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Giancarlo Spagnolo

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Giancarlo Spagnolo, Universität Mannheim and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Managerial Incentives and Collusive Behaviour*

I characterize the effects of empirically observed managerial incentives on long-run oligopolistic competition. When managers have a preference for smooth time-paths of profits – as revealed by the empirical literature on 'income smoothing' – manager-led firms can sustain collusive agreements at lower discount factors. Capped bonus plans and incumbency rents with termination threats make collusion supportable at any discount factor, independent of contracts' duration. When managers have these preferences/incentives and demand fluctuates, 'price wars during booms' need not occur: the most collusive price may then be pro-cyclical. Corporate governance codes invoking transparency may reinforce these effects.

JEL Classification: D43, G30, J33, L13 and L21
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Giancarlo Spagnolo
Department of Economics
Universität Mannheim
D-68131 Mannheim
Germany
Tel: (49 621) 181 1873
Fax: (49 621) 181 1874
Email: gianca@uni-mannheim.de

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1 Introduction

Three decades of empirical research on "income smoothing" revealed that managers invest time, effort and firms' resources, and even use barely legal accounting tricks, in order to smooth accounting profits in time.[1] In a recent paper on the subject, Fudenberg and 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).

A highly debated contribution by Jensen and Murphy (1990) revealed that at least until the '80s – when the "stock-options wave" began – the compensation of US top managers has typically had a low pay-performance sensitivity. Kaplan (1994a,b) found top executives to have similar incentives in other developed countries, such as Germany and Japan, where no stock-options wave has yet taken place.[2]

These findings have puzzled many economists, since classical agency theory teaches us that when good indicators of managerial performance are available – as they are for CEOs (current and future profits and stock prices) – high-powered incentives should be highly beneficial. It is not clear therefore why shareholders continue to face the costs of income smoothing practices instead of suitably modifying their managers' incentives.

This paper focuses on the effects of these common governance practices on firms' long-term competitive attitudes. It shows that as long as managers have the kinds of low-powered incentives that induce "income smoothing," the separation between ownership and control – as well as any more limited form of delegation to professional managers that includes pricing decisions – greatly enhance firms' ability to sustain tacit collusion in oligopolies. This finding provides a new joint rationale for the above mentioned empirical regularities, at least for mature oligopolistic industries: a strong pro-collusive effect may well outweight agency costs and transform apparently puzzling compensation practices into profitable 'governance' instruments.

The phenomenon of tacit collusion among oligopolistic firms has been well understood thanks to three decades of research on repeated games.[3] Most supergame-theoretic analyses of collusion,

[1] Restricting attention to more recent studies, see Degeorge *et al.* (1999); Chaney and Lewis (1998); De Fond and Park (1997); Kasanen *et. al.* (1996); Holthausen *et al.* (1995); Gaver *et al.* (1995); Merchant (1989); and Healy (1985).

[2] See, also, Rosen (1992); Hadlock and Lumer (1997); and Murphy (1999). Hall and Liebmann (1998) show that the widespread adoption of stock-related incentive plans increased US top managers' pay-performance sensitivity in the last years. The question remains why in the US incentives have been low powered for such a long time, and why they still are so outside the US. Moreover, the "highly-powered" stock-related incentives now widespread in the US appear to be designed in a way nicely consistent with the results of this paper (see Spagnolo, 2000).

[3] Classical references include Friedman (1971); Aumann and Shapley (1976); Rubinstein (1979); Green and Porter (1984); Fudenberg and Maskin (1986); Rotemberg and Saloner (1986); and Abreu (1986, 1988).

however, confined themselves to the standard assumption that firms maximize discounted expected profits. In the real world many interacting factors determine the shape of firms' objective function, and it is important to understand how these factors affect firms' product market behavior. 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]

Here we start from what we know about real-world managers' objectives. To analyze the long-term product market implications of income-smoothing managers and low-powered incentives, we embed these pieces of evidence in a classical repeated oligopoly model.

Many theoretical explanations have been proposed for managers' attempts to smooth firms' profits. We find that whatever the reason behind it, managers' "preference for smooth profit streams" implies a "preference for collusive behavior." A preference for smooth profits implies an aversion to profits' variance, which stabilizes collusive agreements simply because defections are followed by a price/output war, hence increase the variability of profits. Firms whose pricing policy is in the hands of managers that prefer smooth profit streams can support a any collusive agreement at lower discount factors than profit-maximizing ones because the preference for smooth profit streams reduces managers' appreciation of short-run profits from unilaterally breaking a collusive agreement and increases that of losses from the punishment phase that follows.[5]

We explore more in detail the product market implications of two leading explanations of income smoothing linked to managerial incentives.

In a highly debated paper by Healy (1985) suggested that income smoothing is driven by the cap typically present in bonus schemes, above which managers' compensation is insensitive to firm profits, and provide evidence in support of this hypothesis. More recently, Fudenberg and Tirole (1995) suggested that incumbency rents (e.g. private benefits of control) together with owners' inability to commit to long-term contracts (and "information decay" – the higher informational content of more recent performance indicators) may be responsible for income smoothing. In this paper we find that capped bonus contracts – whether long or short-term – are powerful collusive devices: well chosen caps on bonuses make the joint monopoly collusive agreement supportable as unique collusive equilibrium, independent of the discount factor. Short-term contracts with incumbency rents and replacement rules by which the manager is not reappointed if the firm's profits fall below a cut-off level of profits have the same implications of capped bonuses, making the joint monopoly collusive agreement supportable at any level of

[4] Most notably, scholars involved in the "managerial" theory of the firm, such as Simon (1957); Baumol (1958); Cyert and March (1963); Marris (1964); Williamson (1964); and Jensen and Meckling (1976).

[5] The result does not depend on imperfections in credit markets. The evidence on income smoothing reveals that managers prefer smooth streams of firms' *accounting profits*. With perfect credit markets managers can freely save and borrow to smooth the time profile of their own income, or that of the firm's available funds, but they cannot affect (at least legally) the firm's accounting profits.

the discount factor.

These results provide a novel explanation why shareholders may be tolerating the mismanagement costs linked to income smoothing. In oligopolistic environments the same kinds of incentives that induce such costly practices also allow shareholders to enjoy high collusive profits, and low-powered incentives are "optimal" in that they induce the kind of "satisfying" managerial behavior that eventually maximizes firm profits.[6] The results also imply that the increased transparency sponsored by Corporate Governance "codes of best practice" may have negative consequences, as it reinforces the pro-collusive effect we characterized by increasing the cost – or preventing all together the secret renegotiation of top managers' compensation.

An ancillary set of results regards the cyclical behavior of collusive prices. We find that when managers have the preferences/incentives discussed above and demand fluctuates, Rotemberg and Saloner's (1986) "price wars during booms" need not occur. In "good" states of demand managers may have a much lower marginal valuation for additional profits (short-run gains from deviations) than in "bad" states of demand, an effect that may dominate the one identified by Rotemberg and Saloner and linked to the absolute size of gains from defection, and even make the most collusive price pro-cyclical. This provides a new rationale for the uncertain empirical performance of Rotemberg and Saloner's model (e.g. Ellison, 1994).

We mentioned the relations between this paper, the theoretical literatures on repeated oligopolies and managerial firms, and the empirical literatures on executive compensation and income smoothing. This paper is also a contribution to the literature on "strategic delegation," that building on Thomas Schelling's (1960) insight that contracts with third parties may have strategic effects, explores the consequences of delegating control to managers with preferences or incentives different from those of the owners in oligopolistic environments (e.g. Vickers, 1985; Fershtman and Judd, 1987; Sklivas, 1987; Fershtman, Judd and Kalai, 1991; Katz, 1991; Reitman, 1993). The most closely related paper in this literature is probably Fershtman, Judd, and Kalai (1991), although our results are also close in spirit to Polo and Tedeschi (1992) and Aggarwal and Samwick (1999). From a methodological point of view, the paper departs from previous work by letting firms interact repeatedly in time (the exception is Spagnolo (1988, 2000), who however focuses exclusively on stock-related compensation).[7] Fershtman, Judd, and

[6] This partly vindicates Herbert Simon's claim that firms/managers most often aim at a "satisfying performance," not at maximizing profits. Since this kind of "administrative behavior" leads to better results in mature oligopolies, it needs not be driven out by "profit maximization" in the process of economic evolution.

[7] 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. A one-shot delegation game followed by a second-stage oligopoly *supergame* between delegates under long-term contracts should be a better approximation for at least some real-world oligopolistic interactions. 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. This paper considers

Kalai (1991) obtain a "folk theorem" for classical two-stage delegation games showing that any second stage outcome can be implemented in weak subgame perfect Nash equilibrium of the delegation game by making them indifferent in equilibrium. This can be implemented with "target compensation functions," contracts that guaranteeing agents a fixed prize as long the principal's utility above a certain level. Capped bonus contracts resemble – but in a dynamic world are not "target compensation functions," as managers incur a net loss (of future bonuses) when they increase the owner's payoffs by deviating from a collusive agreement. Moreover, under our assumptions second-stage equilibria must be strict, so that making agents indifferent would not work. Still, from a purely theoretical point of view our results in Section 3.1 are close in spirit to Fershtman *et al.*'s, and that section can be thought of as the first dynamic extension of their model/insights. Polo and Tedeschi (1992) and Aggarwal and Samwick (1999) are close in spirit to this paper, since both papers obtain a pro-collusive effect of delegation. However, these results are limited to specific market structures (strategic complements) and due to managerial contracts explicitly and positively related to competing firms' profts, where observed managerial contracts are typically not linked (neither positively nor negatively) to competing firms' performance, they are conditional on firm's *own* profits only (see Murphy, 1999).[8]

Section 2 sets up the model and characterizes the effects of preferences for smooth profits. Section 3 analyzes capped bonus plans and incumbency rents. Section 4 discusses robustness issues and extensions; and Section 5 briefly concludes. All proofs are in the Appendix.

2 Income smoothing firms and product market rivalry

2.1 A simple model

Consider a standard homogeneous good oligopoly where $N \geq 2$ identical firms compete repeatedly in price. Time is discrete and trade occurs simultaneously in each period $t = 1, 2, ...$ At the beginning of each period each firm announces its current price. Let c denote the firms' constant and identical marginal cost, δ the common intertemporal discount factor ($0 < \delta < 1$), 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 unless all firms agree on a different allocation. 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

both these situations.

[8]The rare use of relative performance evaluation (RPM) – incentives *negatively* related to competitors performance – for top managers is a recognized empirical puzzle, and our results support Aggarwal and Samwick's suggestion that the fear of increasing product market competition may be limiting firms' use of RPM. However, incentive contracts *positively* related to competing firms' performance are observed even less often that RPM, and if they were to become diffuse they would (hopefully) be questioned by competition authorities.

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.

Throughout the paper, when we write "equilibrium" we will mean subgame perfect Nash equilibrium unless otherwise specified. We focus on stationary collusive agreements supported by "grim trigger" strategies, i.e. by the threat of reverting forever to the Bertrand-Nash equilibrium of the stage game after any defection (Friedman, 1971). This simplifies analysis and exposition does not imply any loss of generality.[9] Extensions to different market structures and more sophisticated punishment strategies are discussed in Section 4.1. When collusive agreements are supported by grim trigger strategies, a collusive price p^* is sustainable in equilibrium if and only if

$$\frac{1}{1-\delta}(p^*-c)Q(p^*)/N \geq (p^*-c)Q(p^*) + \frac{\delta}{1-\delta}0, \quad \Leftrightarrow \quad \delta \geq 1 - \frac{1}{N}. \tag{1}$$

To simplify notation, in the rest of the paper we will let $\pi_i^* = (p^*-c)Q(p^*)/N$ denote the per-period collusive profits of a firm i, π^* denote total industry profits, and $\widehat{\pi}_i^*$ denote short-run profits from deviating unilaterally from that collusive agreement, where with Bertrand competition $\widehat{\pi}_i^* = \pi^* = N\pi_i^*$. The superscripts ^{M} and ^{N} will indicate the value of a variable at the joint monopoly and at the static Nash equilibrium outcomes respectively.

2.2 Income smoothing firms and collusive behavior

The empirical literature on income smoothing reveals that firm managers have a robust preference for smooth time paths of profits. This evidence is inconsistent with the standard model with profit-maximizing firms, while it is consistent with a model of firms averse to variance in profits, i.e. maximizing some intertemporal objective function $V\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$, such that V'_{δ}, $V'_{\pi_i^t} > 0$ but $V'_{\sigma^2} < 0$. This should be the case, for example, when the corporate tax schedule is not perfectly linear in profits or if firm owners and/or managers receive each period a share of profits and face an increasing marginal income tax rate.[10] It would also be the case if Boards discount extreme realizations from managers' compensation, as observed by Joskow and Rose (1994), and if investors evaluate firms' or managers' performance according to prospect theory, taking previous period's profits as a benchmark at which their utility/valuation function has a kink, being steeper below the threshold than above it.[11] Whatever the reason behind firms/managers aversion to profits' variance, we have the following.

[9] 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 that keep players at their security levels (Abreu, 1986).

[10] Personal income tax rate is non linear in most countries. Increasing marginal tax rates are an obvious, disregarded incentive to smooth income in time.

[11] See Daniel Kahneman and Amos Tversky (1977); Francois Degeorge et al. (1999) show that prospect theory can help explan income smoothing, both theoretically and empirically.

