Cooperation among competitors: A comparison of cost-sharing mechanisms

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ABSTRACT

In this paper, we investigate the consequences of using outcome-based versus ex ante-based cost-sharing mechanisms in terms of competing firms' profitability and total welfare. We consider two firms making a joint expenditure, which can positively affect firms' demand and/or unit operating costs, while competing in the final market by setting either price or quantity. We compare two outcome-based cost-sharing mechanisms, i.e., Quantity Proportional (QP) and Total Margin proportional (TM), with the more competitive Fixed Share (FS) mechanism where cost-sharing is set up on an ex ante basis. We show that outcome-based mechanisms, and even a fully collusive behavior induced by the optimal cost-sharing mechanism, might actually enhance total welfare as compared with the more competitive FS mechanism. We also find that, although the FS mechanism is never more preferable than the TM mechanism, it can lead to higher profits than the QP mechanism when competition is mild. These results can support firms cooperating with competitors in the choice of the cost-sharing mechanism as well as provide important implications to policy makers.

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1. Introduction

Cooperation among competitors can take the most disparate forms, such as alliances, consortia, cooperatives, joint production, marketing or R&D agreements, across the most disparate industries, e.g., aerospace, agri-food, automotive, financial, IT and electronics, pharmaceutical, and retail (Hansmann, 1996; Rochet and Tirole, 2002; Akcay and Tan, 2008; Rodriguez Monroy and Vilana Arto, 2010; Chen and Roma, 2011; Ghosh and Morita, 2012; Lo Nigro et al., 2013; Tomlinson and Fai, 2013).

In this context, one important, yet understudied, question relates to the profit and welfare implications of different mechanisms that competing firms may use to share joint expenditures or investments. Cost sharing is indeed one of the most common reasons behind firms' cooperation (Cassiman and Veugelers, 2002). Real examples suggest that cost sharing is usually set up on an ex ante basis in many R&D joint ventures. Consider, for instance, firms investing in a joint venture to develop a new technology, and then competing independently in the product market. In these cases, firms often decide the shares of the joint investment before they engage in market competition and do not allow any ex post adjustment based on market outcomes such as

margins or sales. For instance, the contribution to the R&D investment was set up on an ex ante fixed basis for the R&D agreement between Sony and Samsung to develop new LCD technology (Gnyawali and Park, 2011). The ex ante fixed sharing rule is also utilized by the Blu-ray Disc Association, i.e., the R&D consortium consisting of all major consumer electronics manufacturers that developed the Blu-ray technology (Blu-ray Disc Association, 2015). Similarly, product design and other R&D costs for memory technologies are split based on a fixed share by Intel and Micron in their joint venture IM Flash Technologies (Micron, 2014).

In some other cases, firms might leave room for ex post adjustments or entirely base the joint expenditure allocation on market outcomes. The latter situations may arise in case of stable research consortia. For instance, R&D activities of Sematech, the worldwide R&D consortium of semi-conductor manufacturers, have been financed through members' contributions proportionally to their sales (Katz et al., 1990). Similarly, in the joint production alliance between car manufacturers PSA and Toyota, the capital expenses related to the common plant are divided proportionally to the production output of the two companies (ATZ online, 2004). Outcome-based allocation mechanisms are even more popular in agri-food and retail co-operatives/consortia, where firms cooperate for certain activities but still compete in the product market (Albaek and Schultz, 1997). The US Department of Agriculture explains that manufacturing and marketing operations are usually financed by cooperatives' members through mechanisms, such as patronage refunds or per-unit retains, which are indeed outcome-based mechanisms (US Department of

Agriculture, 1994). For instance, big dairy cooperatives such as Land O'Lakes or Dairy Farmers of America adopt such mechanisms (Chaddad and Cook, 2004). In Europe, numerous cooperatives and consortia utilize allocation schemes based on firms' output (in quantity or in value) to share costs of their regular activities of production quality control and product promotion. Examples include Arla Foods, a Denmark-based dairy cooperative with operations worldwide (Arla Foods, 2015). Furthermore, outcome-based mechanisms are utilized to finance retail cooperatives and buying groups. For instance, Spar, one of the largest retail co-ops worldwide, explains that all joint marketing and supply chain management activities are financed through members' contributions based on their sales (Spar, 2015). In these cooperative settings, the entity established to manage the cooperation (e.g., cooperative, consortium or category association) is usually responsible for joint expenditures, such as quality assurance programs or generic advertising campaigns. However, members still remain competitors in the final market, and thus choose the price of their products or the relative level of output independently (Crespi and Marette, 2002). In this case, members' annual contributions to finance the joint activities often depend on output marketed during the year and adjustments may occur at the end of the year.

Our study is motivated by the fact that a direct comparison of ex ante-based vs. outcome-based mechanisms has not been conducted in the extant literature in spite of the highlighted popularity of these mechanisms. In this paper, we fill this gap by investigating the competitive effects of outcome-based vs. ex ante-based cost-sharing mechanisms in a variety of economic settings. This allows us to understand how different cost-sharing mechanisms shape firms' operational (price or quantities) and cooperative (joint expenditure) decisions and thus influence their profitability. At the same time, it allows us to shed light on their economic viability in terms of total welfare. Hence, our analysis helps increase firms' understanding about the role of outcome-based vs. ex ante-based cost-sharing mechanisms, and thus provide a better support for their decisions of cooperation with competitors. Moreover, our analysis offers a more complete view in terms of policy by shedding light on the reasonableness of the conventional argument provided by previous literature (Grossman and Shapiro, 1986; Katz, 1986; Katz et al., 1990) that outcome-based mechanisms have a negative influence on total welfare.[1]

We model a game where two identical firms cooperate by sharing a joint expenditure, which can positively affect firms' demand and/or unit operating costs. For instance, cooperation can be in the form of production, marketing, and/or R&D expenditures. Still, firms compete with each other in the final market deciding upon a competitive variable independently. The competitive variable can be either the price or the quantity. Therefore, firms face a Bertrand competition or a Cournot competition, respectively. We model firms' cooperative and competitive decisions under both one-stage and two-stage games. In the first case, all decisions are made simultaneously. Specifically, the entity established by the firms to manage the cooperation (e.g., consortium, cooperative, joint venture) is responsible for choosing the

level of the joint expenditure, whereas firms independently set their own prices or quantities. In the second case, the decisions are sequential. In other words, the joint expenditure is chosen first, and firms compete in setting prices or quantities in the second stage. We initially develop the analysis under the one-stage game as it is analytically tractable. Afterwards, we extend the study to a two-stage game with the support of both analytical derivation and numerical analysis and show that the key messages of the paper still hold.[2]

We compare profit and welfare implications of using two outcome-based mechanisms, namely Quantity Proportional (QP) and Total Margin proportional (TM), versus a mechanism where the joint expenditure is allocated to firms on an ex ante basis, which we refer to as Fixed Share (FS). As discussed above, both types of mechanisms are common in a wide range of business settings. The FS mechanism reflects the case where the joint expenditure is split based on bargaining before firms engage in market competition and firms' shares are never changed. Several studies have considered a fixed share mechanism for sharing joint costs of R&D projects (Katz, 1986; Aloysius and Rosenthal, 1999). In contrast, under the QP and TM mechanisms joint expenditures are allocated to firms based on the marketed output and realized profit margins, respectively. Food processing and retail cooperatives are examples of cooperation where these mechanisms are popular (US Department of Agriculture, 1994; Spar, 2015). Also, the logic of QP and TM mechanisms closely reflects that of stable R&D or manufacturing collaborations (Grossman and Shapiro, 1986; ATZ online, 2004). Particularly, the TM mechanism can be implemented in R&D joint ventures when there are no big issues of observability among partners (Lambertini et al., 2008). Finally, we also derive the optimal cost-sharing mechanism, i.e., the mechanism that maximizes firms' total profit, which is itself an outcome-based mechanism, and compare it with the FS mechanism in terms of total welfare.

Our results show that firms' profits are never the highest under the FS mechanism. Indeed, this mechanism is always dominated by the TM mechanism. However, interestingly, under both Bertrand and Cournot competition, the QP mechanism is the preferable mechanism to firms in the presence of fierce competition, whereas it can be dominated by both FS and TM mechanisms when competition is absent or sufficiently mild. Moreover, the findings about welfare comparison suggest that outcome-based mechanisms might have the merit of enhancing the total welfare as compared with a more competitive mechanism, e.g., the FS mechanism. Under the one-stage game, this can hold under Bertrand competition and demand-increasing expenditure. The extension to the two-stage game confirms and further strengthens this result. In this case, the positive effect of outcome-based mechanisms on welfare can emerge under both Bertrand and Cournot types of competition, irrespective of whether the joint expenditure is demand-increasing or cost-reducing. Our findings are robust also when extending our model to non-identical firms via numerical investigation.

The rest of the paper is organized as follows. In Section 2 we present a literature overview. In Section 3 we set up the model. In Section 4 we compare the different cost-sharing mechanisms under the one-stage game. We then analyze the two-stage game in Section 5. Finally, in Section 6 we discuss the implications and conclude.

2. Literature overview

In economics literature, a plethora of studies have shown that cooperation among competitors might be beneficial to both firms

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[1] Note that, in deriving our managerial and policy implications, we consider total welfare rather than consumer surplus. The potential conflict between consumer and society preferences recalls the historical economic debate on the actual goal of antitrust agencies and the appropriateness of total surplus or consumer surplus as welfare standards, which has recently been reawakened by numerous economists (Carlton, 2007). As argued by these researchers, in an economy pursuing total welfare maximization, antitrust agencies should focus on total welfare, leaving to other bodies the task of resolving distributional questions. While an in-depth analysis of the practical issues tackled in this current debate is beyond the scope of this paper, it should be clear that, in line with most of the previous literature on cooperation among competitors (Grossman and Shapiro, 1986; Katz, 1986; d'Aspremont and Jacquemin, 1988; Katz et al., 1990), we espouse the arguments in favor of total welfare throughout the paper.

[2] As explained later in greater detail, we consider both Bertrand and Cournot types of competition and both one-stage and two-stage games to better reflect real business settings, and thus deliver a more general message.

and society in a number of economic settings. For instance, several works focusing on R&D cooperation have shown that partial co-operation, e.g., R&D cooperation and quantity competition, might be not only beneficial to firms, but also to the society, when product market competition is moderate and/or R&D spillovers are large (Grossman and Shapiro, 1986; Katz, 1986; d'Aspremont and Jacquemin, 1988; Katz et al., 1990; Kamien et al., 1992; Motta, 1992). None of these studies have directly examined the impact of different cost-sharing mechanisms, i.e., outcome-based vs. on an ex ante basis, on firms' profitability and total welfare. Nevertheless, it has been consistently argued that the introduction of sharing mechanisms based on market outcomes raises firms' marginal costs. In turn, this tends to reduce output, thus promoting full collusion and increasing firms' profits at the detriment of the society (Grossman and Shapiro, 1986; Katz, 1986; Katz et al., 1990). In contrast, by performing a comparison under a variety of economic settings, we show that outcome-based mechanisms can actually have the merit of enhancing total welfare in spite of their collusive force.

More recently, several studies in the management science and operations management literature have analyzed the economic implications of settings where competitors cooperate in certain business activities (Banker et al., 1998; Akcay and Tan, 2008; Ge and Hu, 2008; Wu et al., 2008; Chen and Roma, 2011; Zhang and Frazier, 2011; Kumar Jena and Sarmah, 2014; Chen et al., 2015). Zhang (2006) points out that today's supply chain economy comprises several supply chains, such as Walmart, Target, and Sears Holdings, which compete in the same business but also cooperate in material procurement, resource utilization, utility consumption, and distribution patterns. Most of the studies in this literature shed light on the conditions under which cooperation is advantageous to competing firms under different business settings. Banker et al. (1998) study whether cooperating in quality decisions is more profitable than full competition from the perspective of competing firms. They assume an ex ante-based mechanism. Chen and Roma (2011) study profit implications of cooperating with competitors in procurement. Chen et al. (2015) analyze profitability of cooperative vs. noncooperative quality investments of two competing manufacturers in presence of a common supplier. Kumar Jena and Sarmah (2014) examine profits under different cooperative and competitive settings in a duopoly closed-loop supply chain. Other studies in this literature have also investigated the impact of cooperation among competitors on total welfare. For instance, Wu et al. (2008) have studied cooperation in the form of information sharing in a Cournot duopoly showing that such cooperation does not necessarily increase total welfare. However, none of the above studies have examined the effects of different cost-sharing mechanisms on firms' profitability and total welfare.

Very few studies in the management science literature have compared different cost or profit sharing mechanisms in real co-operation settings (Aloysius and Rosenthal, 1999; Bhaskaran and Krishnan, 2009; Meca and Sosic, 2014). Aloysius and Rosenthal (1999) consider fixed-share mechanism (referred to as constant share mechanism) and outcome-based mechanisms (referred to as proportional share mechanisms) for R&D consortia. Bhaskaran and Krishnan (2009) analyze investment and innovation sharing in new product development. However, none of these works explicitly consider competition among firms. In contrast, the comparison of ex ante-based vs. outcome-based types of cost-sharing mechanisms in the presence of competition is our focus.

3. Model setup

Consider two identical firms which compete in the same market with differentiated products, but cooperate by making a joint expenditure in some area of their business, e.g., production, R&D, and marketing. Competition in the final market can be either based on

price or quantity, leading to a Bertrand or Cournot competition, respectively. We consider both types of competition because both can be observed in real business settings. For instance, for cooperatives producing commodity inputs, such as livestock, grain, fertilizers, competition is more likely to be on quantities. This is because these markets are usually positioned upstream in the supply chain and prices tend to be determined by matching demand and supply in the market. In contrast, members of retail cooperatives are more likely to set and compete on prices because they sell differentiated consumer products and earn profits from adding mark-ups to wholesale prices. Similarly, when R&D partnerships are set to develop technologies that can be used for a large portion of each partner's product portfolio, competition can be modeled as a Cournot competition. This is because firms tend to compete on quantities at the aggregate level given that production capacity may become stringent (Kreps and Scheinkman, 1983; Haskel and Martin, 1994). In contrast, if R&D cooperation focuses on developing technologies for specific consumer products (for instance, the mentioned case of Sony and Samsung joint venture on LCD technology, which is utilized mainly for TVs), the competition can be modeled as a Bertrand game as firms usually set prices for single consumer products.

In our model firms set the competitive variable, price or quantity, by maximizing their own profit non-cooperatively. The joint expenditure is instead set to maximize the joint profit and split by firms based on a selected cost-sharing mechanism. Joint profit maximization eliminates any free-riding risk when choosing the level of the joint expenditure (Bass et al., 2005). Let p_i and p_j be the prices and $q_i = q_i(p_i, p_j, \cdot)$ and $q_j = q_j(p_j, p_i, \cdot)$ be the direct demand functions of Firms $i = 1, 2$ and $j = 3 - i$, respectively. In case of Cournot competition, we can specify the inverse demand functions $p_i = p_i(q_i, q_j, \cdot)$ and $p_j = p_j(q_j, q_i, \cdot)$. Also, let I be the joint expenditure. Depending on its nature, I can positively affect firms' demand functions $q_i = q_i(p_i, p_j, I)$ ($p_i = p_i(q_i, q_j, I)$), firms' unit operating costs $c_i(I)$, or both, for $i = 1, 2$ and $j = 3 - i$.[3] For instance, an advertising expenditure is likely to have a (positive) effect only on firms' demand, while joint maintenance or quality control expenditures help reduce firms' unit operating costs. A product/process R&D investment can instead influence both firms' demand and unit operating costs. Therefore, we identify three cases: I affects only firms' demand (referred to as Case A); I affects only firms' unit operating costs (Case B); I affects both (Case C). In the interest of length, we investigate cases A and B as implications for Case C can be derived from these two.

We assume that the two firms are identical in that they face symmetric demand and incur identical unit operating costs, namely $c_i = c_j = c$. This also implies that, ceteris paribus, the joint expenditure provides the same benefit to the identical firms. We make standard economic assumptions regarding demand and cost functions.[4] We also assume that the effects of the competitive

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[3] Ceteris paribus, the effect of I on firms' demand and/or unit operating costs positively reflects on total welfare.

[4] Specifically, each firm's direct (inverse) demand function is decreasing and convex in its own price and increasing in the opponent's price (decreasing in both its own and opponent's quantities). Moreover, each firm's demand (unit operating cost) is increasing (decreasing) and concave (convex) in I. The effect of p_i on firm $i's$ demand, $i = 1, 2$, is higher than that of p_j, i.e., $\left| \frac{\partial q_i(p_i, p_j, I)}{\partial p_i} \right| > \frac{\partial q_i(p_i, p_j, I)}{\partial p_j}$, $\left(\left| \frac{\partial p_i(q_i, q_j, I)}{\partial q_i} \right| > \frac{\partial p_i(q_i, q_j, I)}{\partial q_j} \right)$ for inverse demand function), at least at the symmetric equilibrium under all cost-sharing mechanisms. Due to symmetry, this also implies that the total demand is decreasing in both prices, i.e., $\left| \frac{\partial q_i(p_i, p_j, I)}{\partial p_i} \right| > \frac{\partial q_j(p_j, p_i, I)}{\partial p_i}$, $i = 1, 2$. Finally, we have verified that in the range where our equilibrium solutions arise, profit functions are concave in the decision variables under all cost-sharing mechanisms. This verification can be made available from the authors.

variable and the joint expenditure on the demand function are additively separable.[5] Consistent with most of the related literature, we assume a deterministic and complete information scenario to focus on the competitive effects of cost-sharing mechanisms. Under both Bertrand and Cournot competition, M_i indicates firm i's profit gross of the joint expenditure, i.e., $M_i = (p_i - c)q_i$.

Firms commit to share the joint expenditure based on a selected cost-sharing mechanism. Let $\varphi_i(y_i, y_j, I) \geq 0$ be the share of I allocated to firm i. In general, it is a function of the competitive variables y_i, y_j (prices or quantities), and I. Similarly, $\varphi_j(y_j, y_i, I) \geq 0$ is the share allocated to firm j. We assume $\varphi_i(y_i, y_j, I) + \varphi_j(y_j, y_i, I) = 1$ to ensure perfect budget balance. We consider two simple outcome-based mechanisms, namely proportional to marketed quantity (QP), i.e., $\varphi_i(y_i, y_j, I) = \frac{q_i}{q_i + q_j}$, and proportional to total margin (TM), i.e., $\varphi_i(y_i, y_j, I) = \frac{M_i}{M_i + M_j}$. We compare these two mechanisms with the fixed share mechanism (FS), i.e., $\varphi_i(y_i, y_j, I) = \varphi$ and $\varphi_j(y_j, y_i, I) = 1 - \varphi$, where the share is negotiated via ex ante Nash bargaining. We also derive the optimal cost-sharing mechanism and compare it with the FS mechanism in terms of total welfare. These mechanisms ensure perfect budget balance. Under the FS mechanism, price, quantity, and joint expenditure decisions are not affected by the share φ. Thus, the value of φ can be easily obtained via Nash bargaining using backward procedure. Due to symmetry, Nash bargaining naturally leads firms to commit ex ante to the solution $\varphi = \frac{1}{2}$. While the FS mechanism yields equal shares ex ante, the outcome-based mechanisms lead firms to split the joint expenditure equally only ex post, i.e., after firms make decisions and market outcomes are realized.

Finally, we model cooperation among competitors under both one-stage and two-stage games. We consider these two scenarios for two main reasons. First, both one-stage and two-stage games are plausible in real business settings. The two-stage game reflects more the case of joint expenditures related to R&D or production capacity, which have usually impact on firms' profits more in the long term compared with price or quantity decisions. The one-stage game is more suitable for joint expenditures pertaining to more tactical or operational activities such as generic advertising campaigns, quality assurance, and plant maintenance programs. Moreover, modeling multiple decisions, e.g., price and service quality, in a one-stage game is common in both economics and management literature (Dixit, 1979; Bernstein and Federgruen, 2004; Bass et al., 2005). The second reason relates to model tractability. Specifically, the two-stage game easily loses tractability in deriving equilibrium solutions for outcome-based mechanisms. In contrast, the one-stage game model is analytically tractable. Therefore, we develop the full analysis under the one-stage game. In Section 5, we show with the support of both analytical derivation and numerical analysis that the main messages to decision makers remain valid also in the case of a two-stage game.

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[5] Additive separability ensures that $\frac{\partial^2 q_i(p_i, p_j, I)}{\partial I \partial p_i} = \frac{\partial^2 q_j(p_j, p_i, I)}{\partial I \partial p_i} = \frac{\partial^2 q_j(p_j, p_i, I)}{\partial I \partial p_j} = \frac{\partial^2 q_i(p_i, p_j, I)}{\partial I \partial p_j} = 0$ hold under Bertrand competition. Similar conditions can be derived under Cournot competition. This assumption affects only joint expenditure comparison under Bertrand competition and case A. We considered the multiplicative demand function as a representative case where additive separability does not hold and showed that the major findings of this paper still prevail. The proofs are available from the authors.

4. The one-stage game

In a one-stage game, when I affects both demand and unit cost, firm i's profit under Bertrand competition is:

$$\Pi_i = (p_i - c(I))q_i(p_i, p_j, I) - \varphi_i(p_i, p_j, I)I. \tag{1}$$

On the other hand, under Cournot competition, firm i's profit is:

$$\Pi_i = (p_i(q_i, q_j, I) - c(I))q_i - \varphi_i(q_i, q_j, I)I. \tag{2}$$

Recall that $\varphi_i(y_i, y_j, I) = \varphi$ and $\varphi_j = (y_j, y_i, I) = 1 - \varphi$ when the FS mechanism is considered in (1) and (2). Under Bertrand (Cournot) competition, firm i maximizes its own profit in $p_i(q_i)$ given the agreed cost-sharing mechanism. The expenditure I is instead chosen to maximize the joint profit, i.e., $\Pi_{tot} = \Pi_i + \Pi_j$, by the entity established to handle the cooperation (e.g., a consortium or a joint venture). According to this one-stage game, the first order condition in I is the same irrespective of the cost-sharing mechanism adopted by firms. In turn, we analyze cases A and B.

4.1. Case A: I affects only firms' demand

In this case, the effect of the joint expenditure is to increase firms' demand function, thus $c(I) = c$. Generic advertising campaigns among competitors are an example of this kind of situations (Krishnamurthy, 2000; Bass et al., 2005; Roma and Perrone, 2010). In turn, we derive the equilibrium conditions when firms use different cost-sharing mechanisms under both Bertrand and Cournot competition. The first order conditions in $p_i(q_i)$ are reported in Table 1 for each cost-sharing mechanism. In addition, under Bertrand competition, taking the first order derivative of the joint profit in I and setting it equal to zero yield for any mechanism:

$$\frac{\partial \Pi_{tot}}{\partial I} = (p_i - c)\frac{\partial q_i}{\partial I} + (p_j - c)\frac{\partial q_j}{\partial I} - 1 = 0. \tag{3}$$

Similarly, under Cournot competition, we obtain the following:

$$\frac{\partial \Pi_{tot}}{\partial I} = \frac{\partial p_i}{\partial I}q_i + \frac{\partial p_j}{\partial I}q_j - 1 = 0. \tag{4}$$

Based on the first order conditions in Table 1 and in (3) and (4) we provide our first results in terms of price, joint expenditure, demand, and profit comparison. Proofs of this and subsequent results can be found in the Appendix. Under both Bertrand and Cournot competition, we use superscripts FS, QP and TM and remove subscripts i and j to indicate the equilibrium solutions, as they are identical for the two firms given the symmetry.

Proposition 1.

(i) *Under Bertrand competition, price and joint expenditure are ranked as follows: $p^{QP} > p^{TM} \geq p^{FS}$ and $I^{QP} > I^{TM} \geq I^{FS}$. Demand comparison depends on which effect, price or joint expenditure, is dominant.*

(ii) *Under Cournot competition, quantity and joint expenditure are ranked as follows: $q^{QP} < q^{TM} \leq q^{FS}$ and $I^{QP} < I^{TM} \leq I^{FS}$. Price comparison depends on which effect, quantity or joint expenditure, is dominant.*

(iii) *Under both Bertrand and Cournot competition, firms earn higher profits under the TM mechanism than under the FS mechanism, i.e., $\Pi^{TM} \geq \Pi^{FS}$. Moreover, under fierce competition, firms earn higher profits under the QP mechanism than under both TM and FS mechanisms, i.e., $\Pi^{QP} > \Pi^{TM} \geq \Pi^{FS}$. In the absence of competition, $\Pi^{TM} = \Pi^{FS} > \Pi^{QP}$.*

Table 1
Equilibrium conditions in p_i (q_i) under Bertrand (Cournot) competition.

	Bertrand $\left(\frac{\partial \Pi_i}{\partial p_i} = 0\right)$	Cournot $\left(\frac{\partial \Pi_i}{\partial q_i} = 0\right)$
FS	$q_i + \frac{\partial q_i}{\partial p_i}(p_i - c) = 0$	$\frac{\partial p_i}{\partial q_i}q_i + (p_i - c) = 0$
QP	$q_i + \frac{\partial q_i}{\partial p_i}(p_i - c) - \dfrac{\frac{\partial q_i}{\partial p_i}q_j - \frac{\partial q_j}{\partial p_i}q_i}{\left(q_i + q_j\right)^2}I = 0$	$\frac{\partial p_i}{\partial q_i}q_i + (p_i - c) - \dfrac{q_j}{\left(q_i + q_j\right)^2}I = 0$
TM	$\dfrac{\left(q_i + \frac{\partial q_i}{\partial p_i}(p_i - c)\right)M_j - \frac{\partial q_j}{\partial p_i}(p_j - c)M_i}{\left(M_i + M_j\right)^2}\left(M_i + M_j - I\right)$ $+ \dfrac{M_i}{(M_i + M_j)}\left(\left(q_i + \frac{\partial q_i}{\partial p_i}(p_i - c)\right) + \frac{\partial q_j}{\partial p_i}(p_j - c)\right) = 0$	$\dfrac{\left(\frac{\partial p_i}{\partial q_i}q_i + (p_i - c)\right)M_j - \frac{\partial p_j}{\partial q_i}q_jM_i}{\left(M_i + M_j\right)^2}\left(M_i + M_j - I\right)$ $+ \dfrac{M_i}{(M_i + M_j)}\left(\frac{\partial p_i}{\partial q_i}q_i + (p_i - c) + \frac{\partial p_j}{\partial q_i}q_j\right) = 0$

Proposition 1 confirms that outcome-based cost-sharing mechanisms (QP and TM) work as mechanisms to reduce market competition among firms irrespective of the type of competition. Specifically, under Bertrand (Cournot) competition, the use of outcome-based mechanisms tends to raise marginal costs as compared with the FS mechanism. This is because the cost of the joint expenditure is directly connected to the produced quantity under outcome-based mechanisms. In turn, this yields higher (lower) prices (quantities) when firms utilize such mechanisms. However, the effect of outcome-based mechanisms might not be always socially detrimental as the strategic interaction between the joint expenditure and the competitive variable differs across different cost-sharing mechanisms and different types of competition.

Under Cournot competition, the lower output marketed by firms when they use outcome-based cost-sharing mechanisms (QP and TM) results in a lower level of the joint expenditure as compared with the case of the more competitive FS mechanism. As a result, in the one stage-game the total welfare is always lower under outcome-based mechanisms. This is because the total welfare is directly affected only by the level of produced quantities and the level of the joint expenditure. This finding supports the conventional argument that the introduction of outcome-based cost-sharing mechanisms tends to lower final quantities and welfare.

Under Bertrand competition, the effect of using outcome-based cost-sharing mechanisms is quite different. The higher price implies a higher joint expenditure when QP and TM mechanisms are used, instead of the FS mechanism. Therefore, there also exists a positive effect of limiting competition via outcome-based mechanisms as a demand-increasing joint expenditure is beneficial from a welfare perspective. Because of the presence of tension between positive and negative effects, it is unknown in general whether total welfare is higher or lower when firms use outcome-based mechanisms. Consequently, concerns against such mechanisms may or may not be an issue as welfare comparison depends on which factor, i.e., joint expenditure or price, has higher influence on firms' demand. This ambiguity will be unraveled in Section 4.1.1 under specific demand function.

Proposition 1 provides general results on how cost-sharing mechanisms affect firms' profitability. Specifically, the TM mechanism always leads to a higher profit than the FS mechanism. However, the comparisons involving the QP mechanism are ambiguous under both Bertrand and Cournot competition. In the presence of fierce competition the QP mechanism leads to higher

profit than the other two mechanisms. When the level of competition decreases, both TM and FS mechanisms may or may not lead to a higher profit than the QP mechanism. When competition is absent, the QP mechanism is dominated by the FS mechanism, which is equivalent to the TM mechanism. The rationale is that, when competition is low or totally absent, the use of QP leads to unnecessary overpricing or underselling. As a result, the use of QP may end up lowering firms' profits to such an extent that other cost-sharing mechanisms will dominate. In Section 4.1.1, we better characterize the profit comparison using a specific demand function.

These results have important practical implications. First, firms should be aware of the impact that different cost-sharing mechanisms have on operational decisions, e.g., price or quantity. In particular, firms should expect that outcome-based mechanisms will lead them to raise (lower) prices (quantities) as compared with the FS mechanism when they compete à là Bertrand (Cournot). Second, firms should expect that outcome-based mechanisms will lead them to increase (decrease) the joint expenditure as compared with the FS mechanism when they compete on prices (quantities). This implies that outcome-based mechanisms are likely to increase the joint expenditure in settings such as retail co-ops or manufacturing cooperation on single end-user products (e. g., Toyota-PSA alliance), where competition tends to be on prices. In contrast, outcome-based mechanisms may be detrimental in terms of joint expenditure in settings such as commodity co-operatives, as firms positioned upstream in the supply chain are more likely to compete on quantities. Third, our profit comparison has implications for those contexts of stable cooperation, such as agrifood cooperatives, retail buying groups, and durable R&D or manufacturing alliances (e.g., PSA-Toyota alliance), where firms often adopt a QP cost allocation scheme. Specifically, it suggests that even sharing joint expenditures on an ex ante basis instead of using the QP mechanism may guarantee higher profits to firms if competition is mild or there is no competition at all. Therefore, from a practical perspective, firms should carefully look at the competition level before making their choices on cost-sharing mechanisms. They should consider opting for the QP mechanism if competition among competitors is fierce. Otherwise, they may consider the TM mechanism if implementable, or the FS mechanism. Naturally, firms' decisions on cost-sharing mechanisms should be influenced by welfare considerations. The adoption of outcome-based mechanisms may come under lens of authorities if they are detrimental in terms of total welfare. The above results inform that outcome-based mechanisms have a negative effect on

total welfare under Cournot competition in the one-stage game. In contrast, when firms compete on prices, welfare implications are not straightforward, as we will discuss in Section 4.1.1.

Before we resolve the ambiguity about the effect of outcome-based mechanisms on total welfare, we present the optimal cost-sharing mechanism under Bertrand competition. The optimal mechanism is later utilized for welfare comparison with the FS mechanism. The case of Cournot competition can be similarly derived.

Proposition 2. *Under Bertrand competition, the optimal cost-sharing mechanism is for $i = 1, 2$ and $j = 3 - i$:*

$$\varphi_i\big(p_i, p_j, I\big) = \begin{cases} \frac{1}{2} & \text{if } p_i = p_j = p^{opt} \text{ or if } p_i \neq p^{opt}, p_j \neq p^{opt} \\ 1 & \text{if } p_i \neq p_j = p^{opt} \end{cases}$$

where p^{opt} solves the total collusive profit maximization problem in p:

$$\max_p 2(p - c)q(p, p, I^*(p)) - I^*(p)$$

s. t.

$$(p - c)q(p, p, I^*(p)) - \frac{I^*(p)}{2} \geq \max_{p_i}(p_i - c)q(p_i, p, I^*(p)) - I^*(p) \quad i = 1, 2 \quad (5)$$

with $I^*(p)$ chosen to maximize the total collusive profit, i.e., $2(p - c)q(p, p, I) - I$.

The optimal cost-sharing mechanism should naturally lead firms to agree upon the collusive price, i.e., $p^{opt} = p_{coll}$, as it maximizes firms' total profit. However, $p^{opt} = p_{coll}$ might not always hold in a setting where $\varphi_i\big(p_i, p_j, I\big) + \varphi_j\big(p_j, p_i, I\big) = 1$. In fact, in the presence of low impact of the joint expenditure on the demand function, there might be an incentive for firms to deviate from the fully collusive outcome even at the cost of footing the entire bill.[6] In this case, the collusive price is not credible. Therefore, p^{opt} has to be set in a way that firms are indifferent between the agreed price and deviation. That is, the incentive compatibility constraints in (5) have to be satisfied at equality. In this case, firms make obviously lower profit than under full collusion, but still higher than under any other cost-sharing mechanism. As cost allocation depends on a market outcome (the price), the optimal cost-sharing mechanism is de facto an outcome-based mechanism.

Under Bertrand competition, the optimal cost-sharing mechanism can yield higher joint expenditure than the other mechanisms due to the higher price firms can charge using such mechanism.[7] In the one-stage game, the same result never holds when firms compete on quantities. Indeed, in this case, the optimal mechanism leads firms to produce the lowest quantity. This yields the lowest level of joint expenditure and thus the lowest total welfare as compared with the other mechanisms.

4.1.1. Comparison under quasi-linear demand

We consider the case of quasi-linear demand to better illustrate our general findings and explore the effect of outcome-based mechanisms on total welfare. Firms' direct demand functions are derived from the well-known quadratic consumer's utility function (Singh and Vives, 1984):

$$U(q_1, q_2) = \frac{K + r\sqrt{I}}{a - b}(q_1 + q_2) - \frac{a}{2(a^2 - b^2)}(q_1^2 + q_2^2)$$
$$- \frac{b}{(a^2 - b^2)}q_1 q_2, \tag{6}$$

to which the amount of purchased quantities times respective prices, i.e., $p_1 q_1 + p_2 q_2$, is subtracted to obtain the consumer surplus. Therefore, firm i's direct demand function is:

$$q_i\big(p_i, p_j, I\big) = K + r\sqrt{I} - ap_i + bp_j \quad i = 1, 2 \quad j = 3 - i, \tag{7}$$

where $K > 0$, $r > 0$, $a > b \geq 0$. Note that K is the market base of each firm before the joint expenditure is made, whereas r is a measure of the effectiveness of the joint expenditure in increasing the representative consumer's utility, and thus the market base of each firm. Furthermore, a reflects consumers' price sensitivity, whereas b reflects the degree of product substitutability, and thus the degree of price competition in the market. The square root reflects the usual diminishing rate of returns of the joint expenditure. In the Cournot competition case, the inverse demand function can be straightforwardly derived from (7). Note that the quasi-linear demand function satisfies the assumption of separable-additivity. The equilibrium solutions for all cost-sharing mechanisms (including the optimal one) are reported in the Appendix under both Bertrand and Cournot competition (Tables A1 and A2, respectively).[8] The next proposition makes the results presented in Proposition 1 more explicit and sheds light on total welfare comparison.

Proposition 3. *When direct demand functions are as in (7),*

(i) *under both Bertrand and Cournot competition firms earn higher profits under the QP mechanism than under both TM and FS mechanisms if b is sufficiently high or r is sufficiently low. Otherwise, the QP mechanism leads to lower profits than TM or both TM and FS mechanisms;*

(ii) *under Bertrand competition, firms always sell more under the FS mechanism. However, the total welfare is higher under the optimal and TM mechanisms than under the FS mechanism if r is sufficiently high. Moreover, the total welfare is higher under the QP mechanism than under the FS mechanism if r and b are sufficiently high;*

(iii) *under Cournot competition, firms always set a lower price under the FS mechanism. Moreover, the total welfare is always higher when firms use such mechanism instead of the QP, TM, and optimal cost-sharing mechanisms.*

The threshold conditions in b and r are provided in the Appendix due to their complex expressions. Proposition 3 further clarifies the regions of parameters where firms' profits are higher when using the QP mechanism rather than TM and FS mechanisms. Specifically, this occurs in a highly competitive environment (high values of b) or when the possibility to increase market demand is limited (low values of r). This is because in such types of environment the significant sales restriction guaranteed by the QP mechanism considerably increases firms' profits. However, when competition is mild and the effectiveness of the joint expenditure is sufficiently high, the QP mechanism leads to excessive overpricing (or underselling). As a result, in this case firms earn higher profits when using TM and FS mechanisms. Fig. 1 provides a representative example of these results (and relative threshold

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[6] If side payments were allowed, i.e., if $\varphi_i\big(p_i, p_j, I\big) + \varphi_j\big(p_j, p_i, I\big)$ could also be higher than 1, there would not be perfect budget balance so that the deviating firm could be forced to pay more than the entire amount of the joint expenditure, for instance, by transferring additional money to the firm that does not deviate. In this case, the collusive outcome would always be implementable.

[7] As shown in the Appendix, due to the higher price, the optimal mechanism certainly leads to a higher joint expenditure than TM and FS mechanisms. However, it may or may not result in a higher joint expenditure as compared with QP as it may or may not lead to higher price than QP. In fact, when the collusive price is implementable, the QP mechanism might lead to a higher price than the optimal mechanism if competition is mild or absent.

[8] Note that, as also reported in the Appendix, under symmetry, the equilibrium consumer surplus is simply the squared equilibrium quantity divided by $a - b$ for all cost-sharing mechanisms and all economic settings considered in the paper. Therefore, the comparison of consumer surplus strictly follows from demand comparison.
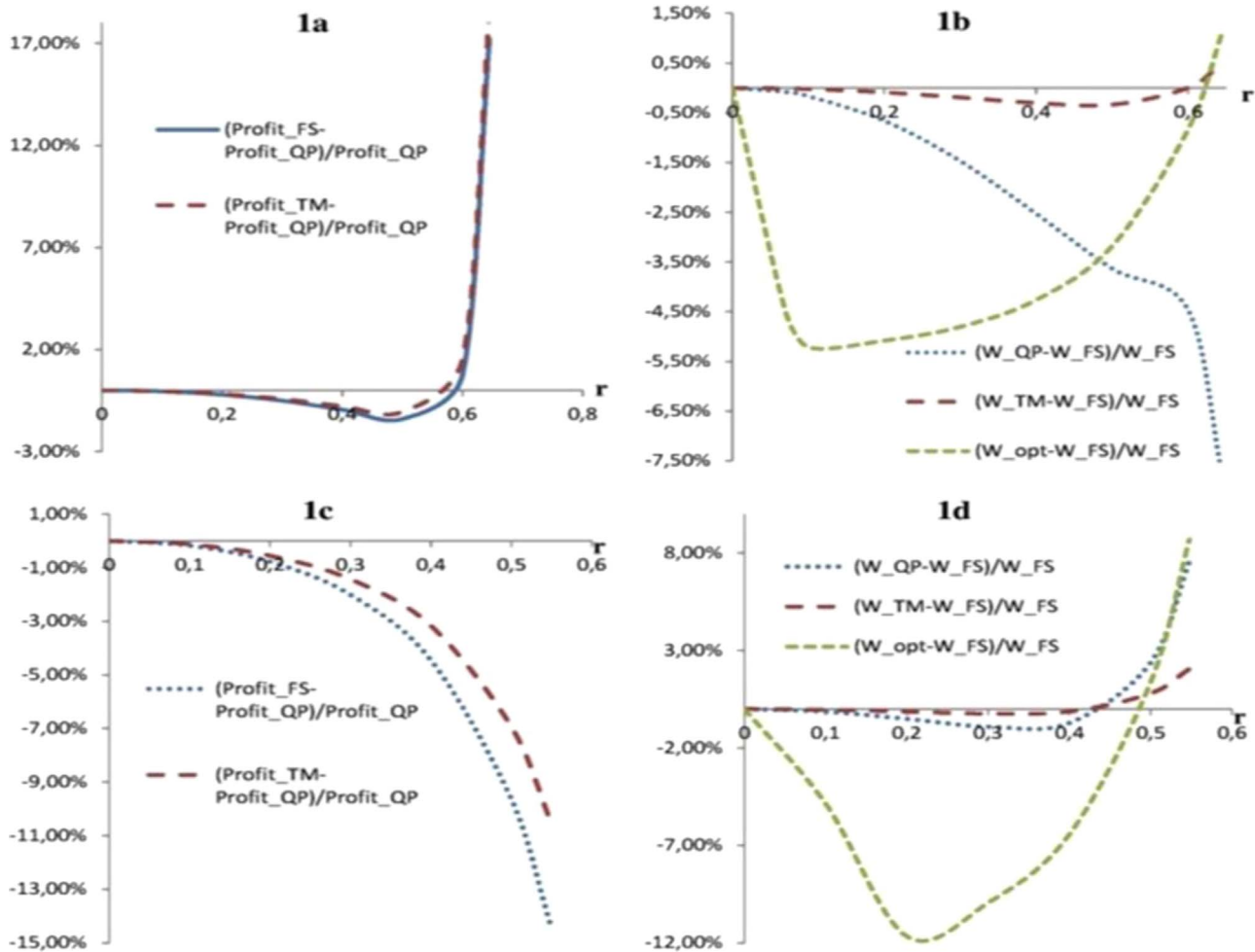
Fig. 1. Profit and total welfare percentage differences among different cost-sharing mechanisms under Bertrand competition, Case A and quasi-linear demand: in 1a and 1b values of parameters are $K=1$, $c=0.1$, $a=0.5$, $b=0.08$; in 1c and 1d values of parameters are $K=1$, $c=0.1$, $a=0.5$, $b=0.2$. The comparisons are carried within the range of parameters that ensure sensible equilibria for all cost-sharing mechanisms.

conditions). In particular, plots 1a and 1c show how the profit percentage differences between FS and QP mechanisms and between TM and QP mechanisms vary with the effectiveness of the joint expenditure for different levels of price competition b. Our results on profit comparison are consistent with the industry evidence that the QP mechanism is usually observed in saturated markets (low values of r) and/or in markets where firms fiercely compete to increase their profits. This is the case of agrifood and retail cooperatives, which usually operate in mature markets, or the alliance Toyota–PSA, which jointly produces three city-car models for the highly competitive European automobile market. In contrast, in case of R&D cooperation for new-to-the-world products or technologies, joint expenditures are usually highly effective and (at least in initial stages of the product lifecycle) there is no need of head-to-head competition as firms have at disposal a large market potential to exploit. In this case, the QP mechanism should never be preferred to the FS mechanism. Consistent with our result, the FS mechanism is often used in these contexts (e.g., Intel-Micron and Samsung-Sony joint ventures), where the difficulty to observe profit margins of each partner of the cooperation may make the TM mechanism not implementable.

It is a common argument that the higher profit under outcome-based mechanisms comes at the expense of a lower total welfare. In contrast, Proposition 3 shows that under Bertrand competition, such mechanisms, and even full collusion induced by the optimal cost-sharing mechanism, can generate higher total welfare as

compared with the more competitive FS mechanism. This can occur when the joint expenditure effectiveness is sufficiently high. However, when comparing QP and FS mechanisms, a high level of competition is also necessary for the former to yield higher total welfare than the latter.[9] These results (and relative threshold conditions) are also exemplified in Fig. 1. Specifically, plots 1b and 1d show how the welfare percentage differences between out-come-based mechanisms and the FS mechanism vary with the effectiveness of the joint expenditure for different levels of price competition b.

When firms compete à là Cournot, our results under the one-stage game support the conventional belief that outcome-based mechanisms are detrimental to society. The different result stems from the fact that under Bertrand competition firms do not reduce the level of the joint expenditure when using an outcome-based mechanism. Rather, a higher price implies a higher joint expenditure under outcome-based mechanisms. A higher joint expenditure is beneficial to society and the relative impact increases with r. For large values of r, the effect of the joint expenditure on total welfare becomes more relevant than the negative effect of a more collusive price setting. In this case, the use of outcome-based cost-sharing mechanisms instead of the more competitive FS mechanism is welfare-enhancing because it helps soften market

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[9] It is noteworthy that, in such a range, the QP mechanism also leads to higher profits than the FS mechanism.

competition. In turn, this helps maintain higher prices in the final market and thus fuels the joint expenditure. Hence, the fundamental intuition behind our important result on total welfare is related to the different strategic interactions between the joint expenditure and the competitive variable under different cost-sharing mechanisms.

These findings provide a richer picture of the role of outcome-based mechanisms on total welfare as compared with previous studies (Grossman and Shapiro, 1986; Katz, 1986; Katz et al., 1990). While arguments in the previous literature have usually suggested that outcome-based mechanisms hurt the total welfare, we show that they can actually be beneficial to society under Bertrand competition when the joint expenditure has a large impact on firms' demand. Our results on total welfare comparison can be useful to competing firms engaging in cooperation as well as antitrust authorities. These actors should be aware that outcome-based mechanisms can offer an incentive to firms to raise the level of welfare-enhancing expenditures and thus the total welfare when decisions are simultaneous (i.e., the one-stage game applies) and competition is on prices. Thus, firms should not be prevented from using outcome-based mechanisms if this helps them to increase welfare-enhancing expenditures considerably. This could be the case of producers of products with geographical indications (e. g., Italian parmesan and German Black Forest ham) that create consortia for product protection, promotion, and internationalization, while remaining competitors in the market. These producers usually adopt outcome-based allocation mechanisms to finance their joint activities. In the case of marketing campaigns for product internationalization, the use of outcome-based mechanisms can be beneficial in terms of total welfare as more consumers become informed about the products. However, if firms use outcome-based mechanisms to raise prices without adequately supporting welfare-enhancing joint expenditures, antitrust authorities should raise serious concerns. There have been several cases where these producers were investigated for restricting competition in their national markets (OECD, 2000). In Section 5, we show that outcome-based mechanisms can be more beneficial in terms of total welfare than the FS mechanism also under Cournot competition.

4.2. Case B: I affects only firms' unit operating cost

In this case the joint expenditure reduces firms' unit operating costs, thus $q(p_i, p_j, I) = q(p_i, p_j)$. Joint expenditures for plant maintenance service or quality control programs in co-manufacturing agreements are examples of this kind of situations. The derivation of equilibrium solutions is similar to Case A. The first order conditions in $p_i (q_i)$ for each cost-sharing mechanism are the same as those in Table 1, where now $c = c(I)$. Under both Bertrand and Cournot competition, taking the first order derivative of the joint profit in I and setting it equal to zero yield the following for any mechanism:

$$\frac{\partial \Pi_{tot}}{\partial I} = -\frac{\partial c}{\partial I}(q_i + q_j) - 1 = 0.$$ (8)

With the support of the first order conditions in Table 1 and in (8), we provide the results of comparison under Case B in the next proposition.

Proposition 4. *Under both Bertrand and Cournot competition,*

 (i) *price, quantity and joint expenditure are ranked as follows:* $p^{QP} > p^{TM} \geq p^{FS}$, $q^{QP} < q^{TM} \leq q^{FS}$, and $I^{QP} < I^{TM} \leq I^{FS}$;
 (ii) *firms earn higher profits under the TM mechanism than under the FS mechanism, i.e., $\Pi^{TM} \geq \Pi^{FS}$. Under fierce competition, firms earn higher profits under the QP mechanism than under both TM*

and FS mechanisms, i.e., $\Pi^{QP} > \Pi^{TM} \geq \Pi^{FS}$. In the absence of competition, $\Pi^{TM} = \Pi^{FS} > \Pi^{QP}$.

Proposition 4 suggests that the collusive effect of outcome-based cost-sharing mechanisms (QP and TM) on the joint expenditure is always negative. With simultaneous decisions, firms and antitrust bodies can certainly expect lower total welfare when the joint expenditure is cost-reducing. This is because the lower produced quantity implies a lower level of the joint expenditure as well as a higher price under both Bertrand and Cournot competition. Under Bertrand competition, the underlying difference with Case A is that here the optimal level of the joint expenditure is directly driven by the quantity rather than the price. The lower quantity under outcome-based mechanisms provides firms with the incentive to spend less to improve operational efficiency. Thus, the findings in Proposition 4 are in line with the argument usually provided by previous literature. Firms should be aware that outcome-based mechanisms are welfare-reducing when decisions are simultaneous (i.e., the one-stage game applies) and the joint expenditure has the purpose of reducing unit operating costs. The results on how sharing mechanisms affect firms' profitability are qualitatively identical to those presented in Proposition 1. Therefore, the same considerations apply to Case B as well.

The optimal cost-sharing mechanism can be determined as in Proposition 2 for both Bertrand and Cournot competition. Thus, we omit the proposition for this result. In the interest of length, we also omit the example with a possible specification of demand and cost functions because welfare comparison under the general model is not ambiguous. Moreover, profit comparisons qualitatively lead to the same results as those presented in Proposition 3. Therefore, the analysis is provided only in the Appendix. In this case, the direct demand function is derived from (6) where the joint expenditure term is removed to study the impact on cost. The unit operating cost function is as follows:

$$c(I) = c - r\sqrt{I}.$$ (9)

The above function is decreasing and convex in the joint expenditure. Here, r measures the effectiveness of the joint expenditure in reducing unit operating cost. The square root reflects the usual diminishing rate of returns of the joint expenditure.

5. The two-stage game

In this section, we tackle the two-stage game with the support of both analytical derivation and numerical analysis to show that the main results of the paper are robust irrespective of the timing of decisions. Recall that in the two-stage game, the sequence of decisions is as follows. The joint expenditure is decided by the entity established to manage the cooperation (e.g., a consortium or a joint venture) in the first stage. Then in the second stage, firms compete in setting prices or quantities and share the realized profits according to the selected cost-sharing mechanism.

Analytically we can only compare the FS mechanism and the optimal cost-sharing mechanism under the demand function in (7) and the cost function in (9). This helps verify whether the finding that the optimal mechanism leads to higher total welfare in case of Bertrand competition remains valid also under the two-stage game. The first order conditions for prices and quantities in the second stage are identical to those derived in the one-stage game in Table 1. However, the first order conditions in I are different from those derived in the one-stage game as now the cooperative expenditure is chosen in the first stage. This implies that the FS mechanism yields different equilibrium solutions as compared with the one-stage game. Such equilibrium solutions are reported in the Appendix (Tables A5 and A6) under both Bertrand

and Cournot competition. In contrast, the optimal cost-sharing mechanism still leads to the same solutions as those in the one-stage game (Tables A1, A2, A3 and A4). Next, we present the comparison.

Proposition 5.

 (i) *Under Bertrand competition, Case A and demand function as in* (7): *Price (demand) is always higher (lower) under the optimal cost-sharing mechanism. The joint expenditure is higher under the optimal cost-sharing mechanism if r is sufficiently high and b assumes relatively low values. Finally, total welfare is higher under the optimal cost-sharing mechanism if r is sufficiently high and b assumes intermediate values.*
 (ii) *Under Bertrand competition, Case B, demand function derived from* (7) *and cost function as in* (9): *The joint expenditure is always higher under the optimal cost-sharing mechanism. Moreover, demand (price) is higher (lower) under the optimal cost-sharing mechanism if r assumes intermediate values and b is sufficiently high. Finally, total welfare is higher under the optimal cost-sharing mechanism if both r and b are sufficiently high.*
(iii) *Under Cournot competition, both Cases A and B, demand function as in* (7) *and cost function as in* (9): *The joint expenditure is always higher under the optimal cost-sharing mechanism. Quantity (price) is always higher (lower) under the FS mechanism. Moreover, the total welfare is always higher under the FS*

mechanism than under the optimal cost-sharing mechanism.

Again, the threshold conditions in b and r are provided in the Appendix due to their complex expressions. Proposition 5 confirms and further strengthens the insight that under certain conditions even firms' collusion on price might be socially preferred to the more competitive FS mechanism. In the presence of price competition, the optimal mechanism can lead to higher total welfare than the FS mechanism not only under Case A, but also under Case B. The rationale is that in contrast to the one-stage game, firms have the incentive to jointly spend more in the first stage under the optimal mechanism given that they can anticipate higher profit in the second stage due to collusion.

Under Cournot competition, the interaction between the joint expenditure and the quantity differs from that in the one-stage game. The possibility to enjoy more collusive profits creates a larger incentive to spend in the first stage. As a result, a lower output leads to a higher joint expenditure. Nevertheless, there is no benefit in terms of welfare. The reason is that the collusion in the second stage depresses the marketed output to such an extent that the positive effect of a higher joint expenditure is not able to compensate for the negative effect of such a lower quantity.

We also conducted an extensive numerical analysis to consider QP and TM mechanisms, which are not tractable under the two-stage game. In our numerical analysis the demand function is derived from (7), whereas the cost function is derived from (9).
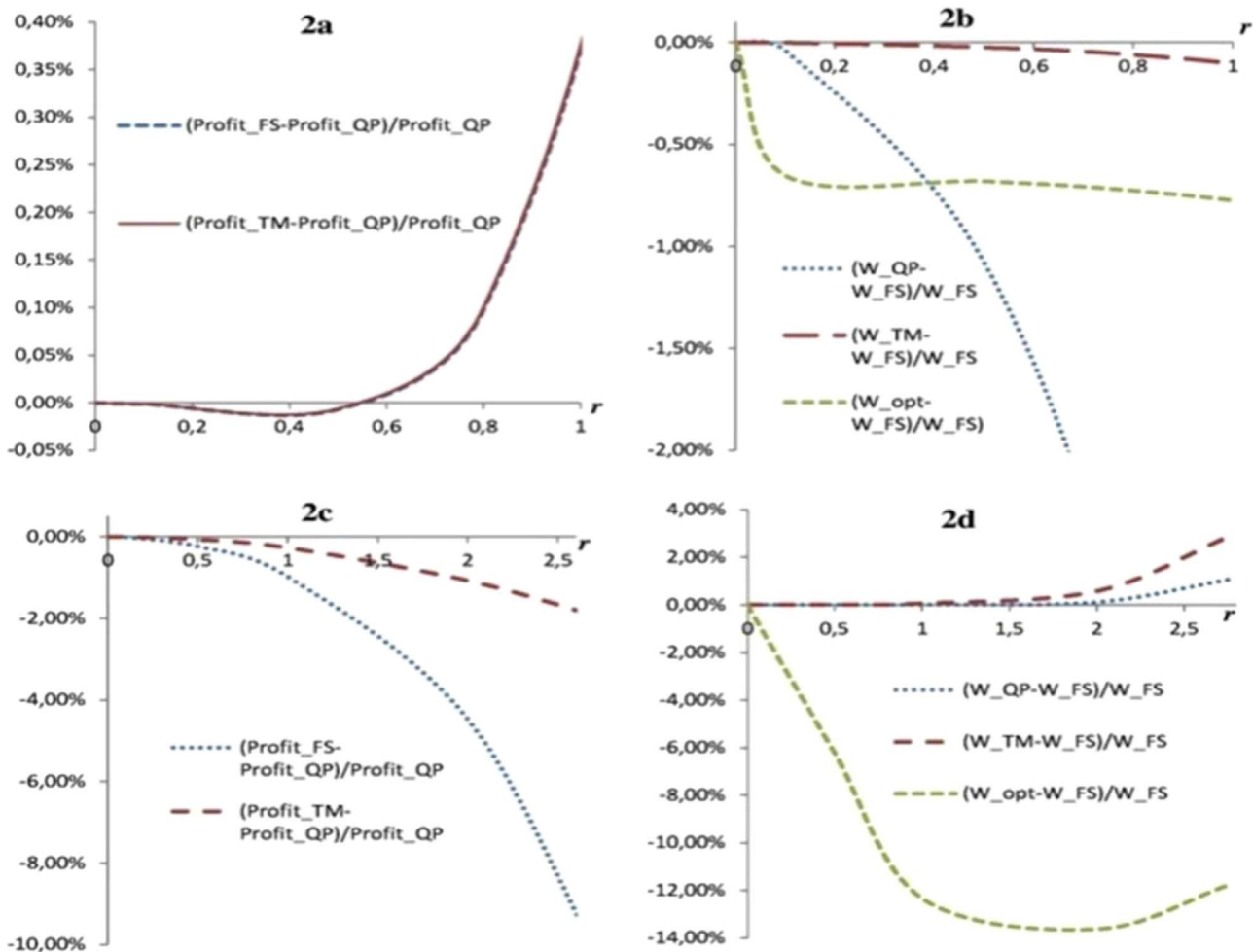

Fig. 2. Profit and total welfare percentage differences among different cost-sharing mechanisms under Cournot competition, Case B and quasi-linear demand and specific cost function: in 2a and 2b values of parameters are $K=1$, $c=1.5$, $a=0.5$, $b=0.01$; in 2c and 2d values of parameters are $K=1$, $c=4$, $a=0.5$, $b=0.37$. The comparisons are carried out within the range of parameters that ensure sensible equilibria for all cost-sharing mechanisms. Also, note that a value of c higher than K is sensible as long as $K-(a-b)c$ is positive.

The comparisons were carried out in the range of parameters ensuring sensible equilibrium for all mechanisms. The main results regarding profit comparison are qualitatively identical to those obtained in the one-stage game. Thus, we only discuss the findings about total welfare comparison. At any rate, Fig. 2 provides representative examples of our results by showing profit and welfare percentage differences among different mechanisms.

The numerical analysis allows us to make a further crucial point. The beneficial effect of outcome-based mechanisms is not restricted to the case of Bertrand competition. Our numerical results indeed reveal that the total welfare can be higher under both TM and QP mechanisms than under the FS mechanism also in the presence of Cournot competition (both Cases A and B). This occurs when quantity competition is sufficiently high and the joint expenditure is highly effective. In addition, when competition is very fierce, the total welfare is higher under both TM and QP mechanisms than under the FS mechanism even in the presence of mildly effective joint expenditure. These results are exemplified in Fig. 2 (2b and 2d). The intuition behind the different welfare result compared with the one-stage game is related to a different strategic interaction between the joint expenditure and the quantity. Under sequential decisions a lower output does not imply a lower joint expenditure under outcome-based mechanisms. Rather, a lower output in the second stage leads to a higher joint expenditure in the first stage because firms can anticipate higher profits when competition is restricted. The collusive power of QP and TM mechanisms is lower than that of the optimal mechanism so that the reduction of produced output is not large enough. As a result, when both quantity competition and effectiveness of the joint expenditure are sufficiently high (or simply when quantity competition is extremely fierce), the benefit of a higher joint expenditure more than outweighs the negative effect of reduced output. In this case, the use of the QP and TM mechanisms instead of the more competitive FS mechanism can increase total welfare, even though favoring collusion. Either QP or TM mechanisms can prevail depending on the range of parameters.

Under Bertrand competition (both Cases A and B), numerical analysis shows that both QP and TM mechanisms can be more beneficial than the FS mechanism in terms of total welfare when price competition and effectiveness of the cooperative expenditure are sufficiently high, or when price competition is very fierce. From Proposition 5, recall that the optimal cost-sharing mechanism can also lead to a higher total welfare than the FS mechanism. Numerical investigation seems to suggest that the QP and TM mechanisms are even more beneficial.

Overall, the analysis under a two-stage game helps strengthen the findings derived under the one-stage game. In terms of firms' profitability, the analysis suggests that results are qualitatively unchanged. Firms should prefer the QP mechanism in highly competitive markets and/or when demand tends to saturation and technology is mature (for instance, food industry or city-car segment in Europe). In contrast, even the FS mechanism could be preferred to the QP mechanism in new-to-the-world markets with initially moderate competition (e.g., LCD technology at the time of joint venture establishment between Sony and Samsung). As for the total welfare, the two-stage game analysis suggests that not only under Bertrand but also under Cournot competition, firms' choice of using outcome-based mechanisms can yield higher total welfare when competition and effectiveness of the joint expenditure are sufficiently high. This result can occur even in case of mild effectiveness of the joint expenditure if competition is extremely fierce. Also, with sequential decisions (e.g., R&D or manufacturing capacity decisions) the positive welfare benefits of adopting outcome-based mechanisms can arise irrespective of whether the joint expenditure is demand-increasing or cost-reducing. Thus, our analysis informs firms and antitrust bodies that

the conventional belief that outcome-based mechanisms facilitate firms' collusion at the detriment of the society might be erroneous in the presence of highly competitive markets, which are far from demand and/or technology maturity.

We have also performed extensive numerical analyses considering the case of non-identical firms (e.g., firms differing in market base or unit operating cost) under both one and two stage games. The comparison with non-identical firms is indeed not tractable analytically. Nevertheless, the numerical study shows that our major findings are robust even in the presence of asymmetry. In the interest of length, the results of this study are omitted and can be made available from the authors.

6. Industry implications and conclusions

Firms consider the opportunity to cooperate and share costs of expenditures/investments with competitors in numerous business settings. In this paper we have studied the economic consequences of using outcome-based vs. ex ante-based mechanisms in a variety of settings, i.e., Bertrand and Cournot competition, demand-increasing and cost-reducing expenditure, and one and two stage games.

There are two essential messages conveyed by this paper that can be useful to support firms' and antitrust bodies' decisions. First, outcome-based cost-sharing mechanisms might actually have the merit of increasing total welfare as compared with the more competitive fixed share mechanism, even though favoring full collusion. We have shown that outcome-based mechanisms can indeed yield higher total welfare in the presence of simultaneous decisions under Bertrand competition and demand-increasing joint expenditure. In the presence of sequential decisions, they can yield higher total welfare under both Bertrand and Cournot competition, irrespective of whether the joint expenditure is demand-increasing or cost-reducing. Therefore, our findings may lead to reconsider the conventional stance on the role of such mechanisms. In fact, the antitrust guidelines on horizontal inter-firm cooperation in the US and EU are stringent when cooperative agreements serve as mechanisms to implement market collusion. For instance, in the US antitrust guidelines, it is explicitly pointed out that anticompetitive harms could result if cooperating competitors utilize mechanisms that raise their marginal costs in the final market. The outcome-based cost-sharing mechanisms have been traditionally identified as examples of such kind in previous literature. However, our results suggest that although outcome-based mechanisms should always be carefully scrutinized, they should not be discouraged under certain circumstances as they can have positive effects in terms of total welfare. From a practical perspective, our study informs firms and antitrust bodies that in markets characterized by intense competition and large room to expand demand and/or improve operational efficiency, the use of outcome-based mechanisms (rather than that of the FS mechanism) could be favored, provided that firms exploit their increased price or quantity-setting power to adequately fuel welfare-enhancing cooperative expenditure. In particular, a useful insight for competing firms aiming at utilizing outcome-based mechanisms for sharing joint expenditures is to demonstrate that the increased price or quantity setting power will be accompanied by adequate welfare-beneficial expenditures. A useful insight for antitrust bodies and policy makers is to carefully scrutinize the type of cooperation (long-term vs. short-term joint decisions, demand-increasing vs. cost-reducing cooperation) and the type of competition (Bertrand vs. Cournot). Particularly, they should measure the extent of price/quantity setting power increase in relation with the increase in level of joint expenditure under outcome-based mechanisms. In addition, taxation policies

for fair re-allocation among firms and consumers of the higher benefits possibly derived from using outcome-based mechanisms should also be considered.

Our second message is that outcome-based cost-sharing mechanisms are in general preferable from a profitability perspective. However, there exist market circumstances where the QP mechanism leads to lower profitability than the more competitive FS mechanism. This result can help increase firms' awareness about the economic implications of using the QP mechanism. Firms should opt for the QP mechanism in business settings where competition is intense, such as the case of the European city-car market targeted by the alliance Toyota–PSA. Similarly, the QP mechanism should be preferred when demand or technology is mature, which may be the case of agrifood and retail cooperatives in US and Europe. This is because this mechanism helps soften the competition better than the other mechanisms. In contrast, in the case of R&D cooperation for new-to-the-world products and mild competition, the QP mechanism should never be preferred by both TM and FS mechanisms. In such contexts, the excessive over-pricing or underselling caused by the QP mechanism prevents firms from taking advantage of the large room available to expand demand or improve operational efficiency by means of the joint expenditure.

In conclusion, we present some ideas for future research. In this paper, we have defined the cooperation in the form of a joint expenditure. However, future research may consider revenue-sharing agreements, which are popular in the airline industry (Chen et al., 2014). We expect that the main results presented in this paper still hold if we model cooperation in the form of revenue-sharing. Similarly, the extension to more than two competitors should not affect the findings of this paper. However, in this case, if the creation of subcoalitions (instead of the grand-coalition with all firms) were allowed, a completely different analysis would be required. This is because the effect of the joint expenditure on firms' demand and/or unit operating costs may depend on the number of members of a certain subcoalition. An analysis along this direction is undoubtedly worth further work.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ijpe.2016.08.002.

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