (3) becomes

$$\frac{1}{1-\delta}\gamma_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i\right] > \gamma_i\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right], \tag{4}$$

or, equivalently,

$$\delta\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right] > V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-V\left(\frac{\pi_i^A}{1-\delta}\right).$$

Then, a manager under an ICA$_{\underline{P}}$-type contract with strike price $\underline{P}_i$ is willing to support any given collusive agreement A as long as

$$\delta > \underline{\delta}_{ICA_{\underline{P}}}^A = \frac{V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}_{ICA_{\underline{P}}}^A\pi_i^N}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\right)-V\left(\frac{\pi_i^A}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\right)}{V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}_{ICA_{\underline{P}}}^A\pi_i^N}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\right)-\underline{P}_i}.$$

By inspection, $\underline{\delta}_{ICA_{\underline{P}}}^A$ is independent of γ_i and is increasing with $\underline{P}_i$. Analogously, the upper bound of the collusive profit streams supportable by a manager under ICA$_{\underline{P}}$-type contracts is $\overline{\pi_i^{ICA_{\underline{P}}}}$, where

$$V\left(\frac{\overline{\pi_i^{ICA_{\underline{P}}}}}{1-\delta}\right)-(1-\delta)V\left(\widehat{\overline{\pi_i^{ICA_{\underline{P}}}}}+\frac{\delta\pi_i^N}{1-\delta}\right)=\delta\underline{P}_i.$$

Take the upper bound $\overline{\pi_i^{ICA'}}$ which satisfies the equality above at a given strike price $\underline{P}_i'$. A reduction in $\underline{P}_i$ makes the condition satisfied as a strict inequality, moving the upper bound to a higher profit level. So $\overline{\pi_i^{ICA_{\underline{P}}}}$ is a decreasing function of $\underline{P}_i$.

Consider now the case of $\underline{P}_i < V\left(\frac{\pi_i^N}{1-\delta}\right)$. The incentive compatibility condition becomes

$$\begin{aligned}\frac{1}{1-\delta}\gamma_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i\right] &> \gamma_i\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right]+ \\ &+\frac{\delta}{1-\delta}\gamma_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i\right].\end{aligned}$$

The minimum level of the discount factor at which the manager can support collusion becomes

$$\underline{\delta}_{ICA_{\underline{P}}}^A = \frac{V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}_{ICA_{\underline{P}}}^A}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\pi_i^N\right)-V\left(\frac{\pi_i^A}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\right)}{V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}_{ICA_{\underline{P}}}^A}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\pi_i^N\right)-V\left(\frac{\pi_i^N}{1-\underline{\delta}_{ICA_{\underline{P}}}^A}\right)},$$

and the condition that identifies the most collusive agreement supportable at the given discount factor $\pi_i^{\overline{ICA_{\underline{P}}}}$ becomes

$$V\left(\frac{\pi_i^{\overline{ICA_{\underline{P}}}}}{1-\delta}\right)=(1-\delta)V\left(\widehat{\pi}_i^{\overline{ICA_{\underline{P}}}}+\frac{\delta\pi_i^N}{1-\delta}\right)+\delta V\left(\frac{\pi_i^N}{1-\delta}\right).$$

The last two equalities are both independent of γ_i and $\underline{P}_i$. All this holds for every firm i and the statement follows. **Q.E.D.**

Proof of Proposition 2: Consider first the class ICB. The incentive compatibility condition for a stationary collusive agreement A to be respected by the manager of firm i under ICB-type contracts is

$$\frac{1}{1-\delta}f_i\left[V\left(\frac{\delta\pi_i^A}{1-\delta}\right)\right]>f_i\left[V\left(\frac{\delta\pi_i^N}{1-\delta}\right)\right]+\frac{\delta}{1-\delta}f_i\left[V\left(\frac{\delta\pi_i^N}{1-\delta}\right)\right],$$

or, equivalently,

$$f_i\left[V\left(\frac{\delta\pi_i^A}{1-\delta}\right)\right]>f_i\left[V\left(\frac{\delta\pi_i^N}{1-\delta}\right)\right],$$

which is *always* satisfied, at any discount factor, for any agreement A, and for every firm i.

Consider now contracts in the class ICC. The expected flow of earnings for the manager of firm i in any period t in which he is running the firm is

$$\begin{aligned}E_t(W) &= E_t\left\{\delta(1-\eta)(1+r)f_i(P_i^{t+1})+\delta^2\eta(1-\eta)(1+r)^2f_i(P_i^{t+2})+\right.\\ &\quad\left.+\delta^3\eta^2(1-\eta)\gamma_i(1+r)^3f_i(P_i^{t+3})+\ldots.\right\}.\end{aligned}$$

As long as the manager sticks to a stationary collusive agreement delivering per period profits π_i^A we have $E_t\left[P^{t+\tau}\right]=V\left(\frac{1}{1-\delta}\pi_i^A\right)$, $\forall\tau>0$. If the manager deviates in any period t we have $E_t\left[P^{t+\tau}\right]=V\left(\frac{1}{1-\delta}\pi_i^N\right)$, $\forall\tau>0$. Because $V\left(\frac{1}{1-\delta}\pi_i^A\right)>V\left(\frac{1}{1-\delta}\pi_i^N\right)$ is always satisfied, whatever the discount factor δ the manager always finds it convenient not to deviate from the agreement. This applies to any agreement A and firm i, and the statement follows. **Q.E.D.**

Proof of Corollary 3: Consider first the class $\text{ICB}_{\underline{P}}$. The incentive compatibility condition for a stationary collusive agreement A to be respected by the manager of firm i under $\text{ICB}_{\underline{P}}$-type contracts becomes

$$\begin{aligned}\frac{1}{1-\delta}\max\left\{\gamma_i\left[V\left(\frac{\delta\pi_i^A}{1-\delta}\right)-\underline{P}_i\right],0\right\} &> \max\left\{\gamma_i\left[V\left(\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\}+\\ &\quad+\frac{\delta}{1-\delta}\max\left\{\gamma_i\left[V\left(\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right],0\right\},\end{aligned}$$

or, equivalently,

$$\begin{cases} V\left(\frac{\delta\pi_i^A}{1-\delta}\right) > \underline{P}_i, & \text{for } \underline{P}_i \geq V\left(\frac{\delta\pi_i^N}{1-\delta}\right), \\ V\left(\frac{\delta\pi_i^A}{1-\delta}\right) > V\left(\frac{\delta\pi_i^N}{1-\delta}\right), & \text{for } \underline{P}_i \leq V\left(\frac{\delta\pi_i^N}{1-\delta}\right). \end{cases}$$

Because owners always choose $\underline{P}_i < V\left(\frac{\delta\pi_i^A}{1-\delta}\right)$ this condition is *always* satisfied. This holds at any discount factor, for any agreement A, and for every firm i.

Consider now contracts in the class ICC. The amount of stock options given to a manager who stops working for the firm τ periods after he started is $\gamma_i(1+r)^\tau$. The expected flow of earnings for the manager of firm i in any period t in which he is running the firm is then

$$\begin{aligned} E_t(W) &= E_t\Big\{\delta(1-\eta)\gamma_i(1+r)(P_i^{t+1}-\underline{P}_i)+\delta^2\eta(1-\eta)\gamma_i(1+r)^2(P_i^{t+2}-\underline{P}_i)+ \\ &\quad +\delta^3\eta^2(1-\eta)\gamma_i(1+r)^3(P_i^{t+3}-\underline{P}_i)+....\Big\}. \end{aligned}$$

As long as the manager sticks to a stationary collusive agreement delivering per period profits π_i^A we have $E_t\left[P^{t+\tau}\right] = V\left(\frac{1}{1-\delta}\pi_i^A\right)$, $\forall\tau > 0$. When owners choose $V\left(\frac{\pi_i^N}{1-\delta}\right) \leq \underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$, manager i's expected payoff function reduces to

$$E_t(W) = \begin{cases} \gamma_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right) - \underline{P}_i\right] & \text{if } q_i^t \leq q_i^A \ \ \forall t < \tau, \\ 0 & \text{otherwise.} \end{cases}$$

Therefore, whatever the discount factor δ, the manager always finds it convenient not to deviate from the agreement. This applies to any agreement A and firm i. The statement follows. **Q.E.D.**

Proof of Proposition 3: Consider the following strategy profile for the delegation supergame.

Each owner's strategy: "*Delegate control to a manager under any kind of stock-related incentive contract (among those defined in Sections 3 and 4) of finite length T such that, if the same contract had infinite length (if $T \to \infty$), the manager would be willing to support the collusive agreement A delivering per-period profits π_i^A; at the beginning of each of the following stage games (in periods $t+T$, $t+2T$, etc.), reconfirm the manager and the contract for one more stage if all other owners have done so in the past and no manager has ever deviated from equilibrium strategies; fire the manager and choose the Cournot-Nash output level (or hire managers under short-term profit-sharing contracts at their reservation wage) forever otherwise.*

Each manager's strategy: "*Respect the collusive agreement A at all steps of each stage game as long as all owners have delegated/reconfirmed managers with the above* *incentive contracts in the first step of each past stage game and no manager has ever deviated from the collusive agreement; maximize the firm's static profits forever otherwise."*

Let us check for unilateral deviations to see whether this strategy profile is a subgame-perfect equilibrium independently of the length of the managerial contract T and of the discount factor δ.

Owners: In step 1 of each stage game an owner can choose to deviate unilaterally from the equilibrium strategy profile by not delegating control, by choosing a different contract, or by replacing the manager. However the owner deviates, and whatever T and δ are, the deviation is observed by the managers of the competing firms who, following equilibrium strategies, start maximizing firms' profits already from Step 2. Therefore, owners' expected payoff from deviation is the discounted flow of Cournot Nash profits. If an owner sticks to equilibrium strategies, his manager continues to support collusion in the product market game, and profits are above the Cournot-Nash level. It follows that owners lose strictly by deviating unilaterally from the strategy profile above, whatever the length of the contract and the discount factor are.

Managers: Managers can deviate from equilibrium in any step of each stage game. Whatever T and δ are, if a manager has a contract in the class ICB, ICC, ICB$^{\underline{P}}$ or ICC$^{\underline{P}}$, he gains nothing by deviating because short-run profits are distributed before he gets his stock-related bonuses (see the Proof of Proposition 2). If the manager has a contract in the class ICA or ICA$^{\underline{P}}$, in the period in which he deviates his stock-related bonus does increase in value. However, starting from the following period other managers maximize static firm profits and the value of his stock related bonus falls. And at the end of the stage game in which he deviated he is fired, so in all periods after that stage game he receives only his reservation wage (that was normalized to zero). It follows that the most profitable deviation is the one that occurs in Step 2 of a stage game. Consider the case of ICA contracts. If explicit contracts are of any finite length T, a manager's no deviation condition is

$$\frac{1}{1-\delta} f_i \left[V\left(\frac{\pi_i^A}{1-\delta}\right)\right] > f_i \left[V\left(\widehat{\pi}_i^A + \frac{\delta\pi_i^N}{1-\delta}\right)\right] + \frac{\delta(1-\delta^{T-1})}{1-\delta} f_i \left[V\left(\frac{\pi_i^N}{1-\delta}\right)\right].$$

Because for any finite T and at any δ it holds $\frac{\delta(1-\delta^{T-1})}{1-\delta} < \frac{\delta}{1-\delta}$, the RHS of this condition is smaller than the RHS of condition (2), and the condition is always satisfied when (2) is. Since equilibrium strategies prescribe owners to use stock-related incentive contract such that, if they had infinite length, the manager would be willing to support the joint monopoly collusive agreement, if in equilibrium managers have ICA-type contracts condition (2) will be satisfied, and so will be the inequality above. The same reasoning holds when owners choose a contract in the class ICA$^{\underline{P}}$. The statement follows. **Q.E.D.**

Proof of Corollary 4: Consider the case of managers under ICA contracts of length T. Managers stick to an agreement A as long as the inequality in the proof of Proposition 3 holds:

$$\frac{1}{1-\delta}f_i\left[V\left(\frac{\pi_i^A}{1-\delta}\right)\right] > f_i\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)\right]+\frac{\delta(1-\delta^{T-1})}{1-\delta}f_i\left[V\left(\frac{\pi_i^N}{1-\delta}\right)\right].$$

Because $\frac{\delta(1-\delta^{T-1})}{1-\delta}$ is increasing in T, the RHS of the inequality is increasing in T. It follows that the condition becomes more stringent the larger T is. Analogous reasoning holds for contracts in the class ICA$^{\underline{P}}$ with $\underline{P}_i < V\left(\frac{\pi_i^N}{1-\delta}\right)$ $\forall i$. **Q.E.D.**

Profit-sharing: Suppose owners can choose the parameters α_i, γ_i and $\underline{P}_i$ of managers' compensation package. We show here that it is a dominant strategy for each owner to maximize managers' ability to support collusive agreements by choosing $\alpha_i = 0$.

Let us normalize the parameters and restrict attention to the case in which $\gamma_i = (1-\alpha_i)$ and $\alpha_i \leq 1$, which encompasses all economically relevant cases. Under such a contract, the incentive compatibility condition for a stationary collusive agreement A to be respected by the manager of firm i becomes

$$\frac{1}{1-\delta}\left\{\alpha_i\pi_i^A+(1-\alpha_i)\left[V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i\right]\right\}\geq$$

$$\geq \alpha_i\widehat{\pi}_i^A+(1-\alpha_i)\left[V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)-\underline{P}_i\right]+$$

$$+\alpha_i\frac{\delta\pi_i^N}{1-\delta}+(1-\alpha_i)\frac{\delta\max\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i,0\right]}{1-\delta},$$

which can be rearranged as

$$(1-\alpha_i)\left\{\frac{V\left(\frac{\pi_i^A}{1-\delta}\right)-\underline{P}_i}{1-\delta}-V\left(\widehat{\pi}_i^A+\frac{\delta\pi_i^N}{1-\delta}\right)+\underline{P}_i\right.$$

$$\left.-\frac{\delta\max\left[V\left(\frac{\pi_i^N}{1-\delta}\right)-\underline{P}_i,0\right]}{1-\delta}\right\}+\alpha_i\left\{\frac{\pi_i^A}{1-\delta}-\widehat{\pi}_i^A-\frac{\delta\pi_i^N}{1-\delta}\right\}\geq 0. \qquad (5)$$

It is evident that condition (5) is a linear combination of conditions (1) and (3), with α_i and $(1-\alpha_i)$ as weights. If owners decide to delegate, they can choose the value of two parameters in their managers' compensation package, α_i and $\underline{P}_i$. Given a level of $\underline{P}_i$, when $\alpha_i = 1$ managers have exactly the same incentives as owners (only condition (1) matters), and when $\alpha_i = 0$ we are in the case of Section 3.2.

Evaluating condition (5) at the most collusive profit stream which owners can sustain, we obtain that the first term of the LHS is strictly positive (by the Proof of Proposition 1) and the second is zero (by definition). This means that as long as $\alpha_i < 1$, condition (5) is satisfied as a strict inequality and managers under this contract can support more collusive agreements than owners. However, because the second term on the LHS is negative, as long as $\alpha_i > 0$ managers under ICA-type contracts will still be able to support more collusive agreements. In the Proof of Corollary 2 we have shown that the member within the first graph parentheses on the LHS of (5) is *always* larger than the content of the second graph parentheses. It follows that owners maximize managers' ability to support collusive agreements by choosing $\underline{P}_i \leq V\left(\frac{\pi_i^N}{1-\delta}\right)$ and $\alpha_i = 0$. Because contracts are observable, managers collude only if all owners delegate under suitable incentive contracts, and can react if an owner deviates from the agreed strategies. Because owners cannot lose by delegating control, while they gain strictly when more profitable collusive agreements become supportable in equilibrium, each owner's dominant strategy is to set $\alpha_i = 0$. **Q.E.D.**

8.2 Appendix 2: Long-term contracts with alternative punishment strategies

8.2.1 Optimal punishments

The results of Section 3 can be extended to the case in which players use two-phase optimal punishment strategies (Abreu, 1986). Consider the case of stock options.

Proposition 5 *When the repeated oligopoly game is played by managers under $ICA_{\underline{P}}$-type contracts with $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$, $\forall i$, then the minimum discount factor at which any collusive agreement delivering per-period profits π_i^A can be supported in subgame-perfect equilibrium by two-phase symmetric optimal punishments (as defined in Abreu, 1986) is strictly lower (and, for a given discount factor, more profitable collusive agreements become supportable,) than when firms are led by owners or by profit-maximizing managers.*

Proof: By Theorem 15 in Abreu (1986), producing for one period a symmetric vector $q^{PA} > q^N$ delivering profits $\pi_i^{PA} = \pi_i(q^{PA})$, with $\pi_i^{PA} < \pi_i^N < \pi_i^A$, and then going back to the collusive output is an optimal two-phase symmetric punishment. The punishment is able to support a symmetric stationary collusive agrement A to restrict production to the vector q^A if the system

$$\begin{cases} \delta(\pi_i^A - \pi_i^{PA}) = \widehat{\pi}_i^{PA} - \pi_i^{PA} \\ \widehat{\pi}_i^A - \pi_i^A \geq \delta(\pi_i^A - \pi_i^{PA}), \end{cases} \tag{OP}$$

is satisfied, where as usual $\widehat{\pi}_i^{PA} = \pi_i(\widehat{q}_i(q_{-i}^{PA}), q_{-i}^{PA})$ are firm i's profit from deviating from the prescribed (punishment) equilibrium path and choosing a best response to other firms' output vector q_{-i}^{PA}.

Denote by $\underline{\delta}_{OP}^A$ the minimum level of the discount factor at which owners can support the collusive agreement A using a symmetric two-stage optimal punishment. This level is defined by the equality

$$\widehat{\pi}_i^A - \pi_i^A = \underline{\delta}_{OP}^A(\pi_i^A - \pi_i^{PA}) = \widehat{\pi}_i^{PA} - \pi_i^{PA}.$$

By Theorems 14 and 18 in Abreu (1986), the symmetric two-stage punishment strategy which delivers profits $\pi_i^{PA} < \pi_i^N$ for one period after a deviation and then reverts to the collusive agreement A is the unique symmetric optimal punishment; further, it is a globally optimal punishment if $\underline{\delta}_{OP}^A$ is not too low. From the definition of $\underline{\delta}_{OP}^A$ we have

$$\widehat{\pi}_i^A - \pi_i^A = \underline{\delta}_{OP}^A(\pi_i^A - \pi_i^{PA})$$

or, equivalently,

$$\frac{\underline{\delta}_{OP}^{A\,2}\pi_i^A}{1-\underline{\delta}_{OP}^A} + \widehat{\pi}_i^A - \pi_i^A = \underline{\delta}_{OP}^A(\pi_i^A - \pi_i^{PA}) + \frac{\underline{\delta}_{OP}^{A\,2}\pi_i^A}{1-\underline{\delta}_{OP}^A},$$

that simplifies to

$$\frac{\pi_i^A}{1-\underline{\delta}_{OP}^A} = \widehat{\pi}_i^A + \underline{\delta}_{OP}^A\pi_i^{PA} + \frac{\underline{\delta}_{OP}^{A\,2}\pi_i^A}{1-\underline{\delta}_{OP}^A}. \tag{6}$$

Consider now managers' incentive compatibility constraint to support the joint monopoly agreement under ICA when optimal two-phase punishments are used and the discount rate is $\underline{\delta}_{OP}^A$.

First we check that these strategies are subgame-perfect for managers too. With $\gamma_i = 1$ in the period after a deviation, if a manager sticks to the agreed strategies he expects discounted payoffs

$$S^{OP} = \max\left\{V\left(\pi_i^{PA} + \frac{\underline{\delta}_{OP}^A\pi_i^A}{1-\underline{\delta}_{OP}^A}\right) - \underline{P}_i, 0\right\} +$$
$$+\frac{\underline{\delta}_{OP}^A}{1-\underline{\delta}_{OP}^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_{OP}^A}\right) - \underline{P}_i\right].$$

If he deviates and causes the other manager to restart the punishment phase he expects

$$D^{OP} = \max\left\{V\left(\widehat{\pi}_i^{PA} + \underline{\delta}_{OP}^A\pi_i^{PA} + \frac{\underline{\delta}_{OP}^{A\,2}\pi_i^A}{1-\underline{\delta}_{OP}^A}\right) - \underline{P}_i, 0\right\} +$$
$$+\underline{\delta}_{OP}^A \max\left\{V\left(\pi_i^{PA} + \frac{\underline{\delta}_{OP}^A\pi_i^A}{1-\underline{\delta}_{OP}^A}\right) - \underline{P}_i, 0\right\} +$$

$$+\frac{\underline{\delta}_{OP}^{A\,2}}{1-\underline{\delta}_{OP}^{A}}\left\{V\left(\frac{\pi_i^A}{1-\underline{\delta}_{OP}^{A}}\right)-\underline{P}_i\right\},$$

and $S^{OP}-D^{OP}=0$ by the definition of owners' optimal punishment (OP). So managers have no incentives to deviate ex post.

Now, with owners' optimal punishment strategies, managers' incentive compatibility condition becomes

$$\frac{1}{1-\underline{\delta}_{OP}^{A}}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_{OP}^{A}}\right)-\underline{P}_i\right]\geq$$

$$\begin{aligned}\geq\; & \left[V\left(\widehat{\pi}_i^A+\underline{\delta}_{OP}^{A}\pi_i^{PA}+\frac{\underline{\delta}_{OP}^{A\,2}\pi_i^A}{1-\underline{\delta}_{OP}^{A}}\right)-\underline{P}_i\right] \\ & +\underline{\delta}_{OP}^{A}\max\left\{V\left(\pi_i^{PA}+\frac{\underline{\delta}_{OP}^{A}\pi_i^A}{1-\underline{\delta}_{OP}^{A}}\right)-\underline{P}_i,0\right\} \\ & +\frac{\underline{\delta}_{OP}^{A\,2}}{1-\underline{\delta}_{OP}^{A}}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_{OP}^{A}}\right)-\underline{P}_i\right].\end{aligned} \tag{7}$$

By equality (6) the first term in squared brackets on the RHS of (7) equals the content of the square brackets in the term at the LHS and in the third term at the RHS of (7), and is strictly larger than the content of the squared bracket in the second term at the RHS of (7). It follows that (7) is satisfied as a strict inequality and, by continuity, there will be a sequence of discount factors lower than $\underline{\delta}_{OP}^{A}$ at which (7) is still satisfied. This applies to any firm i and collusive agreement A. For a fixed δ the same line of reasoning proves that the set of supportable collusive agreements is larger for managers under ICA-type incentives when optimal two-phase punishments are used. For incentives linear in stock price, substitute $\underline{P}_i=0$ and note that the reasoning above continues to hold. The statement follows. **Q.E.D.**

The intuition is analogous to that behind Proposition 1 and Corollary 1. The only difference is that here the negative effect of the punishment is concentrated in the period immediately following the deviation.

8.2.2 Renegotiation-proof strategies

Consider the case in which firms use renegotiation-proof strategies (in the sense of Farrell and Maskin, 1989). For simplicity, let us focus on a duopoly ($i\in\{1,2\}$), so that we can consider renegotiation-proof punishment strategies of the kind proposed by van Damme (1989) for the repeated Prisoner's Dilemma. In our Cournot model, these strategies can be defined as follows:

Punishment strategies "R":

Phase 1: Stick to the collusive output level as long as the other firm did the same in the past; if the other firm deviates, then start Phase 2;

Phase 2: Produce the full monopoly output q^M as long as the other firm's output is positive; if for (say) one period the other firm's output is zero, restart Phase 1 in the following period.[15]

Then we can state the following corollary.

Proposition 6 *When the repeated oligopoly game is played by managers under $ICA_{\underline{P}}$-type contracts with $\underline{P}_i < V\left(\frac{\pi_i^A}{1-\delta}\right)$, $\forall i$, then the minimum discount factor at which any collusive agreement delivering per-period profits π_i^A can be supported in subgame-perfect equilibrium by renegotiation-proof strategies R is strictly lower (and, for a given discount factor, more profitable collusive agreements become supportable,) than when firms are led by owners or by profit-maximizing managers.*

Proof: To support a collusive agreement in subgame-perfect equilibrium, the strategy profile must also satisfy the deviating firm's incentive constraint, that is, it must be convenient for the firm which has deviated to repent after the deviation so that

$$0 + \frac{\delta \pi_i^A}{1-\delta} \geq \frac{\pi_i(\widehat{q}_i(q^M), q^M)}{1-\delta}.$$

Assume this condition is satisfied. Let $\underline{\delta}_R^A$ denote the minimum level of the discount factor at which the joint monopoly collusive agreement is supportable by owners using these renegotiation-proof strategies with one-period "repentance," where – assuming $\pi_i^A \underline{\delta}_R^A \geq \pi_i(\widehat{q}_i(q^M), q^M) - \underline{\delta}_R^A$ is defined by the equality

$$\frac{\pi_i^A}{1-\underline{\delta}_R^A} = \widehat{\pi}_i^A + \frac{\underline{\delta}_R^{A2} \pi_i^A}{1-\underline{\delta}_R^A}. \tag{R}$$

First we check that strategies R are subgame-perfect for managers too. In the period after a deviation, if the manager of firm i who deviated sticks to the agreed punishment strategies R, he gets expected payoffs

$$S_i^R = \max\left\{V\left(\frac{\underline{\delta}_R^A \pi_i^A}{1-\underline{\delta}_R^A}\right) - \underline{P}_i, 0\right\} +$$

[15]These strategies are weakly renegotiation-proof (and strongly renegotiation-proof for the joint monopoly collusive agreement) because after firm i deviates it is supposed to "give a premium" to the other firm j in order to restart cooperation. By not producing for one period, firm i earns zero profits while it makes firm j's profits increase over the level of the joint monopoly collusive agreement. Such a premium makes it more profitable for firm j to insist on the agreed punishment strategies rather than to renegotiate them toward new collusive outcomes.

$$+\frac{\underline{\delta}_R^A}{1-\underline{\delta}_R^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right],$$

while if deviating he causes the other manager to restart the punishment and obtains expected payoffs

$$D_i^R = \max\left\{V\left(\pi_i(\widehat{q}_i(q^M),q^M)+\frac{\underline{\delta}_R^{A2}\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}+$$
$$+\underline{\delta}_R^A\max\left\{V\left(\frac{\underline{\delta}_R^A\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}+$$
$$+\frac{\underline{\delta}_R^{A2}}{1-\underline{\delta}_R^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right].$$

Consider now the incentive not to deviate, the difference

$$S_i^R-D_i^R=\max\left\{V\left(\frac{\underline{\delta}_R^A\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}-\max\left\{V\left(\pi_i(\widehat{q}_i(q^M),q^M)+\frac{\underline{\delta}_R^{A2}\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}$$
$$+\underline{\delta}_R^A\left\{\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right]-\max\left\{V\left(\frac{\underline{\delta}_R^A\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}\right\}.$$

The difference between the first two members on the RHS is positive because when defining R we assumed $\pi_i^A\underline{\delta}_R^A \geq \pi_i(\widehat{q}_i(\overline{q}_j),\overline{q}_j)$; the third member on the RHS is strictly positive by inspection, therefore $S_i^R - D_i^R > 0$.

On the other hand, the manager of firm j, who did not deviate, by sticking to the agreed strategies in the period after a deviation gets expected payoffs:

$$S_j^R=\left[2\pi_j^M+\underline{\delta}_R^A V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right]+$$
$$+\frac{\underline{\delta}_R^A}{1-\underline{\delta}_R^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right],$$

and any deviation from R will cause him a loss.

Then, with punishment strategies R the managers' incentive compatibility condition becomes

$$\frac{1}{1-\underline{\delta}_R^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right]\geq$$
$$\geq\left[V\left(\widehat{\pi}_i^A+\frac{\underline{\delta}_R^{A2}\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right] \qquad (8)$$
$$+\underline{\delta}_R^A\max\left\{V\left(\frac{\underline{\delta}_R^A\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i,0\right\}$$
$$+\frac{\underline{\delta}_R^{A2}}{1-\underline{\delta}_R^A}\left[V\left(\frac{\pi_i^A}{1-\underline{\delta}_R^A}\right)-\underline{P}_i\right].$$

By equality (R) the first term in squared brackets on the RHS of (8) equals the content of the squared brackets in the term on the LHS and in the third term on the RHS of (8), and is strictly larger than the content of the squared brackets in the second term on the RHS of (8). It follows that (8) is satisfied as a strict inequality and, by continuity, there will be a sequence of discount factors lower than $\underline{\delta}_R^A$ at which (8) is still satisfied. This reasoning applies to any collusive agreement other than the joint monopoly one. For incentives linear in stock price substitute $\underline{P}_i = 0$, and note that the reasoning above continues to hold. The statement follows. **Q.E.D.**

Chapter 4

Essay III

Debt as a (Credible) Collusive Device

Debt as a (Credible) Collusive Device*

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Abstract

This paper proposes a theory of the anti-competitive effects of debt finance based on the interaction between capital structure, managerial incentives, and firms' ability to sustain collusive agreements. It shows that shareholders' commitments that reduce conflicts with debtholders – such as a manager with a valuable reputation or "conservative" managerial incentives – besides reducing the agency cost of debt finance also greatly facilitate tacit collusion in product markets. Collusive credit markets or large banking groups can ensure the credibility of such commitments, thereby "exporting" collusion through leverage in otherwise non-collusive product markets.

JEL CLASSIFICATION: D21, G32, L13, L41.

KEYWORDS: Oligopoly, capital structure, tacit collusion, managerial incentives, corporate governance, financial market - product market interactions.

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1 Introduction

Recent empirical work by Judith Chevalier (1995), Dan Kovenock and Gordon Phillips (1995, 1997), and particularly Phillips (1995) has shown that in concentrated industries, high leverage tends to be correlated with low output, high prices, and more passive investment behavior; that is, debt seems to have anti-competitive effects on product markets.

In this paper we propose a theoretical explanation for this evidence based on the interaction between capital structure, managerial incentives, and firms' ability to sustain collusive behavior. Building on Vojislav Maksimovic's (1988) leveraged oligopoly model, we show that shareholders' commitments to a "prudent" behavior aimed at reducing conflicts with debtholders and the ex ante cost of debt finance – such as choosing a manager with a valuable reputation or "conservative" managerial incentives – also greatly facilitate tacit collusion in the product market. The model explains why and how collusive credit markets and large banking groups "export" collusion in otherwise competitive product markets. Even when contract renegotiation is costless, a suitable combination of debt and managerial incentives has the same product market effects of a "hidden" horizontal merger, making collusion sustainable where unleveraged firms' owners would be unable to collude.

The two more established theories of the effects of financial structure on product market competition are not well suited to explain anti-competitive effects of debt finance, as their natural implication is that debt should lead either the leveraged firms or their competitors to behave more aggressively.

According to John McGee's (1958) and Lester Telser's (1966) "long purse" or "deep pockets" theory, when some firms issue debt, their unleveraged competitors will find it convenient to engage in a market war in order to drive them bankrupt and eventually out of the market. This argument has been formalized in models of "predation," for example, by Jean-Pierre Benoit (1984), Drew Fudenberg and Jean Tirole (1986), James Brander and Tracy Lewis (1988), and Patrick Bolton and David Scharfstein (1990).

For the "limited liability" theory, the "asset substitution" problem identified by Michael Jensen and William Meckling (1976) should lead shareholders of leveraged firms to disregard low product market outcomes – from which they are protected by limited liability – and therefore to choose overly aggressive product market strategies. This argument has been developed in models of "strategic default" in leveraged oligopolies by Brander and Lewis (1986), Maksimovic (1986, 1988), and Rune Stenbacka (1994).

Here we start from to observation of Brander and Michel Poitevin (1992), David Hirshleifer and Anjan Thakor (1992), and Daron Acemoglu (1997) that by committing to a prudent behavior through "conservative" managers, shareholders can limit the "asset substitution" problem linked to limited liability, and reduce the ex ante (agency) cost of debt finance.

We introduce such a commitment opportunity in Maksimovic's (1988) model of repeated leveraged oligopoly to analyze its effect on collusive behavior. We find that if owners commit against strategic default by hiring a manager with an established reputation – with much to lose from bankruptcy – debt enhances firms' ability to collude with respect to unleveraged firms. Analogous commitments to debtholder-friendly behavior through low-powered managerial incentive schemes have even stronger pro-collusive effects, which add to that of managers' reputational costs of bankruptcy. We then show that when credit markets are concentrated, colluding lenders can increase their rents by controlling the choice of managers (and their incentives) in oligopolies. They can make the choice of a prudent manager or of conservative managerial incentives renegotiation-proof through high levels of debt, thereby making commitments to conservative (collusive) product market strategies credible even when secret renegotiation is possible and costless. This generates collusion in otherwise competitive product markets. And even when credit markets are perfectly competitive and firms have several lenders, choosing at least one lender in common (or, equivalently, at least a couple of different but "allied" lenders) is shown to remain a feasible way by which oligopolistic firms can credibly commit to "friendly" behavior and enforce tacit collusion, as first suggested by Brander and Lewis (1986).

The role of a common lender (or of a group of allied lenders) here is analogous to that in Poitevin (1989). Poitevin has shown – within a two-stage model analogous to that of Brander and Lewis (1986) – that when firms borrow from a common lender, this may partly curb leveraged firms' overly aggressive product market behavior through a suitable choice of (low) interest rates. However, Poitevin remarks that in his model the overall effect of debt remains pro-competitive, that is, the common-lender leveraged-oligopoly equilibrium output is still larger than the unleveraged Cournot output (although to a lesser extent). In our repeated games framework, instead, through its influence on the choice of managers and their incentives a common lender (or a group of allied lenders) can implement the joint monopoly industry output as the unique subgame perfect collusive equilibrium outcome at any discount rate.

Both this paper and that of Poitevin (1989) are closely related to the work of Douglas Bernheim and Michael Whinston (1985), where it is demonstrated that a common marketing agent can be used by firms that act non-cooperatively to facilitate collusion. The logic common to all three papers is that a contractual device (debt here and in Poitevin, agency in Bernheim and Whinston) is used by competing firms to transfer a fraction of their returns, to "sell out" to a single party who internalizes part or all market externalities between them.

It is well known that during the leveraged-buyout (LBO) wave of the '80s, increases in leverage were accompanied by simultaneous changes in managerial incentives. The results of this paper suggest that, at least in mature oligopolistic industries, tacit collusion could be one channel through which the combination of increased leverage and new managerial compensation packages brought about higher profitability.

More importantly, our results offer a rationale for the common observation that "continental" and Japanese economies tend to be less competitive than Anglo-Saxon ones (Marcus Noland, 1995; Yoshiro Miwa, 1996; Atsushi Maki, 1998). The former economies, particularly the Japanese, are characterized by large banking groups and concentrated credit relations, which are the features required in our model for debt to have pro-collusive effects. Anglo-Saxon financial systems, in contrast, are typically more fragmented and competitive with a much smaller size of banks relative to firms.

Jeffrey Zwiebel (1996) has convincingly argued that an important weakness of many models of the disciplinary role of debt is that financial decisions must be made *ex ante* and must be out of managers' control, as debt leaves managers worse off. In Zwiebel's words:

> "...this contrasts with common perception of leveraged choices being in the domain of standard managerial decisions. Managers commonly undertake capital decisions without any apparent extraordinary external threat..."

For example, in the LBO wave of the '80s it was managers who usually took the initiative. One nice feature of the present model is that it provides a clear explanation for why managers themselves are willing to choose high leverage, to put themselves under the threat of bankruptcy. In oligopolies debt is a credible commitment to prudent, collusive, profitable behavior, and managers appropriate part of the collusive rent.

Finally, our results appear to go along well with several stylized facts in empirical corporate finance. They are consistent with the consolidated evidence that debt issues are perceived as good news by the stock market (Milton Harris and Arthur Raviv, 1991), that the probability of a firm undertaking an LBO is positively related to its competitors' leverage (Paul Marsh, 1982; Chevalier, 1995), and particularly that managerial incentives are often low-powered (Jensen and Kevin Murphy, 1990; Steven Kaplan, 1994, 1998). In mature oligopolistic industries "conservative" managerial incentives are optimal contracts; they simultaneously minimize the cost of debt finance and maximize (collusive) profits in the product market.[1]

Several other theories have been proposed to rationalize the positive (negative) empirical relation between leverage and markups. Phillips (1992) and Kovenock and

[1] Brian Hall and Jeffrey Liebmann (1998) have documented how the widespread adoption of stock-related incentive plans has increased U.S. top managers' pay-performance sensitivity in the last fifteen years. Consistently with the results of this paper Giancarlo Spagnolo (1998a) has recently shown that these highly-powered stock-related incentives are also usually designed so that they greatly facilitate tacit collusion in product markets.

Phillips (1995) obtain a negative output/leverage relation by focusing on the constraints imposed by debt on managers' ability to finance new investments. Glazer (1994), Showalter (1995), Faure-Grimaud (1997), and Nier (1998) obtain analogous results by modifying the assumptions of Brander and Lewis' (1986) two-stage model. Glazer introduces an additional product market interaction before debt is due, and finds that accumulated profits curb firms' overly aggressive behavior. Showalter (1995) assumes price instead of quantity competition, and obtains higher profits for leveraged firms when demand is uncertain. Faure-Grimaud (1997) assumes that lenders cannot observe the realized state of nature nor firms' profits, and finds that the truth-telling constraint generates debt contracts that lead firms to produce lower output. Nier (1998) – in a spirit close to this paper – introduces "conservative" managers whose objective is to avoid bankruptcy. Under the assumption of upward sloping reaction functions he finds that shareholders' conflicts with both debtholders and competitors are softened, although managers are left with no incentives to issue debt.

The explanation proposed in this paper does not contrast with those above; it can be better seen as complementary to them. The relative importance of these different effects will depend on the industry's characteristics, and should be established empirically.

The rest of the paper is organized as follows. In Section 2 we present Maksimovic's (1988) model and main result. In Section 3 we modify the model to study how the direct (reputational) costs that managers incur when their firm goes bankrupt affect the relation between debt and collusion. In Section 4 we show that managerial incentives which reduce the agency costs of debt finance also facilitate collusion in the product market. In Section 5, the heart of the paper, we show how collusive lenders may induce collusive behavior in product markets where unleveraged firms would be unable to collude. In Section 6 we show that competition in financial markets and a multiplicity of firm lenders do not eliminate the pro-collusive effects of debt. In Section 7 we discuss policy implications and briefly conclude. All proofs are in the appendix.

2 The model

Maksimovic (1988) studies a repeated oligopoly model in which leveraged firms repay their debt by periodic installments (coupons), which can alternatively be thought of as repayments of several debt contracts with different maturities in line with, for example, Oliver Hart and John Moore (1995). He finds a negative relation between leverage and firms' ability to collude: because firm owners (throughout the paper we will use the words "owners" and "shareholders" as synonyms) have limited liability, there exists a maximum level of debt at which any stationary collusive agreement can be supported, and above which owners will prefer to deviate and drive the firm into bankruptcy. The point is that limited liability protects the owners of a leveraged firm from part of the losses from the price-quantity war triggered by a deviation, making deviations relatively more attractive.[2]

Maksimovic's model is approximately as follows. There are N identical firms interacting in an infinitely-repeated Cournot oligopoly. Let r denote the market discount rate, π_i^A the profit realized in each period by firm i when firms are sticking to a (stationary) collusive agreement A, π_i^{NC} the firm's profit in each period in which the static Cournot-Nash equilibrium is played, and – abusing notation – let $\widehat{\pi}_i^A$ denote one-period profits from deviating if the other firms adhere to the tacit collusive agreement, and $\underline{\pi}_i^A$ the one-period profits from sticking to the agreed output when another firm deviates unilaterally. The collusive agreement can be sustained in subgame perfect equilibrium by trigger strategies if net short-run gains from deviating are not larger than discounted losses from the punishment phase, that is, if

$$\widehat{\pi}_i^A - \pi_i^A \leq \frac{\pi_i^A - \pi_i^{NC}}{r}, \ \forall i, \ \Leftrightarrow \ r \leq r^* = \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A}, \ \forall i. \tag{1}$$

Suppose firms simultaneously increase leverage by issuing long-term debt or, as in Maksimovic, that when the industry was founded, all firms simultaneously issued debt in the form of bonds sold for a lump-sum amount D_i against the obligation to pay bondholders an amount b_i in every following period, with $D_i = \frac{b_i}{r}$. In each period firms are free to distribute dividends after having paid the coupon b_i. If in one period a firm cannot meet its debt-service obligation, bankruptcy occurs. Following Maksimovic, we assume that in the period after a firm becomes bankrupt, shareholders – who are then indifferent to profits – choose profit-maximizing Cournot-Nash output levels. From this setting Maksimovic's main result follows, which we rephrase here in a "continuous form."

Proposition M (Maksimovic (1988)) *At "high" levels of debt* ($\pi_i^{NC} < b_i \leq \pi_i^A$) *any increase in leverage reduces a firm's ability to support collusion: the higher the leverage, the lower is the maximum discount rate (the larger is the minimum discount factor) at which a firm finds it convenient to respect any collusive agreement supported by trigger strategies. "Low" levels of debt* ($0 \leq b_i \leq \pi_i^{NC}$) *do not affect a firm's ability to collude.*

The result is obtained because after having issued long-term debt, the condition for the collusive agreement to be respected by each firm i under the threat of trigger strategies becomes

$$\pi_i^A - b_i + \frac{\pi_i^A - b_i}{r} \geq \widehat{\pi}_i^A - b_i + \max\left\{\frac{\pi_i^{NC} - b_i}{r}, 0\right\},$$

[2] Maksimovic identifies several financial instruments – such as warrants or convertible debt – that can moderate this pro-competitive effect of debt. He also suggests that dividend restrictions would have a similar effect.

or, equivalently,

$$\widehat{\pi}_i^A - \pi_i^A \leq \frac{\pi_i^A - b_i}{r} - \max\left\{\frac{\pi_i^{NC} - b_i}{r}, 0\right\}. \tag{2}$$

The left hand side (LHS) of condition (2) represents a firm's one-shot (net) gains from deviating from the collusive agreements, while the right hand side (RHS) represents the long-run losses from the punishment triggered by the deviation. As long as $b_i \leq \pi_i^{NC}$, the RHS can be simplified to $\frac{\pi_i^A - \pi_i^{NC}}{r}$ and condition (2) reduces to (1). However, at higher levels of leverage with $\pi_i^{NC} < b_i < \pi_i^A$, condition (2) becomes

$$\widehat{\pi}_i^A - \pi_i^A \leq \frac{\pi_i^A - b_i}{r} \Leftrightarrow r \leq r^{**} = \frac{\pi_i^A - b_i}{\widehat{\pi}_i^A - \pi_i^A},$$

It is evident that at this level of debt, condition (2) becomes more and more stringent when b_i increases, so r^{**} is decreasing in b_i. Of course, after b_i reaches π_i^A, at higher levels of leverage the condition cannot be satisfied at any positive discount rate.

The pro-competitive effect of debt identified by Maksimovic is even more evident if we assume that firms compete in price in a homogenous-good oligopoly. This is because in a Bertrand oligopoly $\widehat{\pi}_i^A - \pi_i^A = \pi_{-i}^A$, $\pi_i^{NC} = 0$, and substituting, (1) becomes

$$\pi_{-i}^A \leq \frac{\pi_i^A}{r}, \ \forall i, \ \Leftrightarrow \ r \leq \frac{\pi_i^A}{\pi_{-i}^A}, \ \forall i, \tag{1'}$$

and (2) becomes

$$\pi_{-i}^A \leq \frac{\pi_i^A - b_i}{r} - \max\left\{\frac{-b_i}{r}, 0\right\} \Leftrightarrow r \leq \frac{\pi_i^A - b_i}{\pi_{-i}^A}, \ \forall i. \tag{2'}$$

By inspection, (1') is always less stringent than (2') when firms are leveraged, therefore *any* positive level of debt reduces a firm's ability to support collusion. The larger the debt, the lower is the maximum discount rate at which the firm finds it convenient to respect any collusive agreement supported by trigger strategies.

The analysis with Bertrand competition turns out to be nearly the same as with Cournot. To simplify exposition in the rest of the paper we will follow Maksimovic by focusing on output decisions only. The results for the case of Bertrand competition, when at all different, are relegated to the appendix (Appendix B).

We wrote before that Maksimovic identifies and discusses the effect of several financial instruments – warrants, convertible debt, dividend restrictions (covenants) – by which shareholders can commit to a more prudent behavior and moderate the pro-competitive effect of debt. In the next sections we consider an alternative form of commitment against strategic defaults: the choice of "prudent" managers.

3 Managerial bankruptcy aversion, debt, and collusion

Maksimovic's results are derived under the standard assumption of profit maximizing firms. However, firms are often led by managers whose incentives may not coincide with shareholders' objectives (e.g. Herbert Simon, 1957; William Baumol, 1958; Oliver Williamson, 1964; Jensen and Meckling, 1976). Even when incentive contracts are so well designed as to lead managers to maximize owners' discounted profits under normal conditions, top managers usually face extra costs when their firms become bankrupt. For professional managers bankruptcy implies a substantial loss of reputation, together with either the loss of the job, or a drastic wage cut (linked to the effect of the loss of reputation on managers' reservation wage). For example, Stuart Gilson (1989) and Gilson and Michael Vetsuypens (1993) find that about half of the managers of firms facing financial distress are replaced and are not rehired by comparable (exchanged-listed) firms for the following three years, and that those who are retained experience very large reductions in salary and bonus.

Managers' losses from bankruptcy have already been taken into account in models addressing, for example, firms' capital structure (e.g. Stephen Ross, 1977) or business cycles (e.g. Bruce Greenwald and Joseph Stiglitz, 1990, 1993). It is therefore of some interest to understand how Maksimovic's result is affected by a firm's objective function which incorporates such losses, as in Ross (1977).

Managers' direct costs from financial distress may be fixed, or may vary depending on "how bad" financial problems are. To consider both cases, let $C_i \geq 0$ denote a fixed loss that the managers incur when the firm can't meet debt service obligations, and $c_i(b_i - \pi_i)$, $c_i \geq 0$, be a variable managerial cost increasing with the amount of debt the firm cannot honor. To simplify exposition it is also useful to define $\mathbf{C}_i = C_i + c_i(b_i - \pi_i^{NC})$.

To isolate the effects of debt and bankruptcy on managerial behavior and tacit collusion in this section we focus on managers under long-term profit-sharing compensation plans which lead them to maximize an objective function equivalent in all aspects to that of shareholders, except in the evaluation of debt and bankruptcy.

Definition 1 *Gross-profit-sharing, long-term contract (GPS): In every period managers are paid a fixed wage (normalized to zero without loss of generality) plus a bonus B^t positively related to that period's profits gross of financial costs: $B^t = \alpha\pi_i^t$, $0 < \alpha < 1$.*

Definition 2 *Net-profit-sharing, long-term contract (NPS): In every period managers are paid a fixed wage (normalized to zero without loss of generality) plus a bonus B^t positively related to that period's net profits, only when these are positive: $B^t = \alpha(\pi_i^t - b_i)^+$, $0 < \alpha < 1$.*

We first need a simple lemma.

Lemma 1 *With long-term, profit-sharing managerial contracts debt and managerial bankruptcy costs do not affect the Nash equilibrium of the static market game.*

This is so because under profit-sharing contracts managers maximize firms' profits, exactly as owners do. Managerial bankruptcy costs and debt repayments are independent of quantity choices, so they do not enter managers' static best response functions, leaving the static Nash equilibrium unaffected.

The long-term incentive contracts between managers and owners end when a change of control occurs. Therefore, after bankruptcy, debtholders can choose whether to replace old managers, or to retain them at a wage reduced by the negative effects of bankruptcy on their reservation wage.

Suppose first that debtholders replace managers when the firm goes bankrupt. With GPS contracts and managerial bankruptcy costs, the necessary and sufficient condition for the manager being willing to respect a stationary, collusive agreement delivering per-period profits π_i^A is

$$\alpha(\widehat{\pi}_i^A - \pi_i^A) \leq \alpha \frac{\pi_i^A - \pi_i^{NC}}{r} \tag{3}$$

for $b_i \leq \pi_i^{NC}$, which is the same as (1), and

$$\alpha(\widehat{\pi}_i^A - \pi_i^A) \leq \alpha \frac{\pi_i^A}{r} + \mathbf{C}_i, \quad \Leftrightarrow \quad r \leq r' = \frac{\pi_i^A}{\widehat{\pi}_i^A - \pi_i^A - \frac{\mathbf{C}_i}{\alpha}}. \tag{3a}$$

when $b_i > \pi_i^{NC}$.

When managers are under NPS contracts, the necessary and sufficient condition becomes instead

$$\alpha\left[(\widehat{\pi}_i^A - b_i) - (\pi_i^A - b_i)\right] \leq \alpha \frac{(\pi_i^A - b_i) - (\pi_i^{NC} - b_i)}{r} \tag{4}$$

for $b_i \leq \pi_i^{NC}$, which also reduces to (1), and

$$\alpha\left[(\widehat{\pi}_i^A - b_i) - (\pi_i^A - b_i)\right] \leq \frac{\alpha(\pi_i^A - b_i)}{r} + \mathbf{C}_i, \quad \Leftrightarrow \quad r \leq r'' = \frac{\pi_i^A - b_i}{\widehat{\pi}_i^A - \pi_i^A - \frac{\mathbf{C}_i}{\alpha}} \tag{4a}$$

for $b_i > \pi_i^{NC}$.

Suppose now that debtholders retain managers after bankruptcy. Conditions (3) and (4) remain unchanged, condition (3a) becomes

$$\alpha(\widehat{\pi}_i^A - \pi_i^A) \leq \alpha \frac{\pi_i^A - \pi_i^{NC}}{r} + \mathbf{C}_i \quad \Leftrightarrow \quad r \leq r^{\clubsuit} = \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A - \frac{\mathbf{C}_i}{\alpha}}, \tag{3b}$$

and, because after bankruptcy old debt is cleared, condition (4a) becomes

$$\alpha\left[(\widehat{\pi}_i^A - b_i) - (\pi_i^A - b_i)\right] \leq \alpha\frac{\pi_i^A - b_i - \pi_i^{NC}}{r} + \mathbf{C}_i \Leftrightarrow r \leq r^{\clubsuit\clubsuit} = \frac{\pi_i^A - \pi_i^{NC} - b_i}{\widehat{\pi}_i^A - \pi_i^A - \frac{\mathbf{C}_i}{\alpha}}. \tag{4b}$$

Comparing these conditions with (2) we obtain the following result.

Lemma 2 *Suppose managers are under long-term, profit-sharing contracts. If leverage is "low" ($0 \leq b_i \leq \pi_i^{NC}$), managerial bankruptcy costs do not affect firms' ability to collude. If leverage is "high" ($b_i > \pi_i^{NC}$), managerial bankruptcy costs facilitate collusion by increasing the maximum discount rate at which firms can support any collusive agreement in subgame perfect equilibrium in all cases except that in which managers are under NPS contracts, are not replaced after bankruptcy, and*

$$\mathbf{C}_i \leq \alpha(\widehat{\pi}_i^A - \pi_i^A)\frac{\pi_i^{NC}}{\pi_i^A - b_i}. \tag{5}$$

The case of NPS contracts when managers are not replaced is special because debt is cleared when debtholders gain control after bankruptcy. Condition (5') compares direct losses incurred by managers when the punishment phase that follows a deviation induces bankruptcy, with their share of gains from deviations and of future profits under the different regimes (collusive and non-cooperative). When the first are larger than the second, managerial bankruptcy costs always facilitate collusion.

What is more interesting, for positive levels of bankruptcy costs there is a range of "high" debt levels – increasing in such costs – at which (3a), (4a), (3b), and (4b) are all less stringent than (1), so that *debt* facilitates collusion by making tacit agreements supportable at higher discount rates. One can state the following result.

Proposition 1 *(I) Suppose managers are under GPS contracts and $\mathbf{C}_i > 0$. Then "high" leverage ($b_i > \pi_i^{NC}$) facilitates collusion by increasing the maximum discount rate at which firms can support any collusive agreement in subgame perfect Nash equilibrium.*

(II) Suppose managers are under NPS contracts. Then high leverage ($b_i > \pi_i^{NC}$) facilitates collusion as long as

$$\mathbf{C}_i > \alpha\frac{b_i - \pi_i^{NC}}{r^*} \tag{5a}$$

when managers are replaced after bankruptcy, and

$$\mathbf{C}_i > \alpha\frac{b_i}{r^*} \tag{5b}$$

when they are retained.

Statement (I) is obtained because when managers are under GPS contracts, debt affects their incentives *only* through the additional costs of bankruptcy, which make deviations more costly. Regarding statement (II), conditions (5a) and (5b) compare the additional direct losses incurred by managers when the punishment phase that follows a deviation induces bankruptcy, with the smaller losses from punishments the managers are subject to because of the flow of "negative profits/bonuses" from which they are protected by the asymmetry of the NPS contract. When the first are larger than the second, punishments are relatively harder for managers under NPS contracts than for owners of unleveraged firms and "high" leverage facilitates collusion.

To summarize, whatever their shape, whether $C_i > 0$ and $c_i = 0$, $C_i = 0$ and $c_i > 0$, or $C_i, c_i > 0$, when managerial bankruptcy costs are large (managers have a valuable reputation) high leverage facilitates collusion in all cases.

4 Debt, managerial incentives, and collusion

On the other hand, if managers were not "afraid" of bankruptcy, should not informed lenders be expected to anticipate the strategic default problem identified by Maksimovic, and ask for some alternative form of commitment before lending money to limitedly liable borrowers? Besides the financial commitments discussed by Maksimovic, in reality lenders often ask shareholders to commit by hiring a top manager with a solid reputation for "prudent behavior," who has much to lose from driving the firm into bankruptcy. For example, Gilson (1989) finds that a significant number of changes of management are initiated by creditors during debt restructuring.[3] However, managerial incentive schemes can do at least as well as managers' reputational losses from bankruptcy in inducing managers to take into account debtholders' interests. The idea of using contracts with a third party as a commitment device goes back at least to Shelling (1960) and has been studied in oligopolistic environments, for example, by John Vickers (1985), Chaim Fershtman (1985), Fershtman and Kenneth Judd (1987) and Steven Sklivas (1987).

With regard to the shareholder-debtholder relationship, Brander and Poitevin (1992) have shown – in a two-stage model which abstracts from the effects on the product market – that shareholders can moderate the asset substitution problem, minimize the cost of debt finance, and maximize firm value by committing to "conservative" (debtholder-friendly) strategies by means of an external manager under a suitable compensation package.

[3]Let us give an Italian example. When Mediaset, Berlusconi's media empire, got into financial troubles a couple of years ago, banks required that Franco Tató – probably the most highly reputed Italian top manager – should be hired as CEO as a condition *sine qua non* for renewing Mediaset's credits.

Brander and Poitevin analyze two kinds of conservative managerial incentive schemes. The first one is a *penalty contract,* which gives managers a per-period salary W as long as the firm is solvent, and the salary minus a penalty T in the period in which the firm is bankrupt (T may consist simply of managers' bankruptcy costs, discussed in the previous section).

The second incentive scheme they consider is a *bonus contract,* which implies a per-period wage composed of a salary W plus a fixed monetary bonus B paid only in periods in which the firm's profits are above a target level π^B. Brander and Poitevin show that the bonus contract is an "optimal contract" (although not the unique one), since through a suitable choice of the target π^B it leads to the ex ante first best outcome (maximizing firm value).

The asset substitution problem generated by limited liability is the mechanism behind both Brander and Poitevin's (1992) and Maksimovic's (1988) models. It is interesting therefore to derive the effects of these contracts within Maksimovic's repeated leveraged oligopoly model.

For the sake of simplicity we assume that when a manager is completely indifferent among two or more available strategies, he chooses the one that maximizes profits (if it exists). This lets the Nash-reversion threat remain credible when managers run the firms.[4]

Consider first the penalty contract. Suppose that such a contract is valid as long as shareholders are in control of the firm, and let R denote the manager's reservation wage. Plugging the outcome of the incentive contract into conditions (2), we obtain the necessary and sufficient condition for the manager being willing to support a collusive agreement when $b_i > \pi_i^{NC}$:

$$W + \frac{W}{r} \geq W + \frac{1}{1+r}(W - T) + \left(\frac{1}{1+r}\right)^2 \frac{R}{r}.$$

Managers' individual rationality constraint requires that $W \geq R$. When $W = R$ and managers earn no rents the condition reduces to

$$\frac{W}{r} \geq \frac{W}{r} - \frac{T}{1+r},$$

which is satisfied at any discount rate. When managers earn rents $W > R$ the condition is even less stringent (therefore it is also satisfied at any discount rate) as it becomes

$$\left(\frac{1}{1+r}\right)^2 \frac{W}{r} \geq \left(\frac{1}{1+r}\right)^2 \frac{R}{r} - \frac{1}{1+r}T.$$

Note that these conditions do not depend on the collusive agreement. This leads to the following result.

[4] Alternatively, one could let managers' compensation contain a small profit-sharing component, or assume that managers own a small amount of firm's shares.

Proposition 2 *When shareholders use "penalty" managerial contracts to reduce the agency costs of debt finance, highly leveraged firms ($b_i > \pi_i^{NC}$) can support any feasible stationary profit stream (which leaves firms solvent) in subgame perfect equilibrium of the repeated market game at any level of the discount rate.*

The point is that the penalty T has the same pro-collusive effect as the managerial costs analyzed in the previous section, while the fixed wage removes any incentive for managers to deviate from a collusive agreement. This result reinforces Brander and Poitevin's argument by which the relatively low power of real world managers' incentive schemes found by Jensen and Kevin Murphy (1990) could be attributed to the role of "conservative" managerial contracts as commitments towards borrowers. Proposition 2 shows that in oligopolies low-powered incentives, besides reducing the agency costs of finance, also maximize firms' value by allowing higher (collusive) profit streams to be supported in equilibrium. Also, Drew Fudenberg and Jean Tirole (1995) have shown that when information asymmetries on the quality of managers are brought into the picture, a "penalty" contract may be optimal even independently of financial and product market considerations.

One would expect that apparently "more aggressive" incentive schemes like bonus contracts would have less pro-collusive effects. However, we can borrow and adapt a result from Spagnolo (1996b).

Proposition 3 *When shareholders use bonus managerial contracts to reduce the agency costs of finance, any stationary collusive agreement that allows managers to receive the per-period bonus (including the joint monopoly agreement) can be supported in subgame-perfect equilibrium at any level of the discount factor.*

Proof: see Proof of Proposition 3 in Spagnolo (1996b).

The point is that the bonus incentive scheme, as the penalty one, is "capped" above.[5] If managers can sustain a stationary collusive agreement delivering profits higher or equal to the trigger level π^B they will have no incentive to deviate whatsoever; they cannot capture any further gain from a deviation, while the following punishment phase makes them lose future bonuses. This holds whatever the discount rate is.

The now fashionable and apparently more "competitive" incentive schemes related to stock price (stock options, cash bonuses linked to stock price, etc.) have also been shown to have strong pro-collusive effects. This is because the stock market anticipates the negative effects of the price/quantity war following a breach of collusion and managers incur a loss in the very same period in which they deviate (Spagnolo,

[5] Bonus schemes used in the real world are usually capped above (e.g. Robert Holthausen *et al.*, 1995; Paul Joskow and Nancy Rose, 1994; Paul Healy, 1985).

1998a). In fact, a proposition analogous to Proposition 3 could be stated here for incentive contracts related to stock price as well.

The pro-collusive effect of managerial bankruptcy costs identified in the previous section does not depend on managerial compensation contracts. Along the same lines as in Section 3, it can easily be shown that the effect is also present when managerial incentive contracts are of the kind considered in this section. The long-term profit-sharing contracts considered in the previous section are clearly the "less pro-collusive" among the incentive contracts one observes in the real world. So, in general, the pro-collusive effect of "conservative" managerial incentive schemes will add to that of managers' reputation costs of bankruptcy to determine the overall pro-collusive effect of debt.

5 Collusive lenders and product market rivalry

Both managerial losses from bankruptcy and managerial incentives must be observable in order to deliver the product market effects above. A top manager's reputation is observable by definition, and when not already in the public domain, managerial incentive contracts can easily be disclosed if this is in the interest of the firm. However, to have strategic effects commitments must also be credible, besides being observable. As pointed out by Mathias Dewatripont (1988), Michael Katz (1991), and others, in the case of contracts with a third party the credibility of the commitment can be undermined by agents' ability to secretly renegotiate the contract, particularly with perfect information. The same reasoning applies to managers' bankruptcy costs: shareholders might secretly promise extra compensation that covers such losses in order to induce top managers to default strategically.

It follows that one important way in which a concentrated credit market may facilitate collusion in product markets is by conferring credibility on shareholders' commitments to "conservative" (collusive) product market behavior. To emphasize the role of debt as a collusive device we adopt the following extreme assumptions:

Assumption 1 *Contract renegotiation is costless.*[6]

Assumption 2 *Condition (1) is not satisfied for any agreement* A :

$$r_i > r_i^* = \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A}, \quad \forall i, \forall A.$$

We will focus on the following contract:

[6]The assumption of zero renegotiation costs is clearly heroic: in the real world such costs can be substantial, particularly for public corporations with dispersed ownership and multiple lenders. It is clear, though, that adding renegotiation costs to the model can only strengthen all its results.

Definition 3 ***The Debt Contract:*** *"Shareholders receive today the amount of cash D_i against the promise of the coupon payment b_i in each future period, where $D_i = \frac{b_i}{r} - g_i$, under the condition that an external manager is hired under a long-term bonus contract (as defined in the previous section, with W_i normalized to 0, and $B_i > 0$) with target profits π_i^B, and $\pi_i^B \geq \pi_i^{NC}$."*

Here g_i denotes the amount of expected collusive profits that the lender extracts from each firm by selling overpriced debt.

When credit markets are collusive, lenders internalize externalities between them and act as a single lender. To simplify exposition we will focus on a monopolist lender, named L, and on *two firms* interacting in the infinitely repeated duopoly (the extension to N firms is straightforward). However, it is important to keep in mind that, from now on, *wherever we write about "a (common) lender," one could substitute "several distinct but 'allied' lenders,"* who are cooperating/colluding either in the classical sense, or because they belong to the same "financial coalition" (e.g. they have a large shareholder in common, they have joint ventures with each other or with a common partner, etc.).

Because there is the possibility that one firm deviates and drives the other bankrupt, we also need to make clear what happens afterwards. In line with Maksimovic, we stick to the following assumption:

Assumption 3 *After a firm goes bankrupt old managers are fired and the firm is sold to new profit-maximizing owners.*[7]

A monopolist lender will have all the bargaining power. Suppose that at the foundation of the industry (or in one given period τ) this lender L can make a take-it-or-leave-it offer of a debt contract to each firm owner.

Can the debt contract confer credibility to managerial contracts and facilitate collusion in the product market?

Consider first the case of a "low" debt contract ($b_i \leq \pi_i^{NC}$). When leverage is low and renegotiation costs are zero the lender does not lose from a deviation in the product market, since firms are able to repay debt even when they are stuck at the static Nash-Cournot payoffs. On the other hand, L may gain from a deviation by obtaining control of the non-deviating firm, if this goes bankrupt because of its competitor's deviation. Because owners' gains from deviating from a collusive agreement are always sufficient to compensate the manager for the loss of future bonuses and to induce him to deviate, all required parties may agree to a joint secret renegotiation of

[7] The alternative assumption, that after bankruptcy firms exit from the product market, readily transforms the model into a "predation" one. It can easily be shown that in this case debt makes collusion impossible: it greatly increases firms' incentives to deviate, drive competitors bankrupt, and monopolize the market, while no credible punishment is available to firms as a deterrent.

debt and managerial contracts, leading to a deviation from the collusive agreement. It follows that with zero renegotiation costs and low leverage, managerial incentives are not credible commitments and, by Assumption 2, no collusive agreement can be supported in the product market. More formally:

Lemma 3 *With zero renegotiation costs and "low" leverage ($b_i \leq \pi_i^{NC}$) managerial bonus contracts are not renegotiation-proof.*

Consider now "high" debt levels ($b_i > \pi_i^{NC}$). In this case – as in Maksimovic's model – when one firm deviates it drives the competing firm bankrupt, after which it becomes bankrupt itself because in the non-collusive (punishment) phase profits are below the debt-service requirements. However, here when a firm deviates from the collusive agreement the lender loses from the side of *both* borrowers. This makes him opposed to any renegotiation of the "conservative" managerial contracts leading to unilateral deviations. Formally:

Lemma 4 *Suppose a "high" debt contract ($b_i > \pi_i^{NC}$) is accepted by both owners. Then, for given managerial bonuses B_i, target profit levels π_i^B, and collusive profits π_i^A ($\pi_i^A \geq \pi_i^B$), the maximum discount rate at which the managerial contracts are renegotiation-proof is higher than that at which owners can collude and is monotonically increasing in firms' leverage. Furthermore, as long as*

$$0 < B_j \leq \widehat{\pi}_i^A + \underline{\pi}_j^A - \pi_i^A - \pi_j^A$$

and

$$\pi_i^A - B_i \geq b_i \geq \widehat{\pi}_j^A + \underline{\pi}_i^A - \pi_j^A, \ \forall i,$$

the debt contract is renegotiation-proof at any level of the discount rate.

In other words, there is a positive relation between firms' leverage and the ability of the debt contract to confer credibility on pro-collusive conservative managerial contracts. Whether managerial contracts are renegotiation-proof may depend on the discount rate because the lender's losses from a deviation are in terms of expected future repayments. So, the debt contract makes collusion supportable at discount rates at which unleveraged owners cannot collude, and for high enough leverage full collusion can be supported at any level of the discount rate.

Because there is only one lender (or a collusive credit sector) who has all the bargaining power, the lender will be able to extract collusive profits in advance and it will not matter whether the contract is offered simultaneously or sequentially to the two owners. However, we will see in the next section that this is not the case when credit markets are competitive and owners capture the collusive rent. Therefore, we will make clear already the timing with which the "capital structure game" develops, when it cannot be perfectly simultaneous for the two owners:

1. The lender offers the debt contract to one owner, *without signing it.*
2. The owner decides whether to sign the debt contract.
3. If the owner has signed, the lender offers the debt contract to the other owner.
4. The other owner decides whether to sign the contract.
5. If both owners have signed the contracts, the lender signs the contracts and finances the firms.
6. If everybody signed the contracts, managers start interacting in the product market supergame. Otherwise, owners do this.

Using Lemma 4 we can now state the proposition.

Proposition 4 *Even with zero renegotiation costs, by offering a debt contract with* $b_i = \pi_i^B = \pi_i^M - B_i$ *the monopolist (or colluding) lender(s) can make managerial contracts renegotiation-proof and implement the joint monopoly agreement as the unique subgame perfect collusive equilibrium at any discount rate. Furthermore, when the lender leaves some of the collusive profits to owners by choosing* $g_i < \frac{\pi_i^M - B_i - \pi_j^{NC}}{r}$, *accepting the debt contract is owners' strictly dominant strategy.*

In other words, everybody is happy – shareholders, debtholders, and managers – except the consumer (and the competition authority, when it has not been captured as well). Of course, a profit maximizing monopolist lender will extract most of the collusive rent, or all the rent minus some minimum "fair" share that guarantees the owners' acceptance. The discounted flow of bonuses $\frac{B_i}{r}$ is the stake of the collusive rent appropriated by managers, and can be interpreted as the intrinsic cost of the commitment technology. Such a cost will depend on the conditions in the managerial labor market, and will tend to zero when this is perfectly competitive. Again, the results above apply whether L is a single monopolist or a concentrated credit sector in which many distinct lenders are colluding.[8]

Also, we have focused on shareholders' commitments to "conservative" product market strategies through managerial incentive contracts. However:

[8] Let us take, again, an Italian example. Most Italian banks have been semi-public in the last decade, and the government's objective has been financial stability rather than competition in product markets. Banks' officials had no incentive whatsoever to induce competition in product markets, as collusive industries are safe sources of income for the banking sector. The few private financing sources have been controlled indirectly by a single investment bank called Mediobanca, which has had veto power on the choice of top managers in most, if not all large Italian groups (financial and non). Bank Lazeard in France and Deutch Bank in Germany appear to have played similar "coordinating" roles.

Remark 1 *Lemmas 3 and 4 and Proposition 4 (and their proofs) hold unmodified when owners commit through the choice of a manager with a valuable reputation. Under such interpretation B_i stands for the (flat) wage differential commanded by the manager's reputation (no-reputation managers' reservation wage was normalized to zero), and $\frac{B_i}{r}$ for the discounted value of the loss of reputation the manager incurs when his firm goes bankrupt.*

In either case the messages of this section are clear: Lemma 3 and Lemma 4 imply a positive relation between leverage and market prices, Lemma 4 and Proposition 4 imply that a concentrated/collusive financial sector, besides colluding on credit price/output, has strong incentives and suitable instruments to "export" collusion through finance in otherwise competitive product markets.

6 Competitive credit markets and multiple lenders

6.1 Large lenders in competitive credit markets

What if credit markets are competitive? Is a competitive financial sector sufficient to prevent the pro-collusive effects of debt-finance? The answer "no" follows naturally from the results in the previous section. Even with perfect competition, as long as firms borrow from the same lender – or from two distinct but allied lenders (for example, belonging to the same large banking group), – such a lender(s) internalizes part of the product market externalities and is therefore able to guarantee the credibility of commitments to "conservative" (collusive) product market behavior. By inspection:

Remark 2 *Even when the credit market is competitive, Lemmas 3 and 4 apply as long as firms borrow from a common lender (or from two allied lenders).*

The difference, of course, is that with competitive credit markets the lender(s) won't be able to extract much of the collusive rent. Now owners have all the bargaining power, and they can make take-it-or-leave-it offers to any large enough lender (the common lender, or the couple of allied lenders, must be large because when $\pi_i^{NC} > 0$ only "high" debt contracts with both firms work as commitment devices against renegotiation). In this case, the timing with which debt is issued becomes important. Because the rent goes to firm owners, the lender has to pay them in advance the equivalent of future gains from collusion. If the lender begins to finance one firm, it makes some costs sink and increases the other firm's bargaining power, which may leave the lender with negative profits even though after debt is issued collusion is sustained. Anticipating this, no lender would be willing to finance firms sequentially. The first owner may be willing to give up some of his rent in order to induce the lender to finance him, but then no owner will want to issue debt first; owners will be caught in a "chicken" game.

One obvious way out of this problem is to arrange for a simultaneous capital structure game, that is, to make sure that owners decide simultaneously whether or not to accept the debt contract. However, this may be impractical, unrealistic, or subject to the judgement of the competition authority. The fact that the debt contracts need not be signed simultaneously by the two parties means that this problem can be overcome by designing the "capital structure game" in the way described in Section 5. Then, in line with Proposition 4, one can state the following result.

Proposition 5 *Suppose credit markets are competitive and the "capital structure game" is designed as described in Section 5 (or is simultaneous for owners). Then, by raising high levels of debt ($b_i = \pi_i^B = \pi_i^M - B_i$) from the same lender, owners can make managerial contracts renegotiation-proof and implement the joint monopoly agreement as the unique subgame perfect collusive equilibrium at any discount rate. Further, accepting the debt contract is a strictly dominant strategy for each owner.*

Again, the statement focuses on managerial contracts, but exactly the same argument applies to commitments through the choice of a manager with a highly valuable reputation. Of course, the lender must be large enough to finance both firms, which implies that the average size of competing credit institutions must be large relative to firms in the product market.

6.2 Multiple independent lenders

One might think that, with competitive credit markets, a multiplicity of unrelated firm lenders would greatly reduce the pro-collusive effects of debt. So, what if no lender or coalition of lenders is large enough or willing to completely finance both firms? Suppose that each firm i is financed by a pool of many (say N_i) independent lenders, that credit markets are competitive, and that only one lender is in both pools (or is allied to one of the lenders in the other pool), holding a share γ_i, where $0 < \gamma_i < 1$, of each firm i's debt.

As a benchmark, consider first the case of equal involvement of the common (allied) lender(s) with the two competing firms, so that $\gamma_i = \gamma_j = \gamma$, and suppose that all debts have the same seniority (the pro-collusive effect does not depend on these simplifications; see the following subsections). We obtain the following result.

Proposition 6 *Suppose that (at least) one of the firms' lenders is in common with a share γ of the debt, and that the "capital structure game" is designed as described in Section 5 (or is simultaneous for owners). Then, by raising high levels of debt with $b = \pi^B = \pi^M - B$ owners can:*

(i) make managerial contracts renegotiation-proof and implement the joint monopoly collusive agreement as the unique collusive equilibrium at any discount rate by choosing $B < 2\pi^M - \widehat{\pi}^M + \underline{\pi}^M$ *as long as* $1 \geq \gamma \geq \frac{\widehat{\pi}^M - \pi^M}{\pi^M - \underline{\pi}^M - B}$;

(ii) for any B *and* γ, *make managerial contracts renegotiation-proof and implement the joint monopoly collusive agreement as the unique collusive equilibrium at higher discount rates than the maximum at which owners can sustain it. Furthermore, accepting the debt contract is a strictly dominant strategy for each owner.*

In other words, as long as loans from a common lender are not too small, the pro-collusive effect is still very strong. Then, an owner's short-run gains from deviation will not suffice to compensate the manager for the expected bonus (or reputational) losses, the independent lenders for the loss of future coupon repayments, and the common lender's losses from both the competing firms' financial distress. And even when the common lender is very small, the pro-collusive effect remains, since the maximum discount rate at which leveraged firms are able to sustain any collusive agreement is always higher than that at which unleveraged firms (owners) can sustain it.

Let us now turn to the effects of asymmetries in the exposure of the lender(s) towards the two firms and of debt structure, that is, the seniority of the different debtholders' claims.

6.3 Asymmetries

To understand the role of asymmetries in claims of the common (or allied) lender(s) towards the two firms we let $\gamma_i \neq \gamma_j$. The case of a **single common lender** is straightforward. We can state the following proposition without proof.

Proposition 7 *Given the total amount of the common lender's claims, the pro-collusive effect of debt decreases with the degree of asymmetry in credits from the two firms.*

This is so, of course, because the pro-collusive effect of debt applies only as long as it prevents deviations from *both* firms. When $\gamma_i > \gamma_j$, the common lender (or the couple of allied lenders) loses less when firm i deviates than when firm j does so, and hence the cost of a secret renegotiation that leads the manager to deviate from a collusive agreement is smaller for firm i. Because owners of firm j are aware of this, they will stick to collusion only if firm i's cost of secret renegotiation (increasing in γ_j) is high enough to prevent it. It follows that the pro-collusive effect of a common lender's debt is increasing in $\min\{\gamma_i, \gamma_j\}$, and therefore is maximal when $\gamma_i = \gamma_j$.

One might think of this result as an easy rule of thumb which can be used to distinguish between cases in which common lending may or may not have serious anti-competitive consequences. Given a common lender's total claims towards competing firms, when the lender has a much smaller stake in one firm than in the other(s) the risk of anti-competitive effects should be low. However, such a rule of thumb may be misleading, as it applies *only* to the case of a single common lender (or a single couple of allied lenders).

In fact, consider the more interesting case of **more than one common lender**. Suppose that, say, two of the N_i and N_j lenders, named 1 and 2, are in both pools of creditors. Let γ_i^h, $h \in \{1, 2\}$, denote the share of lender h's total credit that goes to firm i, and suppose that the common lenders' exposure is strongly asymmetric, so that each lender specializes by lending much more to one firm than to the other.

Proposition 8 *Suppose two (or more) lenders are in common but specialize with different firms. Then the pro-collusive effect is not dependent on the asymmetry of each common lender's claims, but decreases with the asymmetry of total claims from common lenders, that is, it increases with* $\min\left\{\gamma_i^1 + \gamma_i^2;\ \gamma_j^1 + \gamma_j^2\right\}$.

The point is that when a common lender is specialized, he suffers a big loss if secret renegotiation followed by a deviation takes place for the managerial contract of the firm with which he is *not* specialized. Therefore, when two common lenders are specialized with different firms, for each firm there will be one non-specialized common lender with a strong interest in blocking secret renegotiation. This guarantees against renegotiation in both firms and allows collusion to be implemented.

To see how misleading a rule of thumb based on the asymmetry of each common lender's claims could be, consider the case of two common lenders of equal size, with $\gamma_i^1 + \gamma_j^1 = \gamma_i^2 + \gamma_j^2$. In this case the maxima of $\min\left\{\gamma_i^1 + \gamma_i^2;\ \gamma_j^1 + \gamma_j^2\right\}$ are obtained whenever $\gamma_i^1 + \gamma_i^2 = \gamma_j^1 + \gamma_j^2$. From this follows a simple consideration:

Remark 3 *The anti-competitive effect is* maximal *when the two common lenders specialize almost completely in different firms, maintaining in the other firm only the* minimum *amount of claims necessary to be informed of managerial contract renegotiations.*

That is, with more than one common lender, what could appear to be a "marginal" degree of common lending, with strong asymmetries at each lender level, has the strongest possible anti-competitive effect. Moreover, when each of the "common lenders" is composed of a couple of allied but distinct lenders, so that a lender 1^i in N_i holding γ_i^1 of firm i's debt is cooperating with a lender 1^j holding γ_j^1 of firm j's debt, and the same happens to another two lenders 2^i and 2^j, such a pro-collusive degree of common lending will appear even more marginal, if it appears at all (many cooperative relations between firms or banks are implicit and are not made public).

6.4 Seniority

The pro-collusive effect of debt depends on the seniority of the common (or related) lenders' claims, as this affects the distribution of losses from financial distress between debtholders. Consider the case one common lender with symmetric claims $\gamma_i = \gamma_j = \gamma$, and let η, $0 \leq \eta \leq 1$, denote the fraction of other creditors' claims that is senior with respect to the common lender's ones. Then $\eta(1-\gamma)$ and $(1-\eta)(1-\gamma)$ are the fractions of firm's debt that are respectively senior and junior with respect to the common lender's claims. We obtain the following result.

Proposition 9 *The pro-collusive effect of a common lender (or of several allied lenders) is monotonically increasing with η, i.e. is decreasing in the seniority of its (their) claims.*

The intuition behind this result is straightforward: the more debt has been issued senior to that of the common lender (the larger η,), the larger will be the common lender's losses when collusion breaks down and firms enter financial distress, the larger will be the stake of firms' externalities it internalizes, and the stronger will be its aversion to deviations from collusion through secret renegotiation.

This result implies that in real world industries where large finance-providers play the pro-collusive role modelled here, firms' debt structure should be such that large banks' claims are junior with respect to other debtholders' claims. Further, because in the absence of common lenders collusion is harder to sustain, we should expect such debt structure to be reached in two steps. First, firms borrow from large common (or allied) credit institutions who are able to ensure prudent managerial behavior and firms' profitability (collusion) from the beginning; then, senior claims are issued to other debtholders under good conditions, given the expected profitability ensured by the common lender's pre-existing junior debt.

To conclude, it should be noted that our working assumption of given (zero) renegotiation costs is strongly unrealistic for the case with multiple lenders. Taking into account the positive relation between renegotiation costs and the number of debtholders identified, for example, by Patrick Bolton and David Scharfstein (1996), will strengthen the anti-competitive effect of common or allied lenders.

7 Policy implications and conclusions

7.1 Policy implications

The implications of the model for competition policy are straightforward. First, the financial sector should be up on the list of the competition authorities, as it can easily export collusion and monopolize otherwise competitive downstream product markets. Second, collusive profits from oligopolistic product markets are a safe source of stable income for the financial sector; therefore the policy objectives of competition and stability in the financial sector may clash with each other. Concentrating both the financial sector's anti-trust and supervision powers in the hands of the same authority, as is the case, for example, of the Italian central bank, may lead to poor results on at least one of the two policy objectives (letting banks monopolize product marketand enjoy safe and stable collusive profits may reduce bankruptcy risks in the financial sector, thereby substituting for the authority's effort in supervision).

Below we briefly discuss implications with regard to the relative efficiency of different corporate governance systems and to the issue of transition from state to private finance.

7.1.1 Credit market competition, efficiency, and growth

We have focused on lenders' ability to induce collusion in product markets through their control over the choice of managers and of their incentives. However, concentrated credit markets can further facilitate collusion and increase (firms' and banks') profits by increasing entry barriers, that is, by rationing credit to wealth-constrained entrepreneurs who are willing to enter the oligopolistic industries to which they are lending. This may allow large oligopolistic banks to thrive with the safe and profitable finance of mature and collusive oligopolistic industries, on the shoulders of the consumers. Collusion in product markets may have some positive long-run effects, for example in terms of lower variance of firms' profits, lower probability of bankruptcy, and therefore higher willingness of firms to undertake long-term investments. However, in the long run such collusive financial practices may eventually lead to an aggregate shortage of finance for smaller firms in dynamic industries with higher growth opportunities, which tends to reduce the growth possibilities of the overall economic system, employment, and welfare.[9]

A story of collusive financial practices like the one in this paper seems to fit well the stylized fact that in continental Europe, where finance is dominated by large oligopolistic banks, existing firms have a longer expected life and a smaller number of new firms are created and financed than in Anglo-Saxon countries, where financial markets are more fragmented and competitive.

7.1.2 Transition

Abstracting from (important) issues such as politics, lobbying, and corruption, when firms' finance is centralized and public a benevolent state-lender should be able to

[9] I thank Sven-Olof Fridolfsson who suggested this implication.

avoid tacit collusion and maximize social surplus by controlling managerial incentives (say, giving firms' managers incentives linked to sales, or convex in profits). This means that, theoretically, the transition from centralized state finance to private but imperfectly competitive finance could bring about a large loss of social welfare through "collusion diffusion" from financial to product markets, with a substantial redistribution from consumers to banks and firms.

Of course, once political economy, asymmetric information, and firms' internal efficiency issues are brought into the picture things will not be so straightforward and the costs of state finance can become large enough to make even the transition to a highly concentrated privatized credit market an improvement for social welfare. However, the message of the model above is that great care should be taken to ensure that post-transition financial markets are sufficiently competitive, because concentrated financial markets may raise substantially the welfare cost of transition.

7.2 Concluding remarks

The simple picture which we have drawn seems to capture important aspects of the real world, and it fits nicely many empirical regularities encountered in applied corporate finance.

We have tried to keep the model as simple as possible, and therefore it is open to extensions in many directions. For example, asymmetric information could be introduced in several ways, and more sophisticated debt contracts, managerial incentive schemes, and punishment strategies could be analyzed. My guess, though, is that neither of these complications will change the flavor of the results.

Finally, the model offers several testable predictions. First, the model obviously implies that managerial rents and pro-collusive (low-powered or stock-based) incentive schemes should be more common where industry leverage is positively related to firms' markups. In cross-country studies, this correlation should also be increasing with the concentration of financial markets. One could also check whether large banks (or coalitions of banks) tend to specialize in particular industries, and especially in more concentrated ones.[10] Finally, one could check whether large common (allied) lenders' claims tend to be junior, and to be issued before other classes of debt.

[10] I am grateful to Tore Ellingsen who suggested this implication.

8 Appendix

8.1 Appendix A: Proofs

8.1.1 Proof of Lemma 1

With regard to the stage game, managers' compensation under profit–sharing contracts is a monotone transformation of firms' profit function; that is, managers' objective function is a monotone transformation of owners' objective function. The set of Nash equilibria of a game is not affected by monotone transformations of payoff functions, as these generate ordinally equivalent games. **Q.E.D.**

Example: Cournot oligopoly. Let q_i denote the production level of firm i, Q total production, $p(Q)$ the inverse demand function and $k_i(q_i)$ firm i's cost function. In the static market interaction, managers under GPS maximize the discontinuous objective function

$$\alpha\pi_i = \alpha\left[p(Q)q_i - k_i(q_i)\right]$$

for $\pi_i \geq b_i$, and

$$\alpha\pi_i - C_i - c_i(b_i - \pi_i) = (\alpha + c_i)\left[p(Q)q_i - k_i(q_i)\right] - C_i - c_i b_i$$

for $\pi_i < b_i$. For $\pi_i \geq b_i$, the F.O.C. for profit maximization with respect to q_i is

$$\alpha\left[p'(Q)q_i - p(Q) - k_i'(q_i)\right] = 0, \quad \Leftrightarrow \quad p'(Q)q_i - p(Q) = k_i'(q_i),$$

as in the no-debt case. For $\pi_i < b_i$ the F.O.C. is

$$(\alpha + c_i)\left[p'(Q)q_i - p(Q) - k_i'(q_i)\right] = 0, \quad \Leftrightarrow \quad p'(Q)q_i - p(Q) = k_i'(q_i),$$

again, as in the no debt case. Managers under NPS maximize the objective function

$$\alpha(\pi_i - b_i) = \alpha\left[p(Q)q_i - k_i(q_i) - b_i\right]$$

for $\pi_i \geq b_i$, and

$$-C_i - c_i(b_i - \pi_i) = c_i\left[p(Q)q_i - k_i(q_i) - b_i\right] - C_i$$

for $\pi_i < b_i$. In this case also the F.O.C. for profit maximization with respect to q_i is

$$p'(Q)q_i - p(Q) = k_i'(q_i),$$

as in the no-debt case. Because firms' best response functions are not affected by the profit-sharing managerial contracts, by debt, or by managerial bankruptcy cost, the Nash equilibrium is not affected either.

8.1.2 Proof of Lemma 2

The first statement follows from (2), (3), and (4) being all equivalent to (1). For the second statement, when $b_i > \pi_i^{NC}$ the relevant conditions are (3a) and (4a) when managers are replaced after bankrupt, and (3b) and (4b) when they are not. By inspection, (3a), (4a), and (3b) are always less stringent than (2), while (4b) is less stringent than (2) when

$$r^{**} < r^{\clubsuit\clubsuit} \iff \frac{\pi_i^A - b_i}{\widehat{\pi}_i^A - \pi_i^A} < \frac{\pi_i^A - b_i - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A - \frac{C_i + c_i(b_i - \pi_i^{NC})}{\alpha}},$$

or, equivalently, when

$$\frac{C_i + c_i(b_i - \pi_i^{NC})}{\alpha} > \alpha(\widehat{\pi}_i^A - \pi_i^A)\frac{\pi_i^{NC}}{\pi_i^A - b_i}.$$

Q.E.D.

8.1.3 Proof of Proposition 1

(I) When $b_i > \pi_i^{NC}$, managers are under GPS and they are replaced after bankruptcy, debt relaxes incentives to collude whenever

$$r' = \frac{\pi_i^A}{\widehat{\pi}_i^A - \pi_i^A - \frac{C_i + c_i(b_i - \pi_i^{NC})}{\alpha}} > \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A} = r^*,$$

which, by inspection, is always satisfied. Analogously, when managers are not replaced one must compare (3b) and (1), and, by inspection, it is always $r^{\clubsuit} > r^*$. (II) Under NPS, if managers are replaced after bankruptcy, high debt ($b_i > \pi_i^{NC}$) facilitates collusion when

$$r'' = \frac{\pi_i^A - b_i}{\widehat{\pi}_i^A - \pi_i^A - \frac{C_i + c_i(b_i - \pi_i^{NC})}{\alpha}} > \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A} = r^*,$$

an inequality that simplifies to

$$C_i + c_i(b_i - \pi_i^{NC}) > \alpha(b_i - \pi_i^{NC})\frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A},$$

which by substituting from (1) gives (5a). When managers are not replaced after bankruptcy, debt facilitates collusion when

$$r^{\clubsuit\clubsuit} = \frac{\pi_i^A - \pi_i^{NC} - b_i}{\widehat{\pi}_i^A - \pi_i^A - \frac{C_i + c_i(b_i - \pi_i^{NC})}{\alpha}} > \frac{\pi_i^A - \pi_i^{NC}}{\widehat{\pi}_i^A - \pi_i^A} = r^*$$

an inequality that simplifies to

$$C_i + c_i(b_i - \pi_i^{NC}) > \alpha b_i \frac{\widehat{\pi}_i^A - \pi_i^A}{\pi_i^A - \pi_i^{NC}},$$

which by substituting from (1) leads to (5b). **Q.E.D.**

8.1.4 Proof of Lemma 3

After the contract is concluded and debt is issued by both owners, if collusion is sustained each period then owners get $\pi_i^A - b_i - B_i$, managers get B_i, and the lender gets $b_i + b_j$. If instead one owner persuades the manager to deviate, that owner gets $\widehat{\pi}_i^A - b_i - B_i$ immediately and $\pi_i^{NC} - b_i$ afterwards, i.e. net expected gains $\widehat{\pi}_i^A - \pi_i^A - \frac{\pi_i^A - B_i - \pi_i^{NC}}{r} > 0$. If a manager deviates he loses future bonuses $\frac{B_i}{r}$, and must be compensated for such loss in order to be persuaded to deviate. Regarding the lender, we must distinguish two cases. (A) Suppose $b_i \leq \underline{\pi}_i^A$, so that when a firm deviates the competing firm does not go bankrupt. Then the lender loses and gains nothing from a deviation, since even during the punishment phase owners can repay the debt. It follows that an owner has just to compensate the manager in order to renegotiate the contract, and therefore the contract is renegotiation-proof if

$$\frac{B_i}{r} \geq \widehat{\pi}_i^A - \pi_i^A - \frac{\pi_i^A - B_i - \pi_i^{NC}}{r}, \Leftrightarrow 0 \geq \widehat{\pi}_i^A - \pi_i^A - \frac{\pi_i^A - \pi_i^{NC}}{r},$$

which is never satisfied, since the RHS is strictly positive according to our assumption that condition (1) is not satisfied. (B) Suppose $\pi_i^{NC} > b_i > \underline{\pi}_i^A$. Then if a firm deviates, the other firm goes bankrupt. In such a case the lender also gains from a unilateral deviation in the product market, as when a firm goes bankrupt the lender obtains the right to the residual profit flow $\frac{\pi_i^{NC} - b_i}{r}$. This means that the lender will also have incentives to induce one manager to deviate by compensating him for the loss of future bonuses caused by a deviation. Therefore, the contract is renegotiation-proof when

$$\frac{B_i}{r} \geq \widehat{\pi}_i^A - \pi_i^A + \frac{\pi_i^{NC} - b_i}{r} - \frac{\pi_i^A - B_i - \pi_i^{NC}}{r}, \Leftrightarrow 0 \geq \widehat{\pi}_i^A - \pi_i^A + \frac{\pi_i^{NC} - b_i}{r} - \frac{\pi_i^A - \pi_i^{NC}}{r}$$

which is always false, since the RHS is strictly positive by the assumption that (1) is not satisfied. **Q.E.D.**

8.1.5 Proof of Lemma 4

After debt is issued collusion is sustained at a level $\pi_i^A \geq \pi_i^B$, and in each period owners get $\pi_i^A - b_i - B_i$, managers get B_i, and the lender gets $b_i + b_j$. If one owner persuades his manager to deviate, that owner gets $\widehat{\pi}_i^A - b_i - B_i$ immediately and zero afterwards; his net expected gains are $\widehat{\pi}_i^A - \pi_i^A - \frac{\pi_i^A - b_i - B}{r}$, which are strictly positive according to Assumption 2. When firm i deviates the lender loses present profits $b_j - \underline{\pi}_j^A$ from the non-deviating firm's immediate default on debt-service payments, the discounted expected debt repayments from the bankrupt non-deviating firm minus its residual value $\frac{b_j}{r} - \frac{\pi_j^{NC}}{r}$, and the discounted expected debt repayments from the deviating firm minus its residual value $\frac{b_i}{r} - \frac{\pi_i^{NC}}{r}$, since in the period after the deviation the deviating firm earns only $\pi_i^{NC} < b_i$ and goes bankrupt. If a manager deviates he loses future bonuses $\frac{B_i}{r}$. The contract is renegotiation-proof if owner's gains from a unilateral deviation in the product market are not sufficient to compensate both the manager and the lender for their losses from the deviation, that is, if

$$\widehat{\pi}_i^A - \pi_i^A - \frac{\pi_i^A - B - b_i}{r} < \frac{B}{r} + \left[b_j - \underline{\pi}_j^A + \frac{b_j - \pi_j^{NC}}{r} + \frac{b_i - \pi_i^{NC}}{r} \right],$$

or, equivalently, if

$$r < r_i^D = \frac{\pi_i^A - \pi_i^{NC} + (b_j - \pi_j^{NC})}{\widehat{\pi}_i^A - \pi_i^A - \left(b_j - \underline{\pi}_j^A\right)}.$$

By inspection r_i^D is increasing in b_j, and by direct comparison with inequality (1) $r_i^D > r_i^*$ for every $b_j > \pi_j^{NC}$, which proves the first statement. Now rewrite the condition above as

$$r \left[\widehat{\pi}_i^A - \pi_i^A - \left(b_j - \underline{\pi}_j^A\right) \right] < \pi_i^A + b_i - 2\pi_i^{NC},$$

and note that by assumption the RHS is always strictly positive. Consider first the case in which $(\pi_j^B =)\ b_j = \pi_j^A - B_j$ so that the LHS becomes

$$r \left[\widehat{\pi}_i^A + \underline{\pi}_j^A - (\pi_i^A + \pi_j^A) + B_j \right].$$

As long as B_j is not too large and the collusive industry output is smaller than or equal to the monopoly output this term is strictly negative: industry output at the collusive agreement, $q_i^A + q_j^A$ is lower than industry output when one firm unilaterally deviates choosing $\widehat{q}_i(q_j^A) > q_i^A$. Therefore (however they are split) total industry collusive profits are larger than industry profits when a firm deviates unilaterally, that is,

$$\pi_i^A(q_i^A + q_j^A) + \pi_j^A(q_i^A + q_j^A) > \widehat{\pi}_i^A(\widehat{q}_i(q_j^A), q_j^A) + \underline{\pi}_j^A(\widehat{q}_i(q_j^A), q_j^A),$$

so that

$$r \left[(\widehat{\pi}_i^A + \underline{\pi}_j^A) - (\pi_i^A + \pi_j^A) - B_j \right] \leq 0 \text{ as long as } 0 < B_j \leq \widehat{\pi}_i^A + \underline{\pi}_j^A - (\pi_i^A + \pi_j^A).$$

Therefore when $b_j = \pi_j^A - B_j$ and $B_j \leq \widehat{\pi}_i^A + \underline{\pi}_j^A - (\pi_i^A + \pi_j^A)$, the condition for managerial contracts to be renegotiation-proof is strictly satisfied at any discount rate. By continuity, there exist other levels of debt $b_j < \pi_j^A - B_j$ for which the same condition holds, and there is a lower bound b_j^* such that for $\pi_j^A - B_j \geq b_j \geq b_j^*$ the contract is renegotiation-proof at any level of r, where b_j^* satisfies

$$\widehat{\pi}_i^A - \pi_i^A - \left(b_j^* - \underline{\pi}_j^A\right) = 0 \ \Leftrightarrow \ b_j^* = \widehat{\pi}_i^A + \underline{\pi}_j^A - \pi_i^A.$$

Q.E.D.

8.1.6 Proof of Proposition 4

The first statement follows straightforwardly from Proposition 3 and Lemma 4. For the second statement, consider owners' expected payoffs when a debt contract is offered. If both owners accept the deal each of them gets $D_i = \frac{b_i}{r} - g_i$ immediately and expects net profits $\pi_i^M - b_i - B_i$ in each future period, with total expected profits $\frac{\pi_i^M - B_i}{r} - g_i$. If both owners refuse the deal, they remain stuck at the static Cournot-Nash equilibrium for ever. If one owner, say j, accepts but owner i does not, collusion cannot be supported and firms are again stuck at the Cournot-Nash equilibrium. However, while the firm that refuses the deal gets expected profits $\frac{\pi_i^{NC}}{r}$, the firm that accepts it gets $D_j = \frac{b_j}{r} - g_j$ immediately and expects net profits $max\left\{\pi_j^{NC} - b_j, 0\right\}$ in each future period. When $b_i = \pi_i^B = \pi_i^M - B_i$ owners' expected payoffs matrix in the "capital structure game" is

$$\begin{pmatrix} \frac{\pi_i^M - B_i}{r} - g_i, \frac{\pi_j^M - B_j}{r} - g_j; & \frac{\pi_i^M - B_i}{r} - g_i, \frac{\pi_j^{NC}}{r} \\ \frac{\pi_i^{NC}}{r}, \quad \frac{\pi_j^M - B_j}{r} - g_j; & \frac{\pi_i^{NC}}{r}, \quad \frac{\pi_j^{NC}}{r} \end{pmatrix},$$

and the extensive form is

FIGURE 1 ABOUT HERE

By inspection, as long as the lender limits rent extraction choosing $g_i < \frac{\pi_i^M - B_i}{r} - \frac{\pi_i^{NC}}{r}$ it is a strictly dominant strategy for each owner to accept the debt contract. **Q.E.D.**

8.1.7 Proof of Proposition 5

As long as $g_i + g_j > 0$ there will be competition among lenders for this rent, and owners may use such competition to reduce the lender's stake indefinitely. Once $g_i + g_j = 0$ the lenders break even, and we can assume that firms will find at least one lender (or one couple of allied lenders) willing to offer and sign the debt contracts. The payoff matrix and the extensive form of the "capital structure game" will be as in the previous proof and, by inspection, for any $0 \leq g_i < \frac{\pi_i^M - B_i}{r}$ it is a strictly dominant strategy for both owners to sign the debt contract. **Q.E.D.**

8.1.8 Proof of Proposition 6

To induce a deviation through renegotiation, owners must compensate the manager for the expected loss of bonuses after the deviation, all debtholders for the loss of future coupons, and the common lender also for the extra loss from the competing firms' financial distress. With $b = \pi^B = \pi^M - B$ and without deviations, the non-common lenders together expect the full repayment streams with discounted value $(1 - \gamma)\left(\pi^M - B + \frac{\pi^M - B}{r}\right)$, and the common lender expects full repayment streams with discounted value $\gamma\left(\pi^M - B + \frac{\pi^M - B}{r}\right)$ from both firms. After the deviation, debtholders of the deviating firm together expect the remaining discounted value of the firm $\frac{\pi^{NC}}{r}$. Therefore, to compensate losses from the financial distress of the deviating firm only the owner must pay the amount $\frac{B}{r} + \frac{\pi^M - B - \pi^{NC}}{r}$. In addition, the common lender must be compensated for the extra loss he incurs in the non-deviating firm, which amounts to $\gamma\left(\pi^M - B + \frac{\pi^M - B}{r}\right) - \gamma\left(\underline{\pi}^M + \frac{\pi^{NC}}{r}\right)$. So managerial contracts are renegotiation-proof and the joint monopoly collusive agreement is supportable when

$$\widehat{\pi}^M - \pi^M < \frac{B}{r} + \left[\frac{\pi^M - B - \pi^{NC}}{r}\right] + \gamma\left[\pi^M - B - \underline{\pi}^M + \frac{\pi^M - B - \pi^{NC}}{r}\right],$$

or, equivalently, when

$$r\left[\widehat{\pi}^M - \pi^M - \gamma(\pi^M - \underline{\pi}^M - B)\right] < (1+\gamma)(\pi^M - \pi^{NC}) - \gamma B.$$

As long as $B < \frac{1+\gamma}{\gamma}(\pi^M - \pi^{NC})$, which is always satisfied because no debt contract is feasible if a multiple of total gains from collusion must be paid to the manager, the LHS is strictly positive and the condition is satisfied for any r when

$$\left[\widehat{\pi}^M - \pi^M - \gamma(\pi^M - \underline{\pi}^M - B)\right] \leq 0.$$

We know that $\frac{\widehat{\pi}^M - \pi^M}{\pi^M - \underline{\pi}^M} < 1$ because $2\pi^M > \widehat{\pi}^M + \underline{\pi}^M$: industry profits are maximized at the joint monopoly agreement (industry output is higher and industry profits are lower when a deviation occurs). It follows that as long as $B < 2\pi^M - \widehat{\pi}^M + \underline{\pi}^M$, $\frac{\widehat{\pi}^M - \pi^M}{\pi^M - \underline{\pi}^M - B} < 1$, and

$$1 \geq \gamma \geq \frac{\widehat{\pi}^M - \pi^M}{\pi^M - \underline{\pi}^M - B}$$

the condition above is satisfied for any r. This proves claim (i). When $\gamma < \frac{\widehat{\pi}^M - \pi^M}{\pi^M - \underline{\pi}^M - B}$ the contract is renegotiation-proof as long as

$$r < r^\gamma = \frac{(1+\gamma)(\pi^M - \pi^{NC}) - \gamma B}{\widehat{\pi}^M - \pi^M - \gamma(\pi^M - \underline{\pi}^M - B)},$$

and comparing it with (1) evaluated at $\pi_i^A = \pi_j^A = \pi^M$, $r^\gamma > r^*$ when

$$\frac{\pi^M - \pi^{NC} + \gamma(\pi^M - \pi^{NC} - B)}{\widehat{\pi}^M - \pi^M - \gamma(\pi^M - \underline{\pi}^M - B)} > \frac{\pi^M - \pi^{NC}}{\widehat{\pi}^M - \pi^M},$$

which, because $B < \pi^M - \pi^{NC}$ (if managers capture all gains from collusion owners are not interested in issuing debt in the first place) implies $\gamma(\pi^M - \pi^{NC} - B) > 0$ and $-\gamma(\pi^M - \underline{\pi}^M - B) < 0$, is always satisfied. This proves claim (ii). Finally, the payoff matrix and the extensive form of the "capital structure game" are as in the proof of Proposition 4 with $g_i < \frac{\pi_i^M - B_i - \pi_i^{NC}}{r}$, and the last statement follows. **Q.E.D.**

8.1.9 Proof of Proposition 8

With $b = \pi^B = \pi^M - B$ and without deviations, the non-common lenders of each firm i expect now the repayment streams with discounted value $(1-\gamma_i^1-\gamma_i^2)\left(\pi^M - B + \frac{\pi^M-B}{r}\right)$, while the common lender(s) expects full repayment streams with discounted value $(\gamma_i^1 + \gamma_i^2)\left(\pi^M - B + \frac{\pi^M-B}{r}\right)$ from both firms. After the deviation all debtholders of the deviating firm together expect the remaining value of the firm $\frac{\pi^{NC}}{r}$. As before, to compensate losses from the financial distress of the deviating firm only the owner must pay the amount $\frac{B}{r} + \frac{\pi^M-B-\pi^{NC}}{r}$. In addition, now both common lenders 1 and 2 must be compensated for the extra losses due to the financial distress of the non-deviating firm, which amount to $(\gamma_j^1+\gamma_j^2)\left(\pi^M - B + \frac{\pi^M-B}{r}\right) - (\gamma_j^1+\gamma_j^2)\left(\underline{\pi}^M + \frac{\pi^{NC}}{r}\right)$. Managerial contracts are renegotiation-proof and the joint monopoly collusive agreement is supportable when the no-renegotiation conditions for the two firms are simultaneously satisfied:

$$\widehat{\pi}_i^M - \pi_i^M < \frac{B_i}{r} + \left[\frac{\pi_i^M - B_i - \pi_i^{NC}}{r}\right] + (\gamma_j^1+\gamma_j^2)\left[\pi_j^M - B_j - \underline{\pi}_j^M + \frac{\pi_j^M - B_j - \pi_j^{NC}}{r}\right],$$

$$\widehat{\pi}_j^M - \pi_j^M < \frac{B_j}{r} + \left[\frac{\pi_j^M - B_j - \pi_j^{NC}}{r}\right] + (\gamma_i^1+\gamma_i^2)\left[\pi_i^M - B_i - \underline{\pi}_i^M + \frac{\pi_i^M - B_i - \pi_i^{NC}}{r}\right].$$

Firms' and agreement's symmetry and the common managerial labor market imply that these conditions are identical in all but the factors $(\gamma_j^1+\gamma_j^2)$ and $(\gamma_i^1+\gamma_i^2)$. Because the conditions must both be satisfied for collusion to be supported, firms' ability to collude is constrained by the more stringent of the conditions only. By inspection, the conditions are more stringent as the factors $(\gamma_j^1+\gamma_j^2)$ and $(\gamma_i^1+\gamma_i^2)$ become smaller. It follow that firms' ability to collude (the maximum discount rate at which collusion is supportable) is increasing in $\min\left\{\gamma_j^1+\gamma_j^2;\ \gamma_i^1+\gamma_i^2\right\}$. **Q.E.D.**

8.1.10 Proof of Proposition 9

Again, with $b = \pi^B = \pi^M - B$ and without deviations, managers expect their flow of bonuses, the non-common lenders together expect the full repayment streams with expected value summing to $(1-\gamma)\left(\pi^M - B + \frac{\pi^M-B}{r}\right)$, and the common lender expects full repayment streams with expected value $\gamma\left(\pi^M - B + \frac{\pi^M-B}{r}\right)$ from both firms. To accept a renegotiation leading to a deviation, all these parties need at least to be compensated for the losses from financial distress that follow the deviation. After the deviation the manager of the deviating firm expects zero bonuses, while all debtholders of the deviating firm together expect the remaining value of the firm $\frac{\pi^{NC}}{r}$. Therefore, to compensate losses from the financial distress of the deviating firm only the owner must pay the amount $\frac{B}{r} + \frac{\pi^M-B-\pi^{NC}}{r}$. To obtain renegotiation the common lender must also be compensated for the extra losses due to the other firm's financial distress. After the deviation the common lender receives from the other, non-deviating firm the amount

$$\min\left\{\gamma\left(\pi^M - B + \frac{\pi^M - B}{r}\right); \left[\underline{\pi}^M + \frac{\pi^{NC}}{r} - \eta(1-\gamma)\frac{\pi^M - B}{r}\right]\right\},$$

so that his extra loss from the side of the non-deviating firm only, denoted by $\Gamma(\eta)$, is

$$\begin{aligned}\Gamma(\eta) &= \gamma\left(\pi^M - B + \frac{\pi^M - B}{r}\right)\\ &\quad - \min\left\{\gamma\left(\pi^M - B + \frac{\pi^M - B}{r}\right); \left[\underline{\pi}^M + \frac{\pi^{NC}}{r} - \eta(1-\gamma)\frac{\pi^M - B}{r}\right]\right\}.\end{aligned}$$

By inspection, $\Gamma(\eta)$ is increasing in η. To summarize, renegotiation is impossible and collusion is credibly implemented as long as the following condition is satisfied

$$\widehat{\pi}^M - \pi^M < \frac{B}{r} + \frac{\pi^M - B - \pi^{NC}}{r} + \Gamma(\eta).$$

Because $\Gamma(\eta)$ is increasing in η, the larger the value of η, the easier it is to satisfy the above inequality and implement collusion. **Q.E.D.**

8.2 Appendix B: Bertrand competition

8.2.1 Managerial bankruptcy aversion

In the case of homogeneous good Bertrand competition $\mathbf{C}_i = C_i + c_i b_i$, Lemma 1 holds unmodified, and because $\pi_i^{NC} = 0$ it makes no difference for the manager whether he is or is not replaced after bankruptcy. So, with GPS contracts and managerial bankruptcy costs (3) and (4) become

$$\alpha\pi_{-i}^A \geq \alpha\frac{\pi_i^A}{r}, \tag{3'}$$

which are the same as (1'), (3a) and (3b) become

$$\alpha\pi_{-i}^A \leq \alpha\frac{\pi_i^A}{r} + \mathbf{C}_i, \;\Leftrightarrow\; r \leq \frac{\pi_i^A}{\pi_{-i}^A - \frac{\mathbf{C}_i}{\alpha}}. \tag{3a'}$$

and (4a) and (4b) become

$$r \leq \frac{\pi_i^A - b_i}{\pi_{-i}^A - \frac{\mathbf{C}_i}{\alpha}}. \tag{4a'}$$

By direct comparison between these conditions and (2') we obtain

Lemma 5 *Suppose managers are under long-term profit-sharing contracts and firms engage in repeated Bertrand competition. Then when firms are leveraged, managerial bankruptcy costs always facilitate collusion by increasing the maximum discount rate at which firms (managers) find it convenient to respect any collusive agreement.*

Comparing the conditions above with (1') we obtain

Proposition 10 *Suppose firms engage in Bertrand competition. Then: (I) when managers are under GPS contracts and* $\mathbf{C}_i > 0$*, leverage facilitates collusion by increasing the maximum discount rate at which firms can support any collusive agreement in subgame perfect Nash equilibrium; (II) when managers are under NPS contracts, leverage facilitates collusion as long as*

$$\frac{\alpha b_i}{\mathbf{C}_i} < \frac{\pi_i^A}{\pi_{-i}^A}. \tag{5a'}$$

8.2.2 Managerial incentives

With regard to Propositions 2 and 3, it is irrelevant whether firms engage in Bertrand or Cournot oligopolistic interaction.

8.2.3 Collusive lenders

With a Bertrand duopoly Assumption 2 becomes

$$r_i > \frac{\pi_i^A}{\pi_{-i}^A}, \quad \forall i, \forall A,$$

and Lemma 3 does not apply because any positive debt is "high". Instead of Lemma 4 we obtain:

Lemma 6 *For any positive level of firms' leverage, managerial bonuses* B_i*, target profits* π_i^B*, and collusive profits* $\pi_i^A \geq \pi_i^B$*, the maximum discount rate at which the managerial contracts are renegotiation-proof is always higher than that at which unleveraged owners can collude. Further, the maximum discount rate at which the managerial contracts are renegotiation-proof is monotonically increasing in firms' leverage and tends to infinity when* $b_i \to \pi_i^A$ *(and* $B_i \to 0$*).*

Proof After debt is issued collusion is sustained at a level $\pi_i^A \geq \pi_i^B$ and in each period owners get $\pi_i^A - b_i - B_i$, managers get B_i, and the lender gets $b_i + b_j$. Because now $\widehat{\pi}_i^A = \pi_i^A + \pi_j^A$, if one owner persuades his manager to deviate he gets $\pi_i^A + \pi_j^A - b_i - B_i$ immediately and zero afterwards, i.e. net expected gains $\pi_j^A - \frac{\pi_i^A - b_i - B}{r}$ which are positive by the assumption that (1') is not satisfied. In case of a unilateral deviation by firm i the lender loses present profits b_j (now $\underline{\pi}_j^A = 0$) from the non-deviating firm's immediate default on debt-service payments, the discounted expected debt repayments from the bankrupt non-deviating firm $\frac{b_j}{r}$ (firm's residual value is now 0), and the discounted expected debt repayments from the deviating firm $\frac{b_i}{r}$. As before, the deviating manager loses future bonuses $\frac{B_i}{r}$. The contract is renegotiation-proof if

$$\pi_j^A - \frac{\pi_i^A - b_i - B_i}{r} < \frac{B_i}{r} + b_j + \frac{b_i + b_j}{r}, \Leftrightarrow r < r_i^{D'} = \frac{\pi_i^A + b_j}{\pi_j^A - b_j}.$$

The first statement follows by direct comparison with inequality (1'), and the second by simple inspection. **Q.E.D.**

Because of this limit result, Proposition 4 changes to

Proposition 11 *(I) By offering a debt contract with $b_i = \pi_i^B = \pi_i^M - B_i$, the monopolist (or colluding) lender(s) can make managerial contracts renegotiation-proof and implement the joint monopoly agreement as the unique subgame perfect collusive equilibrium at higher discount rates than that at which unleveraged owners can sustain such agreement. (II) The maximum discount rate at which the joint monopoly equilibrium can be implemented tends to infinity when $B_i, B_j \to 0$. Further, when $g_i < \frac{\pi_i^M - B_i}{r}$, accepting the debt contract is a strictly dominant strategy for each owner.*

Proof. The debt contract makes managerial contracts renegotiation-proof when

$$\pi_j^M - \frac{\pi_i^M - b_i - B_i}{r} < \frac{B_i}{r} + b_j + \frac{b_i + b_j}{r}$$

which using $b_i = \pi_i^B = \pi_i^M - B_i$ reduces to

$$r < \frac{\pi_i^M + \pi_j^M - B_j}{B_j}.$$

Claim (II) follows by the inspection of this inequality. Comparing this with (1') evaluated at $\pi_i^A = \pi_i^M$, claim (I) requires

$$\frac{\pi_i^M}{\pi_j^M} < \frac{\pi_i^M + \pi_j^M - B_j}{B_j}, \Leftrightarrow B_j(\pi_i^M + \pi_j^M) < \pi_j^M(\pi_i^M + \pi_j^M),$$

which is always satisfied because $\pi_i^M - B_i = b_i > 0\ \forall i$. The proof of the last statement is as for Cournot competition (see the Proof of Proposition 4). **Q.E.D.**

8.2.4 Competitive credit markets and multiple lenders

For competitive credit markets and a single common lender, with Bertrand competition we have

Proposition 12 *Suppose firms engage in Bertrand competition, credit markets are competitive, and the "capital structure game" is as in Section 5 (or is simultaneous for owners). Then, by raising high levels of debt ($b_i = \pi_i^B = \pi_i^M - B_i$) from the same lender owners can make managerial contracts renegotiation-proof and implement the joint monopoly agreement as the unique subgame perfect collusive equilibrium at any discount rate. Further, accepting the debt contract is a strictly dominant strategy for each owner.*

Proof. This follows straightforwardly from the previous Proof.

Instead, when firms have multiple lenders we get

Proposition 13 *Suppose there is Bertrand competition, (at least) one of firms' lenders is in common with a share γ of the debt, and the "capital structure game" is designed as described in Section 5 (or is simultaneous for owners). Then, by raising high levels of debt with $b = \pi^B = \pi^M - B$ owners can: (I) make managerial contracts renegotiation-proof and implement the joint monopoly collusive agreement as the unique collusive equilibrium at any discount rate by choosing $\gamma \geq \frac{\pi^M}{\pi^M + B}$; (II) for any γ, make managerial contracts renegotiation-proof and implement the joint monopoly collusive agreement as the unique collusive equilibrium at higher discount rates than the maximum at which owners can sustain it. Furthermore, accepting the debt contract is a strictly dominant strategy for each owner.*

Proof. Given that with Bertrand competition $\widehat{\pi}^M = 2\pi^M$ and $\underline{\pi}^M = 0$, when $b = \pi^B = \pi^M - B$ managerial contracts are renegotiation-proof (and the joint monopoly collusive agreement supportable) if

$$\pi^M \leq \frac{B}{r} + (1-\gamma)\left[\frac{\pi^M - B}{r}\right] + \gamma\left[\pi^M - B + 2\frac{\pi^M - B}{r}\right],$$

or, equivalently, if

$$r\left[\pi^M(1-\gamma) - \gamma B\right] \leq \pi^M(1+\gamma) - \gamma B.$$

Because $B < \pi^M \frac{1+\gamma}{\gamma}$ (no debt contract is feasible if a multiple of total gains from collusion must be paid to the manager) the RHS is strictly positive, so the condition is satisfied for any r as long as

$$\pi^M(1-\gamma) - \gamma B \leq 0 \Leftrightarrow \gamma \geq \frac{\pi^M}{\pi^M + B},$$

which proves claim (I). When $\gamma < \frac{\pi^M}{\pi^M+B}$ the contract is renegotiation-proof as long as

$$r < \frac{\pi^M(1+\gamma) - \gamma B}{\pi^M(1-\gamma) - \gamma B}$$

which is less stringent than (1') evaluated at $\pi_i^A = \pi_{-i}^A = \pi^M$ when

$$\frac{\pi^M(1+\gamma) - \gamma B}{\pi^M(1-\gamma) - \gamma B} > 1$$

which is always satisfied, and claim (II) follows. The proof of the last statement is as in the Proof of Proposition 4. **Q.E.D.**

Results for asymmetric lending and seniority analogous to Propositions 8 and 9 for Bertrand competition can also be easily derived along the lines of the proofs of those propositions.

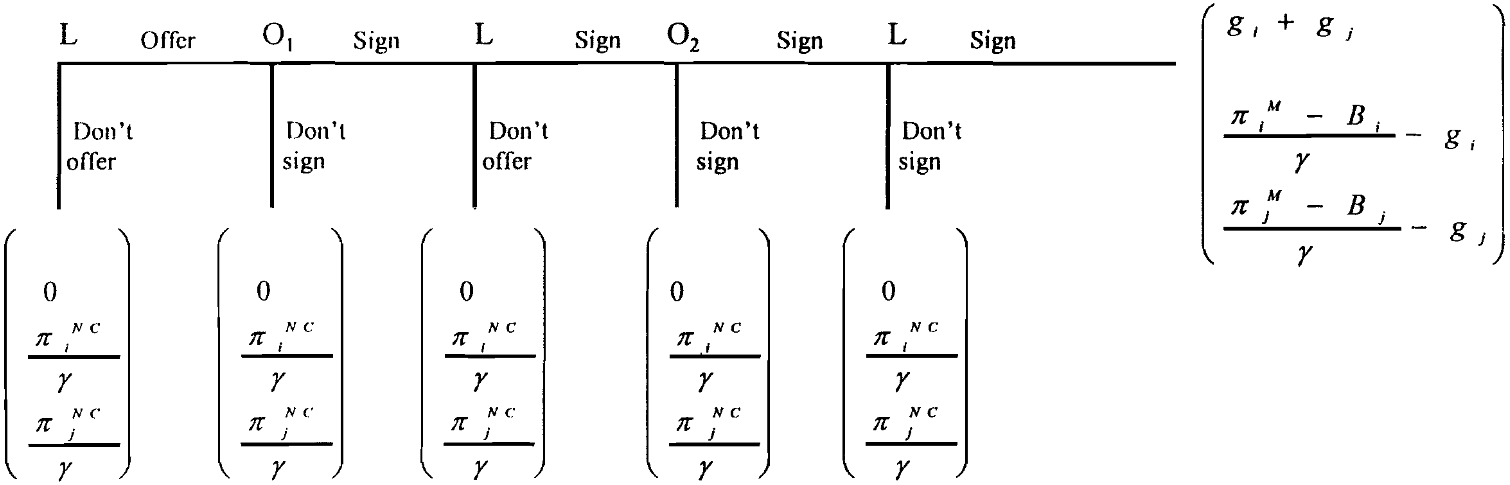
L
Offer
O_1
Sign
L
Sign
O_2
Sign
L
Sign
$\left(g_i + g_j, \ \frac{\pi_i^M - B_i}{\gamma} - g_i, \ \frac{\pi_j^M - B_j}{\gamma} - g_j \right)$
Don't offer
Don't sign
Don't offer
Don't sign
Don't sign
$\left(0, \ \frac{\pi_i^{NC}}{\gamma}, \ \frac{\pi_j^{NC}}{\gamma} \right)$
$\left(0, \ \frac{\pi_i^{NC}}{\gamma}, \ \frac{\pi_j^{NC}}{\gamma} \right)$
$\left(0, \ \frac{\pi_i^{NC}}{\gamma}, \ \frac{\pi_j^{NC}}{\gamma} \right)$
$\left(0, \ \frac{\pi_i^{NC}}{\gamma}, \ \frac{\pi_j^{NC}}{\gamma} \right)$
$\left(0, \ \frac{\pi_i^{NC}}{\gamma}, \ \frac{\pi_j^{NC}}{\gamma} \right)$

Figure 1

Chapter 5

Essay I

Multimarket Contact, Concavity, and Collusion

Multimarket Contact, Concavity, and Collusion*

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Abstract

Following Bernheim and Whinston (1990), this paper addresses the effects of multimarket contact on firms' ability to collude in repeated oligopolies. Managerial incentives, taxation, and financial market imperfections tend to make firms' objective function strictly concave in profits and market games "interdependent"; firms' payoffs in each market depend on how they are doing in others. In this case multimarket contact always facilitates collusion, and may make it sustainable in all markets even when otherwise it would not be sustainable in any. The effects of conglomeration and horizontal mergers are discussed. The results extend to non-oligopolistic supergames with objective functions submodular in material payoffs.

JEL CLASSIFICATION: C72, D43, L13, L21.

KEYWORDS: Repeated games, oligopoly, collusion, cooperation, conglomeration, mergers.

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1 Introduction

The traditional view about multimarket contact is that it always enhances firms' ability to sustain tacit collusion by allowing for "mutual forbearance." Sticking to an established convention in recent studies on the subject, we report Corwin Edwards' words (1955), probably the first clear statement on the effects of multimarket contact:

> "When one large conglomerate enterprise competes with another, the two are likely to encounter each other in a considerable number of markets. The multiplicity of their contact may blunt the edge of their competition. A prospect of advantage from vigorous competition in one market may be weighted against the danger of retaliatory forays by the competitor in other markets. Each conglomerate competitor may adopt a live-and-let-live policy designed to stabilize the whole structure of the competitive relationship." [As quoted by Scherer (1980, p. 340).]

The view that multimarket contact facilitates collusion "in general" has not been supported by Douglas Bernheim and Michael Whinston's (1990) famous supergame-theoretic analysis. In fact, although these authors conclude that in a wide range of circumstances multimarket contact does facilitate collusive behavior, they also begin with an irrelevance result: when firms and markets are identical and there are constant returns to scale, multimarket contact does not strengthen firms' ability to collude. Bernheim and Whinston then proceed by relaxing the assumptions behind this result to understand under which circumstances multimarket contact helps to sustain collusion. Among the many conditions they identify are that firms' production costs, the number of competitors, or the demand growth rates differ across markets, or that a single firm maintains an absolute cost advantage. Most of these conditions imply asymmetries between strategic interactions, due to differences between firms or markets, so that multimarket contact facilitates collusion by allowing the transfer of the slack of enforcing power (of net expected gains from collusion) which may be present in some markets to other markets in which it lacks such power.

This paper identifies a further condition under which multimarket contact facilitates collusion, one that is independent of asymmetries and that brings grist to the mill of the traditional view. We show that when firms' objective function is strictly concave the irrelevance result disppears and multimarket contact *always* facilitates collusion. When ownership is separated from control, so that managerial objectives become relevant, or when corporate taxes are non-linear or financial markets (are) imperfect, the firms' objective function tends to display decreasing marginal utility for profits within each time period. A strictly concave static objective functions make the repeated strategic interactions *interdependent*: firms' evaluation of profits from one market depends on profits realized in other markets. Then, expected losses from simultaneous retaliation in more markets - a threat available only with multimarket contact - are always larger than (the sum of) those from independent retaliations. Further, short-run profits from a simultaneous deviation from collusion in more markets are always less valuable than (the sum of) short-run profits from independent deviations. These two effects both facilitate collusion, whatever the type of repeated oligopoly considered. They can be reinforced by Bernheim and Whinston's conditions, but they will be present even with identical firms, identical markets, and constant returns to scale.

The wealth effect induced by a concave static objective function is also shown to generate "scale economies" in collusion (or cooperation); with multimarket contact collusion can be viable in a set of markets even when, in the absence of multimarket contact, it could not have be supported in *any* of these markets.

A complementary interpretation of these results is that *conglomeration* has negative effects on firms' ability to collude, as it creates independent sub-markets which "insure" firms against too low levels of profits during punishments. Multimarket contact then facilitates collusion by restoring the situation preceding conglomeration.

The effects of horizontal mergers without multimarket contact on the minimum discount factor at which collusion is supportable are ambiguous, as the wealth effect they generate may have different effects at different levels of profitability. On the other hand, we find that mergers always facilitate collusion when the discount factor is relatively low, and cvonversly hinder collusion when the discount factor is relatively high.

The mechanism behind the results is quite general. We show that "multi-game" contact facilitates cooperation in repeated strategic interactions that differ from oligopolistic ones as long as agents' static objective function is strictly *submodular* in stage-games' material payoffs.

Section 2 discusses firms' objective functions; Section 3 considers Bernheim and Whinston's model; the general result is presented in Section 4; Section 5 discusses extensions; and Section 6 concludes. An appendix contains all proofs.

2 On the concavity of firms' objective function

When (a) firms are led by owners and (b) financial markets are perfect the only interesting and relevant modeling assumption is the standard one of profit-maximizing firms. This is, of course, because owners can freely reallocate wealth in time through the financial market to satisfy their intertemporal preferences, so that they will only care about the discounted value of firms' profits. In this case there is little more to say on multimarket contact and collusion apart from what has already been stated by Bernheim and Whinston.

However, in the real world it often happens that at least one of the two conditions above is violated. For example, when ownership is separated from control firms tend to pursue objectives different from profit-maximization (see, e.g., Herbert Simon, 1957; William Baumol, 1958; Oliver Williamson, 1964; or Michael Jensen and William Meckling, 1976).

In what follows we briefly explain why we think that the most interesting non-standard assumption to study is that of a strictly concave utility function.[1]

2.1 Empirical evidence

Income smoothing. The terms "income smoothing" and "earnings management" in the accounting literature refer to firms' common practice of manipulating accounts and tuning production decisions in order to reduce the variability of firms' reported profits. There is a long series of robust empirical results on this phenomenon revealing that real world top managers are strongly averse to intertemporal substitution in firm profits, that is, they have a strictly concave static objective function.[2]

Hedging. Companies invest large amounts of resources in order to hedge risks through various kinds of derivatives (e.g. Christopher Géczy *et al.,* 1997). They even hire specialized staff and create specialized offices for "risk management." The amount of resources spent on hedging risks is indirect evidence that real-world firms are usually risk-averse.

2.2 Theoretical explanations: managerial objectives

Managerial incentive contracts. Healy (1985) explains income smoothing by the fact that managers' monetary bonuses are usually bounded above. This gives managers incentives to transfer income from periods in which it is above the upper bound of the incentive scheme to periods in which it is below it. Healy provides some empirical support for his view. Joskow and Rose (1994) find further evidence that boards discount extreme performance realizations when dealing with managers' compensation, i.e. that managers' bonuses tend to be capped. Capped incentives make managers averse to intertemporal substitution in firms' profits.

Managerial rents, asymmetric information, and career concerns. Fudenberg and Tirole (1995) propose an alternative explanation of income smoothing. They build an optimal contracting model in which incumbent managers earn rents, owners cannot commit to long-term contracts, and performance measures are subject to "information decay" (i.e. new performance measurements are better signals than old ones).

[1] Financial economists - who are closer to the real world than others - often consider risk-averse firms/agents to be the "standard" assumption.

[2] See, for example, Mark De Fond and Chul Park (1997); Francoise Degeorge *et al.* (1997); Eero Kasanen *et. al.* (1996); Robert Holthausen *et al.* (1995); Jennifer Gaver *et al.* (1995); Kenneth Merchant (1989); Mary Greenawalt and Joseph Sinkey (1988); or Paul Healy (1985).

The result is that in equilibrium managers are willing to incur positive costs in order to smooth reported profits and dividends. The point is that with information asymmetries and information decay after some periods of low profits, shareholders may find it optimal to replace the manager even if low profit periods follow high profit ones. Because they enjoy rents managers incur costs if they are fired. This generates a managerial "aversion to low profits" which here translates into a strictly concave objective function.

Managerial risk-aversion. The explanation that financially constrained risk-averse managers smooth their own income in time is one of the first offered for income smoothing (e.g. Richard Lambert, 1984; Ronald Dye, 1988) and for hedging (e.g. Clifford Smith and Rene Stulz, 1985). In the analysis of the shareholders/managers relation as a principal-agent problem, the typical trade-off between incentives and risk-sharing is obtained exactly because managers are assumed to be more averse to risk than owners.

Managerial discretion. Managers are usually thought to be interested in power, in the firm's growth, in "pet projects," etc. They may want to invest even when the expected returns from the investment project are negative. For these investments managers are financially constrained. Because within each time period such projects tend to have diminishing marginal value, managers prefer to have some free cash flow in each period to invest discretionally (e.g. Jensen, 1986). This makes them averse to intertemporal substitution with respect to the firm's profits.

Debt and managerial bankruptcy-aversion. Debt financing may lead firms to behave in an "as if" risk-averse manner. Debt implies the risk of bankruptcy, an event to which managers are strongly averse in that it ruins their future earning opportunities (Stuart Gilson, 1989; Gilson and Michael Vetsuypens, 1993). Bondholders will also want to reduce the variability of earnings to minimize the probability of financial distress and associated bankruptcy costs (e.g. Smith and Stulz, 1985). In the presence of stochastic shocks, this keeps managers from maximizing expected profits and leads them to avoid bankruptcy, i.e. to behave "as if" they had a strictly concave objective function (e.g. Bruce Greenwald and Joseph Stiglitz, 1990, 1993).

2.3 Theoretical explanations: external factors

Financial market's imperfections. Work on both capital structure (e.g. Stuart Myers and Nicholas Majluf, 1984) and on "the credit channel of monetary policy" (e.g. Steven Fazzari *et al.,* 1988; Robert Hubbard *et al.,* 1993; Ben Bernanke and Mark Gertler, 1995) indicates that because of information asymmetries in capital markets, firms' cost of external finance is strictly convex. In this case firms will prefer smooth earnings paths so that some internal funds are always available and suboptimal investment policies can be avoided. This leads them to maximize a strictly concave objective function. In fact, the convex cost of external finance has been proposed as the first reason why firms *should* smooth profits by hedging.[3]

Taxation. Other arguments made for hedging all imply that firms have a strictly concave objective function. For example, it has been argued that firms should hedge to reduce their tax bill.[4] This is because corporate taxes are not perfectly linear. For example, items such as tax credits generate convexity in firms' tax liability (concavity in firms' objective function) because the present value of unused credits diminishes during carry-forward to future periods (e.g. DeAngelo and Masulis, 1980).

Investors' preferences. Many investors seem to value more assets with smooth returns (e.g. Allen and Michaely, 1995). Some institutional investors have constraints that make them prefer assets which pay out stable dividends (e.g., the allowance to spend income but not capital gains). Small investors may face transaction costs when selling their assets and may want smooth returns for consumption reasons. Equityholders may gain from a reduced variance in earnings through improvements in portfolio optimization decisions (e.g. Peter DeMarzo and Durrell Duffie, 1991). In fact, one of the first explanations proposed for income smoothing is that – by reducing the perceived volatility of cash flow – they increase the market valuation of firms by risk-averse investors (e.g. Brett Trueman and Titman, 1988; Ronen and Sadan, 1981).

3 Repeated Bertrand competition

3.1 Bernheim and Whinston's irrelevance result

Consider first Bernheim and Whinston's model of repeated Bertrand competition. Time is discrete and in each market k trade occurs simultaneously in each period t, $t = 1, 2, \ldots$. In each market and in each period demand is a decreasing and continuous function $Q_k(p_k)$ of price p_k. Entry barriers limit the number of firms in each market to two. Each firm i is active in two markets and at every point in time it announces its current prices. When in a market the two firms announce identical prices, half of the consumers buy from each firm. When prices differ, all the consumers buy from the firm which quoted the lowest price. Firms must meet all the demand at the announced price. Let c_{ik} denote the constant marginal cost of production for firm i in market k. An equilibrium in market k will be a path of prices and associated profits, $\{p_{zk}, \pi_{zk}\}_{t=0}^{\infty}$, where $z = \{i \in I \,|i \text{ is active in market } k\}$. When firms are identical and markets are identical we write $Q_k = Q$ and $c_{ik} = c$.

Under the assumptions that industry profits are concave in price and that firms use trigger strategies to sustain symmetric stationary collusive agreements, Bernheim

[3] For example, Alan Shapiro and Sheridan Titman (1986); Donal Lessard (1990); Rene Stulz (1990); Kenneth Froot *et al.* (1993); Géczy *et al.* (1997).

[4] See, e.g., Stulz (1984); Smith and Stulz (1985); Froot *et al.* (1993); and The Economist (1996).

and Whinston derive the irrelevance result: *"When identical firms with identical constant returns to scale technologies meet in identical markets, multimarket contact does not aid in sustaining collusive outcomes"* (1990, p.5). The proof is straightforward: consider any pair of identical markets, say A and B, and call p^m the monopoly price common to these markets. When different firms interact in the two markets, a stationary collusive price $p \in [c, p^m]$ can be sustained in subgame-perfect equilibrium if

$$\frac{1}{1-\delta}(p-c)\frac{Q(p)}{2} - (p-c)Q(p) \geq 0,$$

which implies $\delta \geq \frac{1}{2}$. On the other hand with multimarket contact between firms, say 1 and 2, prices (p_A, p_B) and market shares $\lambda_{ik}, \lambda_{jk}{}_{k=A,B}$ are sustainable as a symmetric-payoffs stationary equilibrium if, for i=1, 2

$$\sum_{k\in(A,B)} \left[\frac{1}{1-\delta}\lambda_{ik}(p_k - c)Q(p_k) - (p_k - c)Q(p_k)\right] \geq 0,$$

with $p_k \in [c, p^m]$. Summing over i they obtain

$$\sum_{k=(A,B)} (p_k - c)Q(p_k)(\delta - \frac{1}{2}) \geq 0,$$

which also requires $\delta \geq \frac{1}{2}$.

3.2 Concavity and collusion

Keeping all the other assumptions, let now the static objective function of a firm i active in markets A and B be $U_i = \ln(1 + \pi_{iA} + \pi_{iB})$. If firms i and j are active on the same two identical markets, i.e. with multimarket contact, firms are able to sustain a constant sequence of monopoly prices in subgame-perfect equilibrium in both markets if

$$\frac{1}{1-\delta}\ln\left(1 + 2[(p^m - c)\frac{Q(p^m)}{2}]\right) - \ln\left(1 + 2(p^m - c)Q(p^m)\right) \geq 0,$$

or, equivalently, if

$$\delta \geq \delta^* = \frac{\ln(1 + 2(p^m - c)Q(p^m)) - \ln(1 + (p^m - c)Q(p^m))}{\ln(1 + 2(p^m - c)Q(p^m))}. \tag{1}$$

In the absence of multimarket contact, in each market only the threat of punishment in that same market can be used; firms' profits from the other market must be taken as a given. Therefore, in this case a constant sequence of joint monopoly prices will be supportable in subgame-perfect equilibrium in each market if

$$\frac{1}{1-\delta}\ln\left(1 + 2[(p^m - c)\frac{Q(p^m)}{2}]\right) - \ln\left(1 + \frac{3}{2}(p^m - c)Q(p^m)\right) +$$

$$-\frac{\delta}{1-\delta}\ln\left(1+\frac{1}{2}(p^m-c)Q(p^m)\right)\geq 0,$$

or, equivalently, if

$$\delta \geq \delta^{**} = \frac{\ln\left(1+\frac{3}{2}(p^m-c)Q(p^m)\right)-\ln\left(1+(p^m-c)Q(p^m)\right)}{\ln\left(1+\frac{3}{2}(p^m-c)Q(p^m)\right)-\ln\left(1+\frac{1}{2}(p^m-c)Q(p^m)\right)}. \quad (2)$$

As expected, both δ^* and δ^{**} are positive and less than one when $(p^m-c)Q(p^m)>0$, but it turns out that $\delta^{**}>\delta^*$, for any p^m, c, and $Q()$. Therefore, when δ is $\delta^{**}>\delta\geq\delta^*$ collusion will be supportable only when there is multimarket contact. In other words, with a logarithmic objective function multimarket contact facilitates collusion even with identical firms, identical markets, and constant returns to scale.

4 A more general result

Consider a finite set of oligopolistic markets $\Omega=\{A,B,C,...\}$ and a finite set of firms I, $I=\{1,2,3,...,N\}$ interacting repeatedly in several of these markets and having a common intertemporal discount factor $\delta<1$. Let S_{ik} denote the pure strategy set of a firm i in the static (one-shot) strategic interaction in market k, let $s_{ik}\in S_{ik}$ denote one particular pure strategy and, abusing notation, let $\hat{s}_{ik}(s_{-ik})$ indicate firm i's static best response to its opponents' strategy profile $s_{-ik}\in S_{-ik}$, where $S_{-ik}=\prod_{j\neq i}S_{jk}$. Let $\pi_{ik}(.)$ denote firm i's profit function in market k, so that $\pi^*_{ik}=\pi_{ik}(s^*_{ik},s^*_{-ik})$ indicates firm i's profits from the strategy profile $s^*_k=(s^*_{ik},s^*_{-ik})$ and $\hat{\pi}^*_{ik}=\pi_{ik}(\hat{s}_{ik}(s^*_{-ik}),s^*_{-ik})$ its profits from the static best response strategy $\hat{s}_{ik}(s^*_{-ik})$ in market k. The standard approach is to assume that each firm i's static payoff function is simply $\sum_{k\in\Omega}\pi_{ik}(s_{ik},s_{-ik})$, so that firms' evaluation of payoffs from each market is independent of conditions in other markets. Instead, we let $U=U(\sum_{k\in\Omega}\pi_{ik}(s_{ik},s_{-ik}))$ denote firms' static objective function, and we assume U to be continuous, monotonically increasing and strictly concave in total profits. Now firms' evaluation of per-period profits from one market depends on profits realized in other markets. We assume, as Bernheim and Whinston implicitly do, that when a firm faces different opponents in the markets in which it is active, these opponents are not able or willing to coordinate their strategies. Also, we follow Bernheim and Whinston in focusing on stationary equilibrium paths sustained by trigger strategies (e.g. Friedman, 1971).[5] Let $\underline{\pi}_{ik}$ denote firm i's monetary payoff in one period of the punishment phase. Then one can state what follows.

[5] It is straightforward to check that all results apply to the case when the length of the punishment phase is bounded by finite renegotiation costs, as in McCutcheon (1997) (see also Blume, 1994). In section 5.4 we extend the results to "repentance" punishment strategies, such as those introduced by van Damme (1989) for the Prisoner's Dilemma, which are renegotiation-proof in the sense of Farrel and Maskin (1989).

Proposition 1 *Suppose firms' static objective function is strictly concave in profits. Then multimarket contact (always) relaxes the necessary and sufficient conditions for any set of profit streams to be supportable in subgame-perfect equilibrium by stationary punishment strategies in any set of infinitely repeated oligopoly games.*

The necessary and sufficient conditions for firms to be willing to stick to a collusive agreement are functions of the discount factor, of the collusive agreement chosen, and of market structure ($\hat{\pi}^*_{ik}$ and $\underline{\pi}_{ik}$). It follows that rearranging the same proof we could alternatively state:

i) "Suppose (...). Then multimarket contact reduces the minimum level of the discount factor at which any given set of profit streams can be supported in subgame-perfect equilibrium in any given set of oligopolistic supergames."

ii) "Suppose (...). Then, given the discount factor, the set of stationary profit streams supportable in subgame-perfect equilibrium with multimarket contact in any given set of repeated oligopolies is no smaller (in the sense of inclusion) than the set supportable without multimarket contact. Further, there exist $\underline{\delta}$ *and* $\overline{\delta}$, $0 < \underline{\delta} < \overline{\delta} < 1$, *such that for* $\underline{\delta} < \overline{\delta}$ *multimarket contact strictly enlarges the set of supportable stationary profit streams."*

iii) "Suppose (...). Then, given the discount factor, multimarket contact strictly enlarges (in the sense of inclusion) the set of oligopolistic supergames in which any (set of) collusive profit stream(s) is supportable in subgame-perfect equilibrium."

The intuition behind this result is straightforward. When a firm faces different opponents in the two markets and these opponents play their market games independently, the threat used to enforce the first firm's respect of a tacit collusive agreement in each of the markets is that of reverting to the static Nash equilibrium in that market only, taking for granted what is happening in other markets. Multimarket contact allows firms to use the threat of a simultaneous punishment in more markets to enforce collusive agreements. A simultaneous punishment is "heavier" because when a firm is already being punished in one market it has a higher marginal valuation of profits, so that it has a relatively greater fear of the loss of gains from cooperation caused by punishments in other markets. Furthermore, with multimarket contact, a firm which decides to "cheat" on a collusive agreement will find it convenient to deviate in all markets simultaneously. Because the marginal utility of profits is decreasing within each period, the simultaneity of the deviation makes the short-run monetary gains from deviating in each market less valuable relative to the case when the firm is cheating in one market only. These two effects both facilitate collusion.

Note that the proposition was proved without reference to any specific market structure, so that the result applies to any type of repeated oligopoly (symmetric, asymmetric, Cournot, differentiated Bertrand, with or without capacity constraints, etc.).

5 Extensions

5.1 "Increasing returns" in collusion

Because of the wealth effects induced by concave objective functions, multimarket contact may allow firms to sustain collusive outcomes in all markets even when without multimarket contact collusion could not be sustained in any of them. To see this, consider the modified Bernheim and Whinston model of Section 3.2. In that model collusion in only one of the existing markets is sustainable if

$$\frac{1}{1-\delta}\ln\left(1+(p^m-c)\frac{Q(p^m)}{2}\right)-\ln\left(1+(p^m-c)Q(p^m)\right)\geq 0,$$

or, equivalently, if

$$\delta \geq \delta' = \frac{\ln\left(1+(p^m-c)Q(p^m)\right)-\ln\left(1+\frac{1}{2}(p^m-c)Q(p^m)\right)}{\ln\left(1+(p^m-c)Q(p^m)\right)}. \tag{3}$$

It easy to check that $\delta^{**} > \delta' > \delta^*$ for any p^m, c, and $Q()$. When $\delta^{**} > \delta \geq \delta'$, with multimarket contact collusion can be sustained in both markets, while in the absence of multimarket contact collusion can be sustained only in one of the markets. However, when $\delta' > \delta \geq \delta^*$, with multimarket contact the collusive price can still be sustained in both markets, while without multimarket contact it cannot be sustained in *either* of them.

This effect depends both on the shape of the objective function and on the structure of monetary payoffs in the different markets; therefore it is difficult to generalize. However, it is easy to check that for sufficiently similar games (markets) the scale effect is present with all most commonly used utility functions (quadratic, logarithmic, and other hyperbolic CRRA functions with elasticity of substitution lower than one).

5.2 Conglomeration, mergers, and collusion

As mentioned in the introduction, the mechanism behind Proposition 1 is open to a complementary interpretation. One can argue that it is the process of *conglomeration* that, by leading firms to operate in several segregated markets, insures them against too harsh punishments and reduces their ability to sustain collusive agreements. Multimarket contact then facilitates collusion by restoring such an ability at the pre-conglomeration level.[6]

This interpretation is valid as long as "conglomeration" denotes the process by which a firm becomes active in more than one market while maintaining the same level of overall activity. For example, consider a situation in which two firms of a

[6] I thank Douglas Bernheim who let me note this alternative interpretation.

given size are first active in one market (no conglomeration). Suppose that in a second period firms reduce their operations in the original market to increase them in other markets where they face different competitors (conglomeration without multimarket contact). The effect of this process is clearly the inverse of that behind Proposition 1, so collusion will be harder to support than before conglomeration.

When conglomeration implies an increase in the size of the firm, the effect on the firm's ability to collude is less clear. To see this, consider how *horizontal mergers* affect firms' ability to collude. Suppose a firm initially active in one market acquires another firm active in a different market, and that the acquired firm is colluding in its own market. The acquisition guarantees the acquiring firm an independent stream of profits which makes it less afraid of punishments, but also less interested in short-run gains from deviating in its original market. Such a wealth effect may enhance or worsen the acquiring firm's ability to sustain collusion in its original market, depending on the exact shape of its objective function. Let $\alpha = \frac{U(\pi^*_{iA})-U(\underline{\pi}_{iA})}{U(\hat{\pi}^*_{iA})-U(\underline{\pi}_{iA})}$. For the marginal merger one can state the following result.

Corollary 1 *Suppose firms' static objective function is strictly concave in profits. Then a horizontal merger with a marginally profitable firm - in the absence of multimarket contact - reduces (increases) the minimum discount factor at which firm* i *can sustain a collusive agreement in its original market A when*

$$\alpha U'(\hat{\pi}^*_{iA}) + (1-\alpha)U'(\underline{\pi}_{iA}) < (>) U'(\pi^*_{iA}). \tag{4}$$

Condition (5.2) is more easily satisfied when firms' marginal valuation of profits is particularly high at low levels of profits. Then the effect of the independent profit stream on firms' evaluation of losses from punishments in its market tends to dominate.

Because a merger affects firms' evaluation of profits for many periods, the discount factor plays an important role. In fact, for a given discount factor we can state a stronger result for the relation between mergers and collusion.[7]

Corollary 2 *Suppose firms' static objective function is strictly concave in profits. Then, in the absence of multimarket contact, any horizontal merger increases (diminishes) the ability of a firm* i *to sustain collusive agreements in its original market A when the discount factor is lower (higher) than a well defined intermediate level* $0 < \widetilde{\delta} < 1$.

The intuition is, of course, that at low enough discount factors the negative effect of a merger on the firm's evaluation of present short-run gains from deviations dominates the negative effect on future losses from the punishment phase.

[7] I am grateful to an anonymous referee whose comments persuaded me to formalize this implication.

5.3 Interdependent supergames

The mechanism behind Proposition 1 applies to any set of repeated strategic interactions other than oligopolistic games (Prisoner's Dilemmas, implicit contracts, reciprocal exchanges, etc.). When players face simultaneously several repeated games, payoffs from some of these may affect agents' evaluation of payoffs from others even though payoffs are of a different nature. Let $\mu_i = (\mu_{i1}, ..., \mu_{in})$ represent the vector of material payoffs from the n stage-games that an agent i plays simultaneously in each time period.

Definition 1 *An agent's static objective function U is strictly supermodular (submodular) in n stage-games' material payoffs if, for any two possible material payoff vectors $\mu_i^{'} = (\mu_{i1}^{'}, ..., \mu_{in}^{'})$ and $\mu_i^{''} = (\mu_{i1}^{''}, ..., \mu_{in}^{''})$ such that $\mu_i^{'}$ and $\mu_i^{''}$ are not comparable with respect to $\geq$,*

$$\begin{aligned} U(\mu_i^{'}) + U(\mu_i^{''}) \quad &< \quad (>)U\left[\min(\mu_{i1}^{'}, \mu_{i1}^{''}), ..., \min(\mu_{in}^{'}, \mu_{in}^{''})\right] + \\ &+U\left[\min(\mu_{i1}^{'}, \mu_{i1}^{''}), ..., \min(\mu_{in}^{'}, \mu_{in}^{''})\right]. \end{aligned}$$

Supermodularity (submodularity) for a function is a generalization of the concept of complementarity (substitutability) of its arguments. An alternative – but in this framework equivalent – generalization of complementarity (substitutability) is the concept of increasing (decreasing) differences:

Definition 2 *An agent i's static objective function U has strictly increasing (decreasing) differences in (μ_{ik}, μ_{ih}) if for all $(\mu_{ik}^{'}, \mu_{ik}^{''})$ and $(\mu_{ih}^{'}, \mu_{ih}^{''})$ such that $\mu_{ik}^{'} > \mu_{ik}^{''}$ and $\mu_{ih}^{'} > \mu_{ih}^{''}$,*

$$U(\mu_{ik}^{'}, \mu_{ih}^{'}, \mu_{i-k-h}) - U(\mu_{ik}^{''}, \mu_{ih}^{'}, \mu_{i-k-h}) > (<)U(\mu_{ik}^{'}, \mu_{ih}^{''}, \mu_{i-k-h}) - U(\mu_{ik}^{''}, \mu_{ih}^{''}, \mu_{i-k-h}).$$

Then one can obtain results analogous to those in previous sections. Here we prove only the result corresponding to Proposition 1.

Proposition 2 *Suppose agents' static objective function is strictly submodular (or has strictly decreasing differences) in stage games' material payoffs. Then "multi-game contact" relaxes the necessary conditions for any stationary cooperative outcome to be supportable in subgame-perfect equilibrium by stationary punishment strategies. (The converse does not hold for supermodular objective functions or functions with increasing differences.)*

Strict submodularity of (or strictly decreasing differences in) the objective function implies that the payoffs from different games are a kind of substitutes. When this is the case, agents who are doing well in one strategic interaction value material payoffs from other interactions less, and vice versa. This is enough to replicate the effects of concavity on agents' evaluation of gains from deviations and of losses from punishments behind Proposition 1.

The converse does not hold for supermodular functions because then short-run gains from simultaneous deviations are more valuable and simultaneous punishments less harsh. Agents can choose to deviate (and be punished) simultaneously in several strategic interactions whether or not there is "multi-game" contact; therefore "multi-game" contact cannot make agents' incentive constraints more stringent.

5.4 Renegotiation-proof strategies

Simple threats based on Nash reversion are widely used in the literature because they are subgame-perfect and easy to handle, both for researchers in models and for firms in markets (agreements and communication between oligopolistic firms are forbidden, so simple threats may greatly reduce coordination problems). However, these threats may be subject to ex-post renegotiation which may undermine their credibility (e.g. Joseph Farrell and Eric Maskin, 1989; Douglas Bernheim and Debray Ray, 1989).

Suppose simple renegotiation-proof strategies are used to support cooperation. Consider a standard repeated symmetric Cournot duopoly with profit functions

$$\pi_{ik}(q_{ik}, q_{jk}) = P(q_{ik} + q_{jk})q_{ik} - c(q_{ik}),$$

where q_{ik} denotes firm i's output, $P(.)$ is the inverse demand function and $c(.)$ is firms' cost function. We adopt the standard assumptions that the inverse demand function satisfies $P' < 0$, $P'' \geq 0$, that profits are concave in output, and that marginal profits are decreasing in rivals' output so that one-shot reaction functions are continuous and downward sloping. Assume firms support collusion by simple two-phase renegotiation-proof "repentance" strategies of the kind proposed by van Damme (1989):

> *Phase 1*: stick to the collusive output q^*_{ik} as long as the other firm did the same in the past; if the other firm deviates, start Phase 2;
>
> *Phase 2:* produce the full monopoly output q^M_{ik} as long as the other firm's output is positive (or larger than some low "repentance" level $\underline{q}_i$); if for one period the other firm's output is zero (or below $\underline{q}_i$), restart Phase 1.

Then one can to state the following.

Corollary 3 *Suppose firms' static objective function is strictly concave in profits and firms use the two-phase renegotiation-proof strategies defined above. Then multimarket contact always facilitates collusion by relaxing the necessary and sufficient conditions for any profit stream to be supportable in subgame-perfect equilibrium.*

6 Concluding Remarks

We have studied the effects of multimarket contact on firms' ability to sustain tacit collusive agreements in an infinitely repeated oligopoly framework. Managerial incentives, taxation, financial market imperfections, and other features of reality tend to make firms' static objective function strictly concave in profits. In this case multimarket contact always facilitates collusive behavior and may even generate "increasing returns" in collusion. The same result applies to infinitely repeated games with non-monetary material payoffs whenever agents' objective function is strictly submodular in the material payoffs vector.

Empirical studies should help to understand how relevant the above arguments are to the real world. Also, it should be relatively easy test these results through experimental work.

We conclude with two direct implications of our results. First, improvements in the incentive power of top managers' compensation and in the efficiency of financial markets should reduce the pro-collusive effects of multimarket contact, as they should reduce firms' aversion to intertemporal substitution in profits. Second, shareholders of conglomerates involved in multimarket contact might find it convenient to delegate control to managers strongly averse to intertemporal substitution (or to create incentives in such a direction, such as capped bonuses, rents, etc.) in order to facilitate collusion and increase profits.[8]

[8] In a repeated version of the strategic delegation game introduced by John Vickers (1985) and Chaim Fershtman and Kenneth Judd (1987), Giancarlo Spagnolo (1996) finds that even in single repeated interactions, that is, independent of multimarket contact, delegation to managers with strictly concave objective functions is a powerful collusive device.

7 Appendix

7.1 Proof of Proposition 1

We prove the proposition for the case of two markets, A and B. The generalization to N markets is straightforward. This simple lemma will be useful:

Lemma 1 *Let U:$R \rightarrow R$ be a strictly concave function. Then for every x, y in R_{++} and z in $R_{+,}$ $U(z) + U(x + y + z) < U(x + z) + U(y + z)$.*

Proof: Define $s = (x + y)$, $\mu_x = \frac{x}{s}$ and $\mu_y = \frac{y}{s}$, so that $0 < \mu_i < 1$, $i = x, y$ and $g = (x + y + z)$. By the definition of strict concavity $U[\mu_i g + (1 - \mu_i)z] > \mu_i U(g) + (1 - \mu_i)U(z)$. Solving inside the squared brackets and summing over i we obtain the expression above. **Q.E.D.**

Without multimarket contact, a firm i which is active in markets A and B will not deviate from a collusive agreement in market A which leads to a stationary sequence of monetary payoffs $\{\pi_{iA}^*\}_t^\infty$ if

$$\frac{1}{1-\delta}U(\pi_{iA}^* + \pi_{iB}) - U(\hat{\pi}_{iA}^* + \pi_{iB}) - \frac{\delta}{1-\delta}U(\underline{\pi}_{iA} + \pi_{iB}) \geq 0.$$

Analogously, firm 1 will not deviate from a collusive agreement in market B which leads to a stationary sequence of monetary payoffs $\{\pi_{iB}^*\}_t^\infty$ if

$$\frac{1}{1-\delta}U(\pi_{iA} + \pi_{iB}^*) - U(\pi_{iA} + \hat{\pi}_{iB}^*) - \frac{\delta}{1-\delta}U(\pi_{iA} + \underline{\pi}_{iB}) \geq 0.$$

Because firms are identical, these two conditions are necessary and sufficient for a collusive agreement to be supportable in each market. This implies that their sum, the pooled incentive constraint across the two markets, will be a *necessary* condition for a collusive agreement leading to a stationary sequence of monetary payoffs $\{\pi_{iA}^*, \pi_{iB}^*\}_t^\infty$ to be simultaneously supportable in both markets without multimarket contact. The following condition must be satisfied

$$\frac{2}{1-\delta}U(\pi_{iA}^* + \pi_{iB}^*) - U(\hat{\pi}_{iA}^* + \pi_{iB}^*) +$$

$$-U(\pi_{iA}^* + \hat{\pi}_{iB}^*) - \frac{\delta}{1-\delta}[U(\underline{\pi}_{iA} + \pi_{iB}^*) + U(\pi_{iA}^* + \underline{\pi}_{iB})] \geq 0. \quad \text{(A1)}$$

With multimarket contact, instead, a collusive outcome generating the stationary sequence of payoffs $\{\pi_{iA}^*, \pi_{iB}^*\}_t^\infty$ will be supportable if

$$\frac{1}{1-\delta}U(\pi_{iA}^* + \pi_{iB}^*) - U(\hat{\pi}_{iA}^* + \hat{\pi}_{iB}^*) - \frac{\delta}{1-\delta}U(\underline{\pi}_{iA} + \underline{\pi}_{iB}) \geq 0. \quad \text{(A2)}$$

If we can show that (A2) is always satisfied when (A1) is, and that for some games (A2) is satisfied but (A1) is not, we will have proved the proposition. To do this we can subtract the LHS of condition (A2) from the LHS of condition (A1) and check if such a difference is always positive. Subtracting and simplifying, we obtain

$$-\frac{1}{1-\delta}U(\pi^*_{iA}+\pi^*_{iB})-U(\hat{\pi}^*_{iA}+\hat{\pi}^*_{iB})+U(\hat{\pi}^*_{iA}+\pi^*_{iB})+U(\pi^*_{iA}+\hat{\pi}^*_{iB})+$$

$$+\frac{\delta}{1-\delta}[U(\underline{\pi}_{iA}+\pi^*_{iB})+U(\pi^*_{iA}+\underline{\pi}_{iB})-U(\underline{\pi}_{iA}+\underline{\pi}_{iB})]>0,$$

and then

$$U(\hat{\pi}^*_{iA}+\hat{\pi}^*_{iB})-U(\underline{\pi}_{iA}+\underline{\pi}_{iB})+U(\underline{\pi}_{iA}+\pi^*_{iB})+U(\pi^*_{iA}+\underline{\pi}_{iB})-U(\hat{\pi}^*_{iA}+\pi^*_{iB})-U(\pi^*_{iA}+\hat{\pi}^*_{iB})>$$

$$>\frac{1}{\delta}\left[U(\pi^*_{iA}+\pi^*_{iB})+U(\hat{\pi}^*_{iA}+\hat{\pi}^*_{iB})-U(\hat{\pi}^*_{iA}+\pi^*_{iB})-U(\pi^*_{iA}+\hat{\pi}^*_{iB})\right].$$

By Lemma 1 the RHS of this inequality is negative, while the LHS may be either positive or negative. If it is positive the inequality is satisfied. If it is negative, we can multiply everything by -1 and rearrange as

$$\delta<\frac{-U(\pi^*_{iA}+\pi^*_{iB})-K}{-U(\underline{\pi}_{iA}+\pi^*_{iB})-U(\pi^*_{iA}+\underline{\pi}_{iB})+U(\underline{\pi}_{iA}+\underline{\pi}_{iB})-K},$$

where $K=\left[U(\hat{\pi}^*_{iA}+\hat{\pi}^*_{iB})-U(\hat{\pi}^*_{iA}+\pi^*_{iB})-U(\pi^*_{iA}+\hat{\pi}^*_{iB})\right]$. By Lemma 1 it is $U(\pi^*_{iA}+\pi^*_{iB})<U(\underline{\pi}_{iA}+\pi^*_{iB})+U(\pi^*_{iA}+\underline{\pi}_{iB})-U(\underline{\pi}_{iA}+\underline{\pi}_{iB})$, therefore in the RHS of the last inequality the numerator is strictly larger than the denominator, and because $\delta\leq 1$ the condition is always satisfied. **Q.E.D.**

7.2 Proof of Corollary 1

Before acquisition the incentive constraint for firm i to sustain a collusive agreement leading to a stationary sequence of monetary payoffs $\{\pi^*_{iA}\}^{\infty}_{t}$ is

$$\frac{1}{1-\delta}U(\pi^*_{iA})-U(\hat{\pi}^*_{iA})-\frac{\delta}{1-\delta}U(\underline{\pi}_{iA})\geq 0,$$

or, equivalently,

$$\delta\geq\underline{\delta}(0)=\frac{U(\hat{\pi}^*_{iA})-U(\pi^*_{iA})}{U(\hat{\pi}^*_{iA})-U(\underline{\pi}_{iA})}.$$

After the acquisition(s), in each period firm i will obtain some positive profits, say π_{iB}, from acquired firms so that the incentive constraint becomes

$$\frac{1}{1-\delta}U(\pi^*_{iA}+\pi_{iB})-U(\hat{\pi}^*_{iA}+\pi_{iB})-\frac{\delta}{1-\delta}U(\underline{\pi}_{iA}+\pi_{iB})\geq 0,$$

or, equivalently,

$$\delta \geq \underline{\delta}(\pi_{iB}) = \frac{U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - U(\pi_{iA}^{*} + \pi_{iB})}{U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - U(\underline{\pi}_{iA} + \pi_{iB})}.$$

The acquisition worsens firm's ability to collude when $\underline{\delta}(0) < \underline{\delta}(\pi_{iB})$. Therefore the marginal acquisition facilitates collusion when:

$$Sign\left\{ \left. \frac{\partial \underline{\delta}(\pi_{iB})}{\partial \pi} \right|_{\pi_{iB}=0} \right\} < 0,$$

which leads to

$$[U'(\hat{\pi}_{iA}^{*}) - U'(\pi_{iA}^{*})]\,[U(\hat{\pi}_{iA}^{*}) - U(\underline{\pi}_{iA})] - [U'(\hat{\pi}_{iA}^{*}) - U'(\underline{\pi}_{iA})]\,[U(\hat{\pi}_{iA}^{*}) - U(\pi_{iA}^{*})] < 0,$$

and then to

$$\frac{U(\pi_{iA}^{*}) - U(\underline{\pi}_{iA})}{U(\hat{\pi}_{iA}^{*}) - U(\underline{\pi}_{iA})} U'(\hat{\pi}_{iA}^{*}) + \frac{U(\hat{\pi}_{iA}^{*}) - U(\pi_{iA}^{*})}{U(\hat{\pi}_{iA}^{*}) - U(\underline{\pi}_{iA})} U'(\underline{\pi}_{iA}) < U'(\pi_{iA}^{*}).$$

Q.E.D.

7.3 Proof of Corollary 2

A merger with a firm active in market B facilitates collusion in market A as long as the firm's incentive compatibility constraint after the merger is less stringent than that before the merger, that is if

$$\frac{1}{1-\delta} U(\pi_{iA}^{*}) - U(\hat{\pi}_{iA}^{*}) - \frac{\delta}{1-\delta} U(\underline{\pi}_{iA}) <$$

$$\frac{1}{1-\delta} U(\pi_{iA}^{*} + \pi_{iB}) - U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - \frac{\delta}{1-\delta} U(\underline{\pi}_{iA} + \pi_{iB}).$$

With few algebraic manipulations the inequality reduces to

$$\delta < \widetilde{\delta} = \frac{[U(\pi_{iA}^{*} + \pi_{iB}) - U(\pi_{iA}^{*})] - [U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - U(\hat{\pi}_{iA}^{*})]}{[U(\underline{\pi}_{iA} + \pi_{iB}) - U(\underline{\pi}_{iA})] - [U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - U(\hat{\pi}_{iA}^{*})]},$$

and because $U' > 0$ and $U'' < 0$ imply

$$U(\underline{\pi}_{iA} + \pi_{iB}) - U(\underline{\pi}_{iA}) > U(\pi_{iA}^{*} + \pi_{iB}) - U(\pi_{iA}^{*}) > U(\hat{\pi}_{iA}^{*} + \pi_{iB}) - U(\hat{\pi}_{iA}^{*}),$$

it is always $0 < \widetilde{\delta} < 1$. **Q.E.D.**

7.4 Proof of Proposition 2

Again, we prove the corollary for the case of agents active in two repeated games, A and B (the extension to more than two repeated games is straightforward, although cumbersome). Let μ^*_{ik} denote player i's static material payoff from supergame k when the stationary cooperative agreement at stake is being respected, $\widehat{\mu}^*_{ik}$ denote player i's static material payoff from deviating by choosing a static best response strategy to such agreement, and $\underline{\mu}_{ik}$ denote his material payoff in a period of the punishment phase which follows the deviation.

We can follow the same steps as in the proof of Proposition 1. Without multimarket contact, agent i playing supergames A and B will not deviate from a cooperative agreement in A leading to the sequence of material payoffs $\{\mu^*_{iA}\}^\infty_t$ if

$$\frac{1}{1-\delta}U(\mu^*_{iA},\mu_{iB})-U(\widehat{\mu}^*_{iA},\mu_{iB})-\frac{\delta}{1-\delta}U(\underline{\mu}_{iA},\mu_{iB})\geq 0,$$

and will not deviate from a cooperative agreement in B leading to the sequence of material payoffs $\{\mu^*_{iB}\}^\infty_t$ if

$$\frac{1}{1-\delta}U(\mu_{iA},\mu^*_{iB})-U(\mu_{iA},\widehat{\mu}^*_{iB})-\frac{\delta}{1-\delta}U(\mu_{iA},\underline{\mu}_{iB})\geq 0.$$

The pooled incentive constraint across the two supergames will be a *necessary* condition for the stationary sequence of material payoffs $\{\mu^*_{iA},\mu^*_{iB}\}^\infty_t$ to be simultaneously supportable without "multi-game" contact, while with "multi-game" contact the sequence $\{\mu^*_{iA},\mu^*_{iB}\}^\infty_t$ is supportable if

$$\frac{1}{1-\delta}U(\mu^*_{iA},\mu^*_{iB})-U(\widehat{\mu}^*_{iA},\widehat{\mu}^*_{iB})-\frac{\delta}{1-\delta}U(\underline{\mu}_{iA},\underline{\mu}_{iB})\geq 0.$$

Subtracting the LHS of the pooled incentive constraint from this condition we obtain

$$U(\widehat{\mu}^*_{iA},\widehat{\mu}^*_{iB})-U(\underline{\mu}_{iA},\underline{\mu}_{iB})+U(\underline{\mu}_{iA},\mu^*_{iB})+U(\mu^*_{iA},\underline{\mu}_{iB})-U(\widehat{\mu}^*_{iA},\mu^*_{iB})-U(\mu^*_{iA},\widehat{\mu}^*_{iB})>$$
$$>\frac{1}{\delta}\left[U(\mu^*_{iA},\mu^*_{iB})+U(\widehat{\mu}^*_{iA},\widehat{\mu}^*_{iB})-U(\widehat{\mu}^*_{iA},\mu^*_{iB})-U(\mu^*_{iA},\widehat{\mu}^*_{iB})\right].$$

By Definition 1 (or 2) the RHS of this inequality is always negative, while the LHS may either be positive or negative. If it is positive the inequality is satisfied. If it is negative, we can multiply everything by -1 and rearrange as

$$\delta<\frac{-U(\mu^*_{iA},\mu^*_{iB})-K'}{-U(\underline{\mu}_{iA},\mu^*_{iB})-U(\mu^*_{iA},\underline{\mu}_{iB})+U(\underline{\mu}_{iA},\underline{\mu}_{iB})-K'}$$

where $K'=[U(\widehat{\mu}^*_{iA},\widehat{\mu}^*_{iB})-U(\widehat{\mu}^*_{iA},\mu^*_{iB})-U(\mu^*_{iA},\widehat{\mu}^*_{iB})]$. By Definition 1 (or 2) $U(\mu^*_{iA},\mu^*_{iB})<U(\underline{\mu}_{iA},\mu^*_{iB})+U(\mu^*_{iA},\underline{\mu}_{iB})-U(\underline{\mu}_{iA},\underline{\mu}_{iB})$, therefore the numerator is strictly larger than the denominator, and given that $\delta\leq 1$ the inequality is always satisfied. **Q.E.D.**

7.5 Proof of Corollary 3

As usual, define $\pi_{ik}^* = \pi_i(q_i^*, q_j^*)$, $\widehat{\pi}_{ik}^* = \pi_{ik}(\widehat{q}_{ik}(q_{jk}^*), q_{jk}^*)$, $\pi_{ik}^M = \pi_{ik}(q_{ik}^M, 0)$, $\widehat{\pi}_{ik}^M = \pi_{ik}(\widehat{q}_{ik}(q_{jk}^M), q_{jk}^M)$, and $\underline{\pi}_{ik} = \pi_{ik}(\underline{q}_{ik} = 0)$. Suppose

$$U(\underline{\pi}_{iA} + \underline{\pi}_{iB}) + \frac{\delta U(\pi_{iA}^* + \pi_{iB}^*)}{1-\delta} \geq \frac{U(\widehat{\pi}_{iA}^M + \widehat{\pi}_{iB}^M)}{1-\delta},$$

$$U(\underline{\pi}_{iA} + \pi_{iB}^*) + \frac{\delta U(\pi_{iA}^* + \pi_{iB}^*)}{1-\delta} \geq \frac{U(\widehat{\pi}_{iA}^M + \pi_{iB}^*)}{1-\delta},$$

$$U(\pi_{iA}^* + \underline{\pi}_{iB}) + \frac{\delta U(\pi_{iA}^* + \pi_{iB}^*)}{1-\delta} \geq \frac{U(\pi_{iB}^* + \widehat{\pi}_{iB}^M)}{1-\delta},$$

so that the strategies are subgame perfect. Then the condition for collusion to be supportable in both markets with no multimarket contact becomes

$$\frac{(1-\delta^2)2U(\pi_{iA}^* + \pi_{iB}^*)}{1-\delta} - U(\widehat{\pi}_{iA}^* + \pi_{iB}^*) - U(\pi_{iA}^* + \widehat{\pi}_{iB}^*) - \delta\left[U(\underline{\pi}_{iA} + \pi_{iB}^*) + U(\pi_{iA}^* + \underline{\pi}_{iB})\right] \geq 0.$$

With multimarket contact the corresponding condition is

$$\frac{(1-\delta^2)U(\pi_{iA}^* + \pi_{iB}^*)}{1-\delta} - U(\widehat{\pi}_{iA}^* + \widehat{\pi}_{iB}^*) - \delta U(\underline{\pi}_{iA} + \underline{\pi}_{iB}) \geq 0.$$

If when subtracting the LHS of the first inequality from that of the second we obtain a positive expression the statement will be proved. Subtracting, we obtain

$$(1-\delta)\left[U(\widehat{\pi}_{iA}^* + \pi_{iB}^*) + U(\pi_{iA}^* + \widehat{\pi}_{iB}^*) - U(\widehat{\pi}_{iA}^* + \widehat{\pi}_{iB}^*)\right] +$$

$$\delta(1-\delta)\left[U(\underline{\pi}_{iA} + \pi_{iB}^*) + U(\pi_{iA}^* + \underline{\pi}_{iB}) - U(\underline{\pi}_{iA} + \underline{\pi}_{iB})\right] - (1-\delta^2)U(\pi_{iA}^* + \pi_{iB}^*).$$

Let us define

$$A = U(\widehat{\pi}_{iA}^* + \pi_{iB}^*) + U(\pi_{iA}^* + \widehat{\pi}_{iB}^*) - U(\widehat{\pi}_{iA}^* + \widehat{\pi}_{iB}^*),$$

$$B = U(\underline{\pi}_{iA} + \pi_{iB}^*) + U(\pi_{iA}^* + \underline{\pi}_{iB}) - U(\underline{\pi}_{iA} + \underline{\pi}_{iB}),$$

$$C = U(\pi_{iA}^* + \pi_{iB}^*),$$

so that the difference can be rewritten as

$$(1-\delta)A + \delta(1-\delta)B - (1-\delta^2)C$$

or, equivalently, as

$$(A-C) + \delta(B-A) + \delta^2(C-B).$$

Using Lemma 1 we have (i) $C < A$ (let $z = \pi_{iA}^* + \pi_{iB}^*$, $x = \widehat{\pi}_{iA}^* - \pi_{iA}^*$, $y = \widehat{\pi}_{iB}^* - \pi_{iB}^*,$), and (ii) $C < B$ (let $z = \underline{\pi}_{iA} + \underline{\pi}_{iB}$, $x = \pi_{iA}^* - \underline{\pi}_{iA}$, $y = \pi_{iB}^* - \underline{\pi}_{iB}$). Suppose first $A = B$. Then the inequality becomes

$$(A-C) + \delta^2(C-A) = (1-\delta^2)(A-C) > 0$$

as desired. Suppose now $B > A$. We can rearrange and obtain

$$(A - C) + \delta(B - A) + \delta^2(C - A + A - B) = (1 - \delta^2)(A - C) + \delta(1 - \delta)(B - A) > 0$$

as desired. Finally, suppose $A > B$. We can rearrange obtaining

$$(A - C) + \delta(B - C + C - A) + \delta^2(C - B) = (1 - \delta)(A - C) + (\delta - \delta^2)(B - C) > 0.$$

Q.E.D.

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