Proposition 1 *Suppose firms are averse to profits' variance having an intertemporal objective function* $V\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$, *with* $V'_{\sigma^2} < 0$ *and* $V'_{\delta}, V'_{\pi_i^t} > 0$. *Then the stronger the aversion to profits' variance (the smaller* V'_{σ^2}*), the smaller is the minimum discount factor at which any collusive price* $p^* > c$ *can be supported in equilibrium in the product market supergame.*

The intuition behind the result is straightforward: a defection from a stationary collusive agreement followed by a punishment phase increases the variance of the profit stream relative to the equilibrium path, hence firms that dislike profits' variance are more prone to sustain collusion, the more the stronger the aversion to variance. A specific functional form for V that sathisfies the requirements is the standard strictly concave time-additive utility function $\sum_{t=0}^{\infty} \delta^t U(\pi_i^t)$, with $U' > 0$ and $U'' < 0$, which allows the pro-collusive effect to be nicely decomposed.[12] Then necessary and sufficient conditions for a collusive price $p^* > c$ to be supportable in equilibrium are relaxed for two reasons: i) lower relative value of short-run gains from unilateral deviations from the agreement (they are evaluated at relatively lower marginal utility); and ii) higher relative value of the losses from the punishment phase which follows a deviation (they are evaluated at relatively higher marginal utility).

A remark is also in order.

Remark 1 *When firms are conglomerates with multimarket contact and maximize a time-additive instantaneous utility function strictly concave in profits* ($\sum_{t=0}^{\infty} \delta^t U(\pi_i^t)$, *with* $U' > 0$ *and* $U'' < 0$) *a further pro-collusive effect adds to the one identified by Proposition 1. This second pro-collusive effect is due to firms' relatively higher valuation of losses from simultaneous punishments, and relatively lower valuation of gains from simultaneous deviations in more markets (see Spagnolo, 1999a).*

These effects reinforce each other and apply independently of the "correct" explanation for income smoothing. All arguments brought up in the finance literature for why firms should hedge risks, such as reducing the tax bill or limiting the costs of external finance linked to information asymmetries (see e.g. Froot *et al.*, 1993), also identify factors that increase firms' willingness to smooth profits by colluding in product markets.

2.3 Delegation, concavity and collusion

Proposition 1 does not distinguish shareholders' from managers' objectives, and fits best the explanations of income smoothing that are not based on a discrepancy between the two.[13]

[12] This is the standard way of modelling preferences for smooth income in macroeconomics. See Spagnolo (1999a) for a detailed discussion of the several real world market imperfections that tend to make firms' objective function strictly concave in profits.

[13] Besides the examples discussed earlier, Truemann and Titman's (1988) theory should be mentioned according to which financial market imperfections ensure that firms with less variable income streams have higher debt capacitiy and value, hence a decreasing marginal valuation of profits within each accounting period.

Though, several authors have argued that income smoothing derive from professional managers' self-serving behavior that has little to do with owners' objectives. For example, Lambert (1984) and Dye (1988) attribute income smoothing to financially constrained risk-averse managers under profit-sharing contracts smoothing their own income in time (under profit-sharing contracts managers receive each period a constant share of firm profits). Similarly, we note here that managers' tax schedule is typically more convex than owners' because the personal income tax rate is more steeply increasing than corporate and capital gains ones, so that managers under profit-sharing contracts would have stronger tax-related incentives to smooth firm profits in time than owners. When it is managers' objective function that is strictly concave and not owners', one should ask whether owners would delegate control to managers under profit-sharing contracts rather than retain control or choose, say, a convex payment schedule.

To clarify this point, consider a two-stage delegation game where a first-stage static interaction in which owners simultaneously choose whether to delegate control and managers' long-term compensation contract – some monotone increasing function of per-period profits – is followed by a second-stage infinitely repeated market game between agents in control.[14] We assume that managerial incentives are publicly observable (secret contract renegotiation is considered in Section 4.2) and that (1) is not satisfied, so that no collusive price can be sustained by profit-maximizing firms. To skip straightforward comparisons between direct costs (absolute amount of managers' compensation) and benefits (owners' free time) from delegation, irrelevant for incentives, we assume that owners' disutility of running the firm equals managers' equilibrium compensation, so that they cancel out.[15]

The timing of the delegation game is as follows.

Long-term delegation game A: Timing

- Stage 1: Owners simultaneously choose whether to delegate pricing decisions to a manager under long term contract with per-period compensation $\omega_i^t = f_i(\pi_i^t)$, with $f_i' > 0$, and the shape of such function.
- Stage 2: Agents in control play the market supergame.

We then obtain the following.

[14] This strategic structure is reminiscent of Benoit and Krishna's (1987) and Davidson and Denekere's (1990) analyses of excess capacity and collusion in Bertrand supergames.

[15] The pro-collusive effect does not rely on this assumption. Alternatively, to avoid carrying around terms for managers compensation we could follow previous work – at the cost of a small loss of generality – in neglecting the possibility that owners retain control (see e.g. Fershtman and Judd, 1987, p. 930 and footnotes 3 and 7). To evaluate these alternative but equivalent approaches the reader may contrast Spagnolo (2000) with Spagnolo (1998).

Proposition 2 *Suppose shareholders maximize discounted profits (e.g. because they are subject to a linear tax schedule), while managers maximize a time-additive objective function strictly concave in income* $\sum_{t=0}^{\infty} \delta^t U(\omega_i^t)$, *with* $U' > 0$ *and* $U'' < 0$ *(e.g. because they are subject to an increasing marginal tax rate), and such that there exist* $p^* > c$ *for which* $U(\alpha^* \pi_i^*) \geq (1-\delta)U(\alpha^* N \pi_i^*) + \delta U(0)$. *Then owners delegating control to managers under long term profit-sharing contracts with* $\omega_i^t = \alpha^* \pi_i^t$ *and managers sustaining* p^* *is an equilibrium of the delegation game.*

The intuition is straightforward. Given other owners delegate under share contracts, owners cannot gain by deviating unilaterally. Not delegating or choosing a payment schedule such that $U(f(\pi_i^*)) < (1-\delta)U(f(N\pi_i^*)) + \delta U(f(0))$ would make collusion unfeasible in the oligopoly supergame leading all managers to maximize profits, with a net loss of future collusive profits for the deviant. Of course, an analogous result obtains when managers maximize discounted income (e.g. their income tax is flat in the relevant range) but owners choose for managers strictly concave compensation functions $\omega_i^t = f_i(\pi_i^t)$, with $f_i'' < 0$, such that $f(\pi_i^*) < (1-\delta) f_i(N\pi_i^*) + \delta f_i(0)$ for all i.

2.4 Income smoothing firms and "price wars during booms"

Rotemberg and Saloner (1986) note that when demand is subject to stochastic shocks and market interaction is not too frequent (the discount factor binds), price-fixing firms may have to condition the collusive price on the state of demand. This is because while the expected losses from a price war – the threat that disciplines the cartel – are constant across states of the world, higher demand implies relatively larger short-run gains from undercutting the collusive price. To avoid that the cartel breaks down when demand is high, firms may have to agree on a collusive price for high states of demand p^{*H} that is lower than the collusive price in low states of demand p^{*L}. Collusive agreements with a countercyclical price path $p^{*H} < p^{*L}$ would then appear as "price wars during booms."

Let θ denote the stochastic shock that affects demand, so that 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 $0 < q < 1$, and that the monopoly price is the same p^M in both states of the world (alternatively, one could rephrase everything in terms of markups). We can now state the following.

Proposition 3 *Suppose firms maximize* $\sum_{t=\tau}^{\infty} \delta^t U(\pi_i^t)$, *with* $U' > 0$ *and* $U'' < 0$ *and demand fluctuates. Then "price wars during booms" need not occur: when* U'' *is sufficiently small and the discount factor binds, the most profitable collusive price path supportable in equilibrium is pro-cyclical* ($p^{*H} > p^{*L}$).

The intuition is the following. Independent of why they do it, when firms maximize a strictly concave instantaneous objective function they have a relatively lower marginal valuation of profits when demand is high. This means that in good states of the world firms' valuation of the additional short-run gains from deviating from collusive strategies 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 the firms' preference for smooth profits is sufficiently strong.

3 Bonus contracts and incumbency rents

The final behavior of a manager is determined by the complex interaction between a number of different components of a his compensation – bonuses, share ownership, career concerns, termination threats, taxation, private benefits, etc. In the previous section we followed a revealed preference argument suggesting that this complex interaction leads managers to behave as if their reduced-form marginal valuation of firm profits were decreasing within each period, and we looked at the product market implication of this hypothesis. In this section, instead, we go into detail by focussing on the product market implications of two specific components of managers' compensation that have been identified as possible major causes of income smoothing: caps on bonuses (Healy, 1985) and incumbency rents (Fudenberg and Tirole, 1995).

These components are specific to professional managers and the question again arises whether it is reasonable to expect that owners would choose such incentive components for their managers. To answer this question and characterize the product market effects of these incentives we sterilize other effects by assuming that managers maximize their discounted wage, and consider first long-term managerial contracts inducing a two-stage delegation game similar to the one of Section 2.3, then short-term managerial contracts where both delegation and pricing decisions are dynamic.

We continue assuming binding publicly observable managerial contracts, that inequality (1) is not satisfied, and that owners' disutility of running the firm equals managers' equilibrium compensation. In addition, we adopt the tie-breaking assumption that when managers are indifferent with respect to two or more actions they choose the one that maximizes owners' payoffs (firm profits).[16]

3.1 Long-term bonus contracts

The empirical findings of Healy (1985), Gaver *et al.* (1995) and others suggest that income smoothing may be driven by the "compensation caps" typical of managers' bonus schemes.

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

Bonus schemes are non-linear compensation plans where each year a bonus is paid only if a predetermined minimum level of firm profits is obtained. Above such level there may be a small range of profit levels where the bonus increases with profits, but then there is always an upper bound, a cap above which bonuses do not increase anymore with profits (see Murphy, 1999).

Define a long-term bonus contract as a stationary sequence of values for the triple of parameters $\beta := \left\{W_i, B_i, \pi_i^B\right\}$, where W_i denotes the manager's fixed salary, $B_i = B_i^t(\pi_i^t)$ denotes a positive monetary bonus conditional on firm profits and potentially increasing (and weakly concave) in the relevant interval, $\underline{\pi}_i^B$ denotes the weakly positive minimum level of profits that triggers the bonus, and π_i^B the profit level at which the bonus reaches its cap, with $\underline{\pi}_i^B \leq \pi_i^B$ (when B_i is constant it is of course $\underline{\pi}_i^B = \pi_i^B$). A manager total compensation in period t, under bonus contracts is therefore

$$w_i^t = \begin{cases} W_i \text{ if } \pi_i^t < \underline{\pi}_i^B \\ W_i + B_i(\pi_i^t), \text{ with } B_i' \geq 0 \text{ if } \pi_i^t \geq \pi_i^B \\ W_i + B_i(\pi_i^B) \text{ if } \pi_i^t \geq \pi_i^B \end{cases} .$$

With long-term contracts, the timing of the full delegation game is as follows.

Long-term delegation game B: Timing

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

We have the following.

Proposition 4 *Owners delegating control to managers under long-term bonus contracts with cap $\pi_i^B = \pi_i^M$, and managers sustaining the joint monopoly price p^M is an equilibrium of the delegation game, independent of the discount factor.*

The delegation game has many other equilibria all Pareto dominated by the one we focus on in the proposition.[17] However, it is worth noting the following.

Corollary 1 *When B_i is constant (i) the delegation equilibrium with $\pi_i^B = \pi_i^M$ implements the joint monopoly price as the* unique collusive equilibrium *of the second stage oligopoly game; and (ii) if managers can choose the allocation of market shares among firms at the collusive price,*

[17] For example, owners not delegating or choosing bonus schemes under which collusion is never sustainable are always (rather implausble) equilibria delivering zero profits. If the discount factor is sufficiently large and B_i are not constants, equilibria with owners delegating with $\pi_i^B = \pi_i^M$ and managers sustaining a price lower than the joint monopoly one will also exist (also rather implausible, given that switching to the joint monopoly price would both increase managers' wage and stabilize collusion).

the delegation equilibrium with $\pi_i^B = \pi_i^M$ is the only equilibrium of the delegation game with positive profits.

That is, in a very competitive industry where profit maximizing firms can do nothing else than setting $p = c$, delegation under bonus contracts implements $p = p^M$ solving both enforcement and coordination problems.

We focused on bonus contracts, but the result remains valid when owners can choose from a larger set of managerial incentive contracts. For example, the result goes through unchanged if in stage 1 owners can choose the parameters of the compensation function $w_i^t = W_i + \gamma_i g_i(\pi_i) + \beta_i f_i(S_i) + B_i \cdot 1_{\{\pi_i \geq \pi_i^B\}}$, where S_i denotes firm i's sales, $\gamma_i \geq 0$ 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.[18]

As usual in the strategic delegation literature the equilibrium characterized by Proposition 4 does not pin down the ratio $B_i/W_i > 0$, nor the absolute amount managers are paid which will be determined by conditions on the market for professional managers (see e.g. Fershtman and Judd, 1987, footnotes 3 and 6). In equilibrium owners remain free to choose any combination of fixed wage W_i and bonus B_i that in satisfies the manager's participation constraint because as long as $B_i > 0$ managers' choices are driven exclusively by the marginal incentive, the cap π_i^B. This makes the result compatible with a rich variation in bonus size across firms.

Note that when $B_i = 0$ the only continuation equilibrium in Stage 2 is the repeated play of the Bertrand outcome because of our assumptions that (1) is not satisfied and that when managers are indifferent they maximize discounted profits. This is also why the "target compensation functions" Fershtman, Judd and Kalai (1991) used to prove their folk theorem would not work in our environment.[19]

3.1.1 Price wars during booms

To see that price wars during booms need not take place when colluding firms are run by managers under long-term bonus contracts, consider the two extreme cases of fully contractible and non-contractible demand shocks, where the demand shock is as in Section 2.4.

Suppose that the demand shock θ is contractible. It follows straightforwardly from Proposition 3 that by delegating control to managers under long-term bonus contracts that are contingent on the state of demand, so that $\pi_i^B = \pi_i^M(\theta^H)$ when demand is high and $\pi_i^B = \pi_i^M(\theta^L)$

[18] A proof can be found in Spagnolo (1999b). The indicator function $1_{\{\pi_i \geq \pi_i^B\}}$ assumes value 1 when $\pi_i \geq \pi_i^B$ and 0 otherwise.

[19] Target compensation functions pay agents a fixed prize as long as principal profits are equal or above a target level, and in Fershtman Judd and Kalai (1991) lead to a "folk theorem" by making agents indifferent with respect to defecting from a strategy profile that allows them to meet the target. Bonus contracts are reminding of but are not target compensation functions (when a manager defects from a collusive equilibrium owners payoffs increase while the manager loses future bonuses), nor would these functions work under our assumption that indifferent managers maximize firm's profits, implying that all Stage 2 continuation equilibria must be strict.

when it is low, owners can implement the monopoly price as the unique subgame perfect collusive equilibrium outcome in all periods, in which case price wars during booms obviously would not take place.

Suppose now that third parties cannot observe reliable signals of the demand state, so that owners cannot condition incentive contracts on the state of demand. By setting a stationary trigger level of profits $\pi_i^B = \pi_i^M(\theta^L)$ owners guarantee that managers can sustain collusion in all states, and again price wars during booms need not take place: under the assumption that indifferent managers maximize their owners' profits choosing the highest collusive price sustainable in each period, equilibrium price will be constant and equal to p^M and bonus contracts with $\pi_i^B = \pi_i^M(\theta^L)$ are "equilibrium incentives" (if other owners delegate under these incentives and managers are expected to sustain the joint monopoly price in all states, an owner cannot gain by choosing different incentives). On the other hand, price wars during booms may occur under these same delegation contracts when managers fail to coordinate on the joint monopoly price in high demand states, as well as in other equilibria of the delegation game.

3.2 Short-term contracts and incumbency rents

With long-term contracts, delegation under capped bonus contracts emerges as a powerful device to coordinate on and enforce collusive agreements. In this subsection we consider whether and how this conclusion is affected by owners' or managers' inability or unwillingness to commit to long-term contracts, and how the other component of managerial incentives that have been associated to income smoothing, incumbency rents, may affect product market rivalry.

3.2.1 Short-term bonus contracts

Maintaining all previous assumptions, let us consider managerial contracts that last one period only, inducing an infinitely repeated delegation-oligopoly game with a classical 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 delegate, the parameters of the manager's compensation function. At the end of the same time period agents in control interact in a one-shot Bertrand oligopoly game. The timing of period t stage game is as follows:

Stage game t

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

We obtain the following.

Proposition 5 *Owners delegating control each period to managers under bonus contracts with* $\pi_i^B = \pi_i^M$*, and managers setting each period the joint monopoly price is an equilibrium of the dynamic delegation game independent of the discount factor.*

The intuition is that even though explicit managerial contracts last one period only, owners and managers are free to agree on *implicit/relational* contracts with each other, which are long-term by definition (Bentley MacLeod and James Malcomson, 1989; Jonathan Levine, 2003). 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 gains from deviation realize. Managers always find it convenient to respect the collusive agreement, since their capped incentive contract is such that they gain nothing by deviating, while after a deviation they are fired and/or kept at their reservation wage forever. It is straightforward to check that the same argument applies when managerial contracts last any finite number of periods other than one.

3.2.2 Incumbency rents

The equilibrium set of the delegation game with short-term capped bonus contracts differs from that with long-term contracts only in that in the former managers must receive some strictly positive rent (which needs not be the case with long-term contracts). This is because a fraction of the collusive rent must be left to the manager to generate the expected gains from compliance necessary to enforce the implicit/relational contract.[20] 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 in the form of bonuses, but by the same logic an analogous pro-collusive effect must be linked to managers' fear of losing other common kinds of incumbency rents, such as private benefits of control. As mentioned, Fudenberg and Tirole (1995) proposed an explanation of income smoothing based on managers' fear of losing incumbency rents, and incumbency rents need not necessarily take the form of a bonus contract. In fact, it can be shown that in our model private benefits of control or other incumbency rents, coupled with the termination threat in the form of a replacement rule – a cut-off level of profit below which the manager is replaced – have a pro-collusive effect fully analogous to that of short-term capped bonus contracts (the formal result is in Spagnolo, 1999b). 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 is observed by competing firms' managers who react before gains from deviation realize. And again, as long as managers under

[20] 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 (i.e. defect from the collusive price given that (1) is not satisfied).

flat wage compensation enjoy incumbency rents they find it strictly convenient to respect any collusive agreement that allows them to be reappointed and enjoy their rents in future periods.[21]

4 Robustness

For the sake of crispness we focused on the Bertrand oligopoly, but it can be easily verified that analogous results apply to other standard market structures, like Cournot oligopoly or Bertrand oligopolies with differentiated products or capacity constraints.[22] With Cournot competition, though, somewhat different delegation equilibria than those discussed in the previous sections may be preferred, where equilibrium incentives are also function of sales.

4.1 Cournot competition and "mixed" incentives

Consider a Cournot duopoly. Since Stackelberg profits π_i^S are typically lower than joint monopoly profits π_i^M, owners expecting others to choose bonus contracts with $\pi_i^B = \pi_i^M$ could not gain by deviating and choosing aggressive incentives linked to sales, such as those considered in Fershtman and Judd (1987) and Sklivas (1987) (FJS from now on).[23] However, if owner j deviates by choosing aggressive incentives, or if collusion between managers is not sustained or breaks down owner i would be better off having chosen incentives linked to sales. Owners may therefore wish to coordinate on a more robust equilibrium of the delegation game. One such equilibrium has owners giving 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 per-period compensation scheme linear in profits and sales but including a capped 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 have the following.

Proposition 6 *Owners 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*

[21] To prove this, the proof of Proposition 5 can easily be by adapted reinterpreting variables, letting B_i be a constant denoting 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 that – when checking for unilateral deviations on the side of the managers – 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.

[22] The only required modification in most proofs is the addition of a stream of positive profits during the punishment phase, which leaves the logic of the reasoning unaffected (see Spagnolo, 1999b).

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

constraint at the joint monopoly collusive agreement and managers sustaining the joint monopoly price in the oligopoly supergame is also a subgame perfect equilibrium of the delegation game.

The pro-collusive effect of capped bonuses and/or incumbency rents remains when these are only part of a more complex managerial compensation package, but with mixed incentives the delegation equilibrium is "less risky" in the sense that deviations become both less attractive and less costly for the non-deviating party. If an owner deviates optimally by choosing $\rho_i = 1$, a manager under mixed incentives reacts by maximizing the FJS-type part of his incentive scheme (since he cannot get the bonus anyway). The deviating owner then obtains the profits of the FJS model $\pi_i^{FJS} < \pi_i^N$, both in the period of the deviation and in the following periods, rather than Stakelberg leader's profits $\pi_i^S > \pi_i^N$, and the other agent also gets π_i^{FJS}, which is higher than Stackelberg follower's profits.

4.2 Renegotiation-proof punishment strategies

As persuasively argued by Barbara McCutcheon (1997), in the case of collusive agreements between firms renegotiation costs tend to be positive because of the increased risk of being caught and fined by the competition authority. In this case the optimal renegotiation-proof punishment in a Bertrand supergame consists in pricing competitively for a finite number of periods such that the loss of gains from cooperation caused by the price-war is just below the cost of renegotiation (see Andreas Blume, 1994). All our results continue to apply when these renegotiation-proof punishment strategies are used instead of grim trigger strategies. The pro-collusive attitude of income-smoothing firms/managers highlighted in Proposition 1 is then further strengthened because the cost of renegotiation is concentrated in time (in the period of the fine), hence it is relatively larger for income-smoothing managers – whose marginal utility of firms' profits is higher at low levels of profits – than for owners. Therefore, for any given cost of renegotiation, income-smoothing firms/managers can use the tougher threat of a longer price war to enforce collusion, which adds to the other pro-collusive effects identified by Proposition 1.[24]

4.3 Renegotiation of managerial incentives

In previous sections we assumed observable and binding managerial incentive contracts, as done in most previous work on strategic delegation. Mathias Dewatripont (1988), Michael Katz (1991) and others pointed out that under symmetric information the commitment value of contracts with third parties can be undermined by agents' ability to *secretly* renegotiate the contracts. This correct argument has been sometimes improperly used to cast doubts on the overall relevance of strategic delegation. In this section we try to briefly clarify the issue.

[24] A (quite straightforward) proof of this statement is available from the author upon request.

Even with symmetric information, managerial contracts loose all commitment value only if secret renegotiation is feasible and *costless*. As long as secret renegotiation is costly, the commitment value of observable contracts is positive and proportional to renegotiation costs. If renegotiation is costless but cannot be kept secret, then contracts have full commitment value.

As for managerial contracts, in reality several established institutions makes the secret renegotiation of CEOs' incentives unfeasible or costly. We list below some of these institutions each of which is sufficient *alone* to give commitment value to managerial contracts. Also, space forces us to limit the discussion to the most important factors and keep arguments heuristic.[25]

4.3.1 "Internal" factors: charters and boards

Observability is more and more a characteristic of top managers' compensation, also thanks to the more stringent disclosure requirements pushed forward by various "Corporate Governance Codes" around the world.[26] A commitment to transparency makes secret renegotiation costly impossible. Moreover, two established institutions may help further in preventing secret renegotiation.

The charter. Since the charter of public companies is publicly observable, a rule in the charter prescribing changes of top managers' compensation to be approved in shareholders' meetings is sufficient to make the secret renegotiation of managerial incentives impossible.[27]

The board of directors. We mentioned the evidence that boards themselves usually discount extreme performance realizations from managers' compensation, making it "capped" as in bonus contracts (e.g. Joskow and Rose, 1994). The ultimate question is why boards give managers the kind of low-powered incentives that lead to income smoothing and collusive behavior. An obvious answer is that this is the result of boards' incentives: directors leave top managers with capped incentives and incumbency rents because directors themselves have that kind of incentives. Directors typically enjoy firm perquisites and have generous compensation with even lower-powered incentives than managers, which make them very interested in a smooth, continuous flow of "satisfactory" profits that ensures reappointment.[28] All the results in previous

[25] Additional factors and a more detailed discussion can be found in Spagnolo (1999b) and (2003).

[26] The first Code of Best Practice of the recent years, the celebrated Cadbury Report (1992), with regard to executives' compensation states: *"There should be full and clear disclosure of [executive] directors' total emoluments [...] including pension, contribution and stock options. Separate figures should be given for salary and performance-related elements and the basis on which performance is measured should be explained."*

[27] In our framework, the only reason for shareholders to renegotiate the manager's contract or the rule in the charter that makes such renegotiation public (public companies' shareholders' meetings are public events) would be to induce a deviation from the collusive agreement, hence as soon as any renegotiation (of the managerial contract or of the rule in the charter) is observed other firms' managers anticipate a deviation and react optimally by abandoning the agreement, which makes renegotiation worthless.

[28] This is also considered the best practice. Again, the Code of Best Practice of the Cadbury Report (1992) states: "The Committee regards it as good practice for non-executive directors not to participate in share option

sections can be restated after replacing the word "managers" with the word "directors," and directors' contracts must be renegotiated/renewed in public shareholders' meetings, so they cannot be secretly renegotiated.

4.3.2 External factors: directors' "information network"

Directly interlocking directors. Kevin Hallock (1997) finds that 20 to 30% of US firms have directly interlocked boards of directors, in the sense that they have a manager or a director sitting on each other's board. The US is the only country we are aware of where interlocking directorships between competing firms are forbidden.[29] In most other countries directly interlocking directorships between competitors are not forbidden, and are in fact quite common. To renegotiate a public company's CEO's contract at least a meeting of the compensation committee is required. Since such committees are composed of outside directors, each interlocked director will know in advance of any renegotiation attempt, and can therefore veto it by threatening to the CEO of the firm in which he is executive (who would react and nullify any gain from renegotiation; if the interlocked director is the CEO himself, this threat is particularly credible...).[30]

Indirectly interlocking directors. La Porta *et al.* (1999) find pyramidal ownership to be the most common mechanism by which controlling shareholders of large companies separate (and sell) cash flow rights and control rights around the world. Of the 75% of the companies in their cross-country top-twenty sample that have a dominant shareholder, 26% belong to a pyramidal structure. Consider a duopoly and suppose the two firms are controlled through pyramids. Suppose, further, that the CEO (or another top executive) of any firm at a higher level of each pyramid serves as outside director in the board of the duopolistic firm controlled by the other pyramid. We name these *indirectly interlocking* directors. Since executives of firms within a pyramid are all accountable to the same controlling shareholder, these directors would veto (or make public) the secret renegotiation of a CEO's contract that could lead to a breach of collusion.

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schemes and for their service as non-executive directors not to be pensionable by the company, in order to safeguard their independent position."

[29] They were forbidden in the early 1900, thanks to the efforts of Louis Brandeis. See Miguel Cantillo Simon (1998) for a recent account of how this prohibition – together with the others in the Clayton and Glass-Steagall Acts – came about in the US.

[30] Again, this is considered the best practice. Once more, the Code of Best Practice of the Cadbury Report (1992) states: "Executive directors' pay should be subject to the recommendation of a remuneration committee made up wholly or mainly of non-executive directors."

5 Concluding remarks

We showed that the most commonly observed managerial compensation practices *greatly* facilitate collusive behavior in long-run oligopolies. The results are not only relevant for public companies with dispersed shareholders: pricing and quantity-setting decisions are normally in the hands of professional managers also when ownership is concentrated, and even in large private companies. These strong results can be somewhat softened by allowing managers to have a shorter time horizon than owners and career concerns inducing "short-termism". However, the incentives we discussed are typical of all levels of management, and price-fixing agreements are often implemented by intermediate management whose turnover is typically low, particularly in continental economies where low-powered managerial incentives are more common.

We endogenized owners' choice of managers' incentives for theoretical completeness, but we don't want to push at the extreme the idea of shareholders rationally choosing to precommit through pro-collusive managerial incentives. Another interpretation of our findings is "evolutionary." Boundedly rational investors may select directors' and CEOs' incentives on the basis of their past performance.[31] In a world dominated by oligopolies, investors may not be aware of exactly why choosing "conservative" or "prudent" incentives pays more in the long run than choosing aggressive incentives, and will be even less aware that secretly renegotiating incentive contracts might pay even more. In the many market games they have played over time they have tried different incentives, and because of the oligopolistic structure of most industries the "conservative" incentives we discussed are those that performed better and survived.

[31] Evolutionary models in this spirit have already been studied: managers in our delegation supergame can be seen as automata chosen by owners/players in a "metagame" to play a subsequent supergame, as in Abreu and Rubinstein (1988). Under such interpretation the capped incentive schemes we discuss would correspond to automata instructed not to deviate first, to play "nice" strategies, but also to fight "nasty" automatas (managers with aggressive incentives). The work of Axelrod (1984) and others has shown that in the repeated Prisoner's Dilemma, isomorphic to repeated oligopoly games, even simpler automata with nice strategies tend generally to survive.

6 Appendix

Proof of Proposition 1. We first state a simple lemma.

Lemma 1 *The Bertrand equilibrium remains the unique pure strategy Nash equilibrium of the stage game when this is played by agents maximizing* $V\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$, *with* $V'_{\delta}, V'_{\sigma^2} < 0, \quad$ *and* $V'_{\pi_i^t} > 0$ *for every* t.

Proof of lemma 1. With respect to any period t stage game, V is a monotone transformation of the original profit function π_i^t. 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 ensures that reversion to the static Bertrand equilibrium remains a credible threat when firms' objective function is $V\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$. Consider now two objective functions $V^1 = V^1\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$ and $V^2 = V^2\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right]$ differing only with respect to $V'_{\sigma^2} < 0$, and such that $V^1\Big|_{\sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}=0} = V^2\Big|_{\sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}=0}$ but $V^{2\prime}_{\sigma^2} < V^{1\prime}_{\sigma^2} < 0$. Then a stationary collusive agreement on price p^* can be supported in equilibrium under V^1 if

$$\begin{aligned} & V^1\left[\delta, \left\{\pi_i^t = (p^* - c)Q(p^*)/N\right\}_{t=0}^{\infty}, 0\right] \\ \geq \quad & V^1\left[\delta, \left\{\pi_i^0 = (p^* - c)Q(p^*)\left\{\pi_i^t = 0\right\}_{t=1}^{\infty}\right\}, \sigma^2\left\{\pi_i^0 = (p^* - c)Q(p^*)\left\{\pi_i^t = 0\right\}_{t=1}^{\infty}\right\}\right] \end{aligned}$$

and under V^2 if

$$\begin{aligned} & V^2\left[\delta, \left\{\pi_i^t = (p^* - c)Q(p^*)/N\right\}_{t=0}^{\infty}, 0\right] \\ \geq \quad & V^2\left[\delta, \left\{\pi_i^0 = (p^* - c)Q(p^*)\left\{\pi_i^t = 0\right\}_{t=1}^{\infty}\right\}, \sigma^2\left\{\pi_i^0 = (p^* - c)Q(p^*)\left\{\pi_i^t = 0\right\}_{t=1}^{\infty}\right\}\right]. \end{aligned}$$

The terms at the left hand sides of these two inequalities are equal, while the term at the right hand side of the second inequality is strictly larger than the correspondent term at the right hand side of the first inequality, from which the statement follows. **Q.E.D.**

Proof of Proposition 2. If managers' utility was linear in income ($U(\omega_i^t) = \omega_i^t$) the relevant condition for a collusive price $p^* > c$ to be supportable in equilibrium in the the second stage by managers under share contract would again be (1), and since $V\left[\delta, \left\{\pi_i^t\right\}_{t=0}^{\infty}, \sigma^2\left\{\pi_i^t\right\}_{t=0}^{\infty}\right] = \sum_{t=0}^{\infty} \delta^t U(\pi_i^t)$ with $U' > 0$ and $U'' < 0$ sathisfies $V'_{\delta}, V'_{\sigma^2} < 0$, and $V'_{\pi_i^t} > 0$, by Proposition 1 there exist $p^* > c$ for which $U(\alpha^*\pi_i^*) \geq (1-\delta)U(\alpha^* N \pi_i^*) + \delta U(0)$ when (1) is not satisfied. Consider now the following strategy profile:

Owners: *Delegate control to the manager under a long term profit-sharing contract with* $\omega_i^t = \alpha^*\pi_i^t$

Managers: *Set*

$$p_i^t = \begin{cases} p_i^1 = p^* \quad \text{for } t = 1 \\ \quad p_i^t = p^* \text{ if for all } i \text{ and } 1 \leq \tau < t,\ p_i^\tau = p^* \\ c \ \text{ otherwise} \end{cases},$$

if all owners delegate control under profit-sharing contracts with $\omega_i^t = \alpha^* \pi_i^t$*;*

Set $p^t = c$ *forever otherwise.*

To verify that these are equilibrium strategy profiles for the full delegation game we proceed by backward induction.

Stage 2. Since $U(\alpha^* \pi_i^*) \geq (1-\delta)U(\alpha^* N \pi_i^*) + \delta U(0)$ a manager cannot gain by deviating from equilibrium strategies, hence p^* is a subgame perfect equilibrium of the Stage 2 continuation game.

Stage 1. By following equilibrium strategies each owner expects discounted profits $\frac{\pi^*/N}{1-\delta}$. If an owner defects unilaterally by either choosing a compensation function such that $U(f(\pi_i^*)) < (1-\delta)U_i(f(N\pi_i^*)) + \delta U_i(f(0))$ or by not delegating at all, other managers react according to strategies and collusion is not sustained in the second stage, and expected discounted profits are nihil. It follows that owners' strategies are a Nash equilibrium of the Stage 1 simultaneous game. **Q.E.D.**

Proof of Proposition 3. The incentive compatibility conditions for a collusive agreement to set price p^H when demand is high and p^L when it is low, with $p^H, p^L \leq p^M$, are:

$$U\left[\pi_i(p^H, \theta^H)\right] + \frac{\delta}{1-\delta}\left\{qU[\pi_i(p^H, \theta^H)] + (1-q)U[\pi_i(p^L, \theta^L)]\right\} \geq U\left[N\pi_i(p^H, \theta^H)\right] + \frac{\delta}{1-\delta}U[0]$$

for periods in which demand is high, and

$$U\left[\pi_i(p^L, \theta^L)\right] + \frac{\delta}{1-\delta}\left\{qU[\pi_i(p^H, \theta^H)] + (1-q)U[\pi_i(p^L, \theta^L)]\right\} \geq U\left[N\pi_i(p^L, \theta^L)\right] + \frac{\delta}{1-\delta}U[0]$$

for periods in which demand is low. When the discount factor is binding, so that either $p^H < p^M$ or $p^L < p^M$ or both, firms maximize collusive profits by setting p^{*H} and p^{*L} so that the incentive constraint is satisfied as an equality (short-run gains from defection equal to expected losses from the punishment phase):

$$U\left[N\pi_i(p^{*H}, \theta^H)\right] - U\left[\pi_i(p^{*H}, \theta^H)\right] = U\left[N\pi_i(p^{*L}, \theta^L)\right] - U\left[\pi_i(p^{*L}, \theta^L)\right] = \overline{U}^*,$$

where

$$\overline{U}^* = \frac{\delta}{1-\delta}\left\{U\left[q\pi_i(p^{*H}, \theta^H) + (1-q)\pi_i(p^{*L}, \theta^L)\right] - U[0]\right\}.$$

The profit maximizing collusive must be pro-cyclical, i.e. $p^{*L} < p^{*H}$, when

$$\begin{aligned} U[N\pi_i(p^{*H}, \theta^H)] - U\left[\pi_i(p^{*H}, \theta^H)\right] &= \overline{U}^* < U\left[N\pi_i(p^{*H}, \theta^L)\right] - U\left[\pi_i(p^{*H}, \theta^L)\right] \Leftrightarrow \\ U\left[\pi_i(p^{*H}, \theta^H)\right] - U\left[\pi_i(p^{*H}, \theta^L)\right] &> U\left[N\pi_i(p^{*H}, \theta^H)\right] - U\left[N\pi_i(p^{*H}, \theta^L)\right]. \end{aligned}$$

Approximating the RHS of this last inequality with the Taylor expansion of U around $N\pi_i^*(p^{*H},\theta^L)$ and simplifying, we get

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

with $\Delta>0$, and one can always choose U sufficiently concave that $U'\left[N\pi_i(p^{*H},\theta^L)\right]<\frac{U\left[\pi_i^*(p^{*H},\theta^H)\right]-U\left[\pi_i^*(p^{*H},\theta^L)\right]+\Delta}{N\left[\pi_i^*(p^{*H},\theta^H)-\pi_i^*(p^{*H},\theta^L)\right]}$. **Q.E.D.**

Proof of Proposition 4. Consider the following strategy profile:

Owners: *Delegate control under bonus contracts with* $\pi_i^B=\pi_i^M$ *and* $B_i>0$.

Managers: *Set*

$$p^t=\begin{cases} p^M \text{ as long as for all } i \text{ and } \tau<t,\ p_i^\tau=p^M \\ c \text{ forever otherwise}\end{cases}$$

if all owners delegated control and set $\pi_i^B\leq\pi_i^M$ *and* $B_i>0$*;*

Set $p^t=c$ *otherwise.*

To verify that this strategy profile constitutes an equilibrium of the delegation game (i.e. prove that bonus contracts with $\pi_i^B=\pi_i^M$ are "equilibrium incentives") we proceed by backward induction.

Stage 2..The Bertrand equilibrium ($p=c$) is a pure strategy Nash equilibrium of the stage game played by managers under bonus contract, hence managers can support collusive prices in equilibrium by grim trigger strategies. Independent of the discount factor, each manager i under bonus contract with $\pi_i^B>0$ loses by defecting from an agreed collusive price p^* such that

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

because in equilibrium he expects discounted expected payoffs $\frac{W_i+B_i}{1-\delta}$, while a defection allows him to get the bonus in that period but triggers a punishment phase during which profits are zero and the bonus is not paid, leaving him with $B_i+\frac{W_i}{1-\delta}$, i.e. with a net loss of $\delta\frac{B_i}{1-\delta}$.

Stage 1. If an owner deviates by choosing to keep control or to delegate to a profit-maximizing manager (e.g. setting $B_i=0$) collusion cannot be supported and he expects zero profits forever. If an owner deviates by setting $\pi_i^B>\pi_i^M$ collusion cannot be supported and, again, all owners (including the deviating one) get zero profits. If an owner deviates by choosing $\pi_i^B<\pi_i^M$ he also cannot gain, hence delegating under bonus contract with $\pi_i^B<\pi_i^M$ and $B_i>0$ is an equilibrium of Stage 1 simultaneous game. **Q.E.D.**

Proof of Corollary 1. *i)* By inspection if all managers are under bonus contracts with B_i constant the set of collusive prices supportable in subgame perfect equilibrium in the market

supergame P^* is non-empty iff $0 < \pi_i^B \leq \pi_i^M$ for all i, where $\pi_i^M = \frac{(p^M - c)Q(p^M)}{N}$.[32] If all managers have $\pi_i^B = \pi_i^M$, any collusive price lower than p^M would not allow managers to get the bonus, leading them – being indifferent – to defect to maximize firm profits. It follows that the joint monopoly price p^M is the only stationary collusive price managers can support in equilibrium in the second-stage supergame.

i) Consider as a candidate alternative equilibrium any vector of targets with $\pi_i^B < \pi_i^M$ for some i. This cannot be an equilibrium of the first-stage delegation game because owner i would find it profitable to deviate unilaterally and raise π_i^B up to π_i^M to prevent managers reaching collusive agreements with $\pi_i^B \leq \pi_i^* < \pi_i^M$.

Proof of Proposition 5 Consider the following strategy profile for N owners and N managers.

Owners: *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 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.*

Managers: *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 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.*

Let R_i denote the constant reservation wage of manager i, let $W_i = R_i$ (to save on notation and without loss of generally) so that the bonus $B_i > 0$ also denotes the per-period 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 generic 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. An owner cannot gain anything by choosing $\pi_i^B < \pi_i^M$ (and may lose since his manager may settle on a collusive agreement delivering profits π_i^* with $\pi_i^B \leq \pi_i^* < \pi_i^M$). If an owner deviates by choosing $\pi_i^B > \pi_i^M$, the only way the manager can get the bonus is by deviating unilaterally from a collusive

[32] If the condition 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).

agreement, and because this is common knowledge no agreement can be sustained. 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 finds 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 $\frac{B_i}{1-\delta}$. **Q.E.D.**

Proof of Proposition 6 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. 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. **Q.E.D.**

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