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Abstract

This paper studies the incentives for firms competing in vertically differentiated markets to sign binding collusive agreements, as in the case of mergers and alliances. Empirical investigations show that firms involved in mergers and acquisitions revise prices and qualities as to maximize their joint profits. In a few cases merging firms are also observed shutting down some lines of activities (so called *market pruning*). In this paper we attempt to test these predictions by modelling a three-stage game in which, at the first stage, three firms selling goods independently in a vertically differentiated market can commit to sign either a full or a partial voluntary agreement (with a subset of firms) *via* a sequential game of coalition formation while, at the second and third stage they can optimally revise their qualities and prices, respectively. In such a setting we study whether some binding agreements (as full or partial mergers) can be sustained as subgame perfect equilibria of the coalition formation game. Moreover, we analyse the final effects of different coalition structures on equilibrium qualities, prices and profits accruing to firms. We obtain the following results: (i) initial firms' *heterogeneity* appears a crucial factor for mergers to arise; (ii) although profitable, the grand coalition of firms (i.e. the whole market merger) is not the outcome of the finite-horizon negotiation, where only partial mergers arise; (iii) all stable mergers comprehends the firm producing the bottom quality good; (iv) all stable mergers reduce the number of variants on sale (*market pruning*); (v) stable mergers always increase the quality gap among variants. All model findings seem compatible with the existing empirical observations.

Keywords: *Vertically Differentiated Markets*, *Mergers*, *Merger Policies*, *Cannibalization*, *Market Pruning*, *Endogenous Coalition Formation*, *Price Collusion*, *Grand Coalition*, *Coalition Stability*, *Core*, *Sequential Game of Coalition Formation.*

JEL Classification: D42, D43, L1, L12, L13, L41.

1 Introduction

This paper studies the incentives for firms competing in vertically differentiated markets to sign binding collusive agreements, as in the case of mergers and alliances. Empirical investigations show that firms involved in mergers and acquisitions usually revise prices and qualities, as to maximize their joint profits.[1] In many cases the companies involved in mergers also shut down part of their product lines (so called *market pruning*).[2] These possibilities are explicitly considered by the U.S. Horizontal Merger Guidelines (2010) when stating that:

> "Enhanced market power can also be manifested in non-price terms and conditions that adversely affect customers, including reduced product quality, reduced product variety, reduced service, or diminished innovation." (U.S. Horizontal Merger Guidelines, 2010). [3]

Only recently the complex interaction between mergers and price-quality combinations has started to attract attention (among the others, Mazzeo 2002, Crawford and Shum 2006, Gandhi *et al.* 2008, Draganska *et al.* 2009, Chu 2010, Byrne 2012, Fan 2013, Lee 2013). For instance, Berry and Waldfogel (2001) found that the series of mergers followed to the 1996 Telecommunications Act drastically reduced the number of stations but increased the relative number of varieties of formats available. Sweeting (2010) and George (2007) reported similar evidence for U. S. radio music industry and Fan (2013) for U.S. newspapers market.[4] For airline industry, Peters (2006) observed a reduction of flight frequency on segments where merging carriers are competing against each other, whereas Mazzeo (2003) showed that carriers deteriorate their on-time performance as result of a less competitive after-merger market structure.

To the best of our knowledge, a full-fledged study of the effects of mergers on market prices and qualities in a *vertically* differentiated industry has not yet been provided. Similarly unexplored is the analysis of *mergers stability* between firms in vertically differentiated markets when firms can re-shape prices and qualities of all products once merged. On this ground, anecdotal evidence shows that frequently mergers and acquisitions occur among firms selling

[1] See, for instance, Berry and Waldfogel (2001) and Sweeting (2010) for an analysis of mergers in radio music industry, George (2007) and Fan (2013) for US newspapers, Giraud-Heraud *et al.* (2003) for mergers occurred in the mineral water market and Peters (2006) and Lee (2013) for those in US airline industry.

[2] A top cited case is Apple withdrawing from the market its i-phone 5 when marketing its enhanced smartphone i-phone 6. See also Johnson and Myatt (2003) for a detailed description of pruning by an incumbent as effect of an entrant in the market.

[3] For an analysis of recent US antitrust trials in which quality issues arise see, for instance, McMillan (2015).

[4] In particular, using data on the assignment of reporters to topical areas at 706 newspapers in the US, George (2007) observes that differentiation increases with ownership concentration. Sweeting (2010) finds instead that those firms that buy competing stations tend to emphasize "service differentiation" among themselves.

products which are fairly differentiated along the quality spectrum. For example, most of mergers that took place after the deregulation of U.S. airline market in 1979 occurred between one big national/international carrier and one low fare local carrier (e.g. the merger between American Airlines and AirCal in 1986 or between Delta and Atlantic Southeast Airlines in 1999)[5] or, alternatively, among intermediate-quality carriers (as for Southwest Airlines and AirTran Airways in 2010).[6] The European Airlines industry similarly experienced a high number of mergers among highly differentiated airlines as, for instance, those between Air France and Air-Inter in 1999 or between Lufthansa and Air Dolomiti, started in 1993 and concluded in 2003.[7] In a similar way, the automobile industry is plenty of examples of premium segment car producers absorbing economy automobile manufacturers, as in the merger between Volkswagen Group and Skoda in 1991 or between BMW and Rover in 1994.[8] The main consequences of these consolidation processes are often which to re-position the lower quality brand towards a higher segment of the market as well as, in some other cases, to *un-brand* intermediate quality products to create a *fighting brand* able to compete more aggressively with the firms positioned at the bottom of the quality spectrum. However, the latter strategy appears more as a temporary strategy, since a fighting brand can incur the risk to cannibalize the market of the merging firms. This could be one reason why Lufhtansa decided to sell its share of the low-cost airlines Condor in 2006. Ultimately, a consolidated group can find more advantageous to *re-brand* its economy products rather than *un-brand* some of its intermediate quality outlets. Instead of letting Mini Cooper competing in the low segment of the market, BMW preferred to transform this city car into a premium car. In a similar vein, the boom of mergers recently observed in pharmaceutical industries, involving top pharmaceutical companies acquiring generics drugs manufacturers (as in the recent case of Teva absorbing Allergan Generics), may represent a similar trend.[9]

To study all these issues, in this paper we introduce a simple framework in which three firms initially selling three vertically differentiated products have to decide whether to merge or not

[5] A complete list of U.S. airlines industry mergers is available at: http://www.airlines.org.

[6] Other mergers between medium and small airlines are also those between Republic Airways and Midwest Airlines in 2009, Republic Airways and Frontier Airlines in 2010 and many others. Such a long series of mergers finally turned the U.S. Airlines industry into a quadriopoly between Delta, United Airlines, Southwest and American Airways which, together, control more than 80% of the passenger capacity.

[7] In some other cases the low-cost carriers have attempted to take over small-medium companies, as in the recent hostile takeover launched by Ryanair to Air Lingus.

[8] Also the purchase in 1964 by Volkswagen of Auto Union (later known as Audi) from Daimler-Benz was mainly due, at that time,to the production of economy cars by Auto Union.

[9] See, for instance, Jen Wieczner (2015), "The real reasons for the pharma merger boom", *Fortune*, July 28, 2015.

with all or with part of the rival firms. Once merged, firms are allowed to optimally reshape their qualities and prices according to the new market structure. Thus, taking into account all alternative price-quality equilibrium configurations, we study whether full or partial mergers can be sustained as subgame perfect equilibria of the coalition formation game. Moreover, we analyse the final effects of different coalition structures on equilibrium qualities, prices and profits accruing to firms.

In the remaining of this section we briefly review some of the existing literature on collusion and mergers under vertical differentiation and present in more detail our paper content.

1.1 Related Literature

The relationship between *collusive agreements* and *vertical product differentiation* was formerly analysed by Hackner (1994). In his work, the key question is whether *price collusion* is more likely to arise when products are close substitutes or, rather, highly differentiated. In a duopoly setting, he finds that monopoly pricing is easier to sustain in markets in which products are similar. Further, he proves that the incentive to deviate from a collusive agreement is always stronger for the high-quality firm. The main reason is that when the quality gap between products is significant, the profit of the top-quality firm is already high under no collusion, so that its incentive to collude is weak. As the quality gap decreases and the noncooperative payoff become smaller for the high-quality firm, reaching a collusive agreement gets more and more attractive. Along the same research line, Ecchia and Lambertini (1997) study how the stability of price collusion in a duopoly setting is affected by the introduction of a minimum quality standard. They observe how the introduction of a welfare-maximizing minimum quality standard makes collusive agreements more difficult to sustain. This is because the existence of a standard decreases product differentiation by providing the bottom quality firm with a stronger incentive to break the agreement.[10]

There are two common traits in these works. First, (i) the degree of product differentiation does not change after a coalition has formed, since the collusive behavior is restricted to pricing. The former assumption is a natural entry point in the literature on cartel stability under product differentiation, as it enables to disentangle the effect of quality gap on the stability of a cartel. Further, conceiving collusion in terms of pricing is particularly reasonable in a short-run perspective. Still, it leaves unexplored a companion question, namely the effect

[10] In Hackner, the opposite holds since, due to the cost structure, in his model the asymmetry in profits gives an advantage to the high quality firm.

of the cartel on product differentiation. This analysis is particularly pregnant in a long-run perspective since one cannot exclude that in a more extended time span a coalition (typically a cartel or a merger) entails structural changes, such as relocations of production facilities, or adjustment in the product range and quality.

Secondly, (ii) the market is populated by two firms so that it turns out to be fully monopolized by a *grand coalition* in the case of cooperation between firms.[11] While considering at the start a duopoly enables to detail the effects of a full cooperation, casual observations show that, there exist circumstances under which firms choose to form a partial alliance (i.e. one including a subset of firms in the market) rather than the *grand coalition.* While in any partial alliance, colluding firms compete against some rivals outside the coalition so that a noncooperative behavior is still preserved. Of course, *a priori* the effects of a partial alliance or merger are not equivalent to those observed when all agents collude and mimic a monopolist.

None of the above mentioned contributions focusses on the effect of collusion in vertically differentiated markets.

To the best of our knowledge, the possibility that firms cooperate both along a price dimension and a quality dimension in a vertically differentiated market has been investigated only by Lambertini (2000). He studies how the cartel stability is related to R&D activity in a duopoly with convex costs, and assumes that the collusive quality choice can occur either under price or quantity-setting behaviour.[12] The issue concerned with the alliance formation when more than two firms are active in a vertically differentiated market is however still unexplored, like so the impact of partial collusion on the market equilibrium. The introduction of an intermediate quality firm sheds light on some interesting features of the coalition formation process. As far as we know, the only model of vertical differentiation with three independent firms competing in quality and price is provided by Scarpa (1998).[13] Considering the role of a minimum quality standard, Scarpa (1998) stresses that the demand level of a firm in a vertically differentiated market depends on quality and price of adjacent firms in the product space. This property, reminiscent of a spatial competition approach, is rather interesting when considering the rationale adopted by the colluding firms to define the optimal range of variants. Indeed, since only adjacent variants compete against each other, under partial collusion defining the optimal set of products to market requires to put in balance *the cannibalization effect* that a

[11] The grand coalition is the one formed by *all* firms in the market.

[12] A different strand of literature considers the possible impacts of R&D joint ventures on product market collusion. See on this, Martin (1995) and Lambertini *et al.* (2002).

[13] Pezzino (2010) analyses quantity competition among three firms in a vertically differentiated market.

variant produced by the coalition may exert *within* the coalition with the possibility that this variant *steals* consumers from the rival firm (henceforth *stealing effect*).[14]

Other closely related papers are those by Lommerud and Sorgard (1997), Gandhi *et al.* (2008), Chen and Schwartz (2013) and Brekke *et al.* (2014), all devoted to the analysis of price-quality post-merger re-positioning.[15] The first paper is inspired by Salant *et al.* (1983) and Deneckere and Davidson (1985) and it is devoted to evaluate the profitability of a merger under both Cournot and Bertrand competition. The authors assume that the market is initially populated by three firms and, therefore, two firms can merge and decide on the number of brands to market. When the fixed cost of marketing a brand is 'high', the merged entity reduces its product range. This increases the profitability of mergers both under Bertrand and Cournot competition due to reduced marketing costs. With a 'low' cost of marketing, the effect on the product range depends both on the nature of competition and on the degree of product differentiation. For example, under Cournot or Bertrand competition and sufficiently differentiated products, the non-merging firm finds profitable to introduce a new brand, thereby damaging the merged entity. In order to highlight the impact of a merger on non-price competition, Gandhi *et al.* (2008) assume that firms can instantaneously and costlessly reposition their products after a merger, thereby choosing both price and location in a Hotelling market. They show that after a merger the products are repositioned away from each other to reduce the resulting cannibalization effect. Consequently, non-merging substitutes are repositioned between the merged products and, after all these location strategies, the merged firm's incentive to raise prices decreases. Similarly, in a Hotelling framework, Chen and Schwartz (2013) analyse the incentive for firms to introduce a product innovation when proposing a merger-to-monopoly. In contrast to Arrow's finding for process innovation, where the monopolist never undertakes R&D efforts to innovate, in this paper the incentive to invest in incremental product innovations can be higher for the merged entity (a monopolist) than for a rival facing competition from the existing good. Indeed, the monopolist can coordinate the pricing of the two products overcompensating the erosion of profits coming from cannibalization. In a spatial competition model *à la* Salop with three *ex ante* identical firms, Brekke *et*

[14] These effects resembles the so called *peer effect* and *pecking order effect*. The peer effect takes place when joining organization with high-quality agents increases the payoff of its members. This effects explains why outstanding researchers tend to join top research department. On the other hand, the pecking order effect takes place when the payoff an individual gets depends on his/her relative position in a ranking. Typically, people at the top in the pecking order have a greater chance to obtain further internal promotions.

[15] Other recent papers by Mazzeo (2002), Einav (2003) and Seim (2006) focus on the price-quality startegies decided by industry entrants. These models are particularly relevant for the analysis of the strategic behaviour of *ex ante* symmetric firms deciding their price-quality positioning (see on this, the discussion of Section 4).

al. (2014) show that any two-firm merger reduces its product quality whereas the non-merging firm responds increasing its quality. Final prices can either increase or decrease according to the responsivness of demand functions. Moreover, it is shown that if a merger entails the closure of one of the two merged firms, it always leads to higher qualities and prices for all firms in the market.

1.2 Our Paper

In the present paper we consider a vertically differentiated setting in which three firms initially produce three vertically differentiated products as independent firms. In this environment, we study their incentives to sign full or partial binding agreement among firms, knowing in advance that the formed alliances can manipulate collusively their quality-price combinations.

More specifically, we introduce a three-stage game where, at the first stage, every firm expresses its willingness to form an alliance or, alternatively, to play as singleton. An alliance can either contains all firms in the market (*grand coalition*) or a subset of them (two firms colluding against the third one playing alone). As in Bloch (1995, 1996) and Ray and Vohra (1999) we assume that the coalition formation game is *sequential*, with an exogenous order of play. Differently from them, we assume that every firm proposes not only an alliance, but also a division of the coalition joint payoff.[16] Each recipient of the proposal can either accept or reject the offer and, in case of rejection, it becomes its turn to make a proposal. The game is assumed finite-horizon and every firm only possesses one turn of proposal in each period.[17] Once a coalition structure has formed, at the second stage firms decide simultaneously the optimal quality of their products. When considering this issue, we take into account how a full or partial merger among firms may affect their incentives to differentiate products in the market. Choosing the optimal quality after colluding, in turn, affects their incentives to merge. Finally, at the third stage, firms set simultaneously prices. When in an alliance, quality and price are set so as to maximize the joint profits of firms which belong to it. Notice also that, when merging, firms can choose at the second stage (resp. third stage) to produce a quality so low (resp. to quote a price so high) that no consumer is willing to buy it. This is equivalent to stop producing the variant, thereby reducing the range of products sold at equilibrium.

[16] Bloch (1995, 1996) and Ray and Vohra (1999) assume identical players and a fixed allocation rule within each coalition. See also Belleflamme (2000) for an extension of the model to the formation of asymmetric alliances, and also Bloch (2002, 2003), Marini (2009) and Currarini and Marini (2014) for extensive surveys on alliance formation models applied to oligopoly.

[17] Both Bloch's (1995, 1996) and Ray and Vohra's (1999) models are, instead, infinite-horizon. Our assumptions are meant to describe an environment in which the time of negotiation is quite limited in each period.

We find that, although the full monopoly merger would arise in an infinite-horizon sequential game of coalition formation, under a finite horizon the incentive for firms to enter the full market merger is always dominated by that to form partial coalition structures (partial mergers). Furthermore, we prove that all equilibrium mergers always contains the bottom quality firm which, in all cases, drops its low-quality variant from the market. In particular, whoever is the additional player included in coalition (either the intermediate or the top quality firm), equilibrium prices and qualities always coincide with that observed in the case of a duopoly, with a high-quality firm competing against a low-quality rival, as in Motta (1992). At first sight, this result seems to be counterintuitive. A natural conjecture when considering that players producing different variants collude is that either the range of variants or the quality gap between variants in the market changes with the players involved in the alliance. We find on the contrary that only profits accruing to the single players change with the type of partial merger, range of products, quality gap and price being unchanged. Indeed, the cannibalization effect and the stealing effect induce the merger, whatever its members, to withdraw from the market the lowest quality variant between the set which can be produced *a priori*. Interestingly, depending on the intensity of these effects, in some circumstances this variant is withdrawn from the market at the price stage, in some other circumstances at the quality stage. In particular, the merger formed by the intermediate quality and by the low-quality firm stops immediately to market the bottom-quality product at the price stage. In contrast, the merger formed by the top and the bottom-quality firm keeps the bottom product (as a fighting brand) at the price stage whereas ultimately drops it at the quality stage. As argued above, keeping a fighting brand in an alliance is mostly a short-run (price) than a medium/long run strategy (quality) and it is, therefore, dropped when the merging group can re-position its product lines. Finally, we find that, in all equilibrium (partial) mergers, the bottom-quality firm is always present. This appears in line with numerous theoretical and experimental studies on coalition formation in triads of heterogeneous individuals, i.e. possessing different skills or fighting ability (e.g. Caplow 1956, 1959, 1968, Vinacke and Arkoff 1957, Gamson 1961). A central conclusion of these studies is that "weakness is strength" (see, for instance, Mesterton-Gibbons *et al.* 2011, p.189), with this meaning that less-powered individuals have usually more chances to be part of a coalition. We obtain the same result with the firms competing in a vertically differentiated market. Here the main reason to merge with a lower quality firm is to soften competition.

The structure of the paper is as follows. Section 2 briefly introduces the paper setting. Section 3 describes in detail the various equilibrium market configurations, the *noncooperative* case,[18] the *fully collusive* case and all different cases of *partial collusion.* Section 4 characterize all equilibria of the alliance formation game. Section 5 briefly concludes. Most of the proofs are gathered in the Appendix.

2 The Model

As mentioned in the introduction, firms are assumed to play a three-stage game: (i) an *alliance formation* (sub)*game* (stage 1) assumed sequential; (ii) a *market* (sub)*game* including a *quality stage* (stage 2) and a *price stage* (stage 3). The next section is devoted to introduce the alliance formation game.

2.1 The Coalition Formation Game

Our game of coalition formation occurs at the first stage of the game. Following Bloch (1995, 1996) and Ray and Vohra (1999) we model the process of coalition formation as a *sequential* unanimity game in which, in an exogenous order, firms propose to their rivals an alliance to which they also belong.[19] The firm which follows in the given order among those receiving the proposal may, in turn, either accept or reject it. In case of acceptance, the turn passes to the subsequent firm in the proposed alliance according to the exogenous order and, if all proposed firms accept, the alliance is irrevocably formed and its members can decide cooperatively qualities and prices. If, alternatively, one of the firms rejects the offer, it becomes its turn to make a proposal and the game continues with the same logic until a given coalition structure of the firms is obtained. Differently from Bloch (1996) and Ray and Vohra (1999) and following Selten (1981) and Chatterjee *et al.* (1993) we let the allocation rule be part of the bargaining process.[20] Specifically, when it is its turn to offer, a firm proposes both an *alliance* and a *division* of the alliance profit among its members. A second difference between our game and Bloch's (1995, 1996) is that firms are *ex ante* heterogeneous, since when they enter the negotiation they are independently producing three vertically differentiated variants, denoted high (H), medium (M) and low (L). The third (and most drastic) distinction of our game with respect to Bloch's (1996) and Ray and Vohra's (1999) is that, in our case, the alliance formation game is a finite-horizon game in which every player can make *at most* one proposal at each period. This means that once a firm has proposed an alliance and has been rejected,

[18] Part of this analysis is also contained in Scarpa (1998).

[19] To be formed, an alliance needs the unanimous agreement of all participants (hence, *unanimity* game). As a result, a player can always remain independent by simply declaring the coalition only containing himself/herself.

[20] The same assumption is also made in Moldovanu's (1992).three-player coalition formation game.

it can enter an alliance in that period only if it is proposed by another firm and it accepts, remaining singleton otherwise. Our coalition formation game describes a limited negotiation process in which the order of play can become crucial for the final outcome. For this game, we look at the profiles of strategies which are subgame perfect Nash equilibria. We will discuss below the implications of all our assumptions.

Formally, our *alliance formation game* is a triple $G = \left(N, \{\Sigma_i, \Pi_i\}_{i\in N}\right)$, with player set $N = \{L, M, H\}$, strategy set Σ_i and payoff $\Pi_i(\sigma) : \Sigma \to \mathcal{R}$. For every firm (player) $i \in N$, a strategy $\sigma_i \in \Sigma_i$ defines the *actions* $a_i \in A_i$ available at each node (or information set $I_i \in \mathcal{I}_i$) in which it is its turn to play. In our game, an *action* for a firm $i \in N$ can either be an element of the set {Yes, No} coming in response to another firm's proposal p_j with $j \neq i$ or, in turn, a proposal $p_i = (S, \Pi)$ including an alliance $S \subset N$ to which i belongs to and a division $\Pi \in \mathcal{R}^{|S|}$ of the alliance joint profit Π_S, such that $\sum_{i\in S} \Pi_i = \Pi_S$. Thus, for a firm a *strategy* $\sigma_i \in \Sigma_i$ is a mapping from its information sets to the set of its feasible actions A_i available therein, namely, $f(I_i) : \mathcal{I}_i \to A_i$, where $A_i \subset \left(\left(2^N \backslash \{\varnothing\}, \mathcal{R}^{|S|}\right) \cup \{\text{Yes,No}\}\right)$, with the property that, in every period, a proposal $p_i \in \left(2^N \backslash \{\varnothing\}, \mathcal{R}^{|S|}\right)$ can be made by a firm only if, when it is its turn to play, there are no other players' proposals on the floor and the firm itself has not already made a proposal. That is, for every firm $i \in N$ the action available at every information set I_i^t is $a_i(I_i^t) = p_i$ if both $p_j(I_j^t) = \varnothing$ for $j \neq i$ and $p_i(\{I_i^\tau\}_{\tau<t}) = \varnothing$ for any previous information set, and $a_i(I_i^t) \in \{\text{Yes,No}\}$ otherwise. Note that every *strategy profile* $\sigma = (\sigma_H, \sigma_M, \sigma_L)$ of G induces an *outcome* $O(\sigma) = (C(\sigma), \Pi(\sigma))$, namely a coalition structure $C \in \mathcal{C}$ and a profile of payoffs $\Pi = (\Pi_H, \Pi_M, \Pi_L)$ assigned to firms in C. The payoff of every firm $\Pi_i(p(v)) \in \Pi$ is obtained by associating to each coalition structure C a price-quality equilibrium profile $p(v)$ which will be described in Section 3. As last step, we need to define a *subgame perfect Nash equilibrium* (SPE) of the alliance formation game and, accordingly, a notion of *stable coalition structure.*

Definition 1 *A subgame perfect Nash equilibrium (SPE) of the alliance formation game is a strategy profile σ such that, for every firm $i \in N$, for every proper subgame $G' \subset G$, and for every $\sigma_i \in \Sigma_i$, $\Pi_i\left(\sigma_i^*, \sigma_{-i}^*\right) \geq \Pi_k\left(\sigma_i, \sigma_{-i}^*\right)$.*

Definition 2 *A coalition structure $C \in \mathcal{C}$ (a partition of the N firms) is stable if and only if it is sustained by a SPE σ^* of the alliance formation game, namely, $C = C(\sigma^*)$.*

Once again, it is important to mention that the outcome of the game would be completely different if the firms were *ex ante* identical, i.e. they would no possess any pre-assigned quality level. In this case no merger would arise and all firms would remain independent producing three vertically differentiated goods, as at the starting point of our coalition formation game. So, at least in this respect, our game is consistent. We will discuss the implications of this point in the section devoted to the results of the alliance formation game (cfr. Section 4).

2.2 The Market

To keep things simple we adopt the well known specification of Mussa and Rosen's (1978) model of a vertically differentiated market. In particular, we assume an uncover market initially populated by three *firms*, $i = H, M, L$ selling three vertically differentiated goods, denoted v_H, v_M, v_L with $v_H > v_M > v_L$.[21] Also, for every i, $v_i \in [0, \bar{v}]$, where $\bar{v} \in \mathcal{R}_+$ is the highest quality level which is technologically feasible.[22] There exists a quality specific fixed cost, say $c_i = \frac{1}{2}v_i^2$. Consumers are indexed by θ which is uniformly distributed in unitary interval, with density function denoted $f(\theta)$.[23] The parameter θ captures consumers' willingness to pay (henceforth WTP) for quality: the higher θ, the higher the corresponding WTP. Each consumer can either buy one variant or not buying at all. Formally, consumers' utility can be written as

$$U(\theta) = \begin{cases} \theta v_i - p_i \text{ if she/he buys variant } i \\ 0 \text{ if she/he refrains from buying.} \end{cases}$$

From the above formulation, the consumer indifferent between buying variant i and not buying is:

$$\theta_i = \frac{p_i}{v_i},$$

while the consumer indifferent between buying variant i and $i+1$ is:[24]

$$\theta_i = \frac{p_i - p_{i+1}}{v_i - v_{i+1}}.$$

Of course, since qualities are endogenously defined at stage 1, the demand function for firms when producing v_H, v_M, and v_L can be written, respectively, as:

[21] Since the market is always *endogenously* uncovered in the case of a monopolist, the assumption of *uncovered market*, that some of the consumers refrain from buying goods, appears in our model as the most natural one (cfr. Section 3.3).

[22] We share this assumption on the quality interval with Wauthy (1996).

[23] Considering an interval $[0, m]$ simply leads to the addition of a parameter on which prices, quantities and quality levels depend linearly, with no substantial changes in the payoff structure (see, for istance, Scarpa 1998).

[24] We easily deduce the expression of the indifferent consumer from: $U_L(\theta) = U_M(\theta)$ and $U_M(\theta) = U_L(\theta)$

$$\begin{aligned}
D_H &= \int_{\theta_H}^{1} f(\theta)d\theta = (1-\theta_H)\,, \\
D_M &= \int_{\theta_M}^{\theta_H} f(\theta)d\theta = (\theta_H-\theta_M)\,, \\
D_L &= \int_{\theta_L}^{\theta_M} f(\theta)d\theta = (\theta_M-\theta_L)\,,
\end{aligned}$$

and, the corresponding profit functions are:

$$\Pi_H = \left(1-\frac{p_H-p_M}{v_H-v_M}\right)p_H - \frac{1}{2}v_H^2 \tag{1}$$

$$\Pi_M = \left(\frac{p_H-p_M}{v_H-v_M} - \frac{p_M-p_L}{v_M-v_L}\right)p_M - \frac{1}{2}v_M^2 \tag{2}$$

$$\Pi_L = \left(\frac{p_M-p_L}{v_M-v_L} - \frac{p_L}{v_L}\right)p_L - \frac{1}{2}v_L^2. \tag{3}$$

3 Equilibrium Analysis: Prices and Qualities

Since the whole game is solved backward, we can start characterizing the two final stages of the game. In particular, we firstly present the benchmark case of the analysis, that is the case in which all firms decide *noncooperatively* prices and qualities (*noncooperative equilibrium*); secondly, we turn to the case in which the grand coalition of firms has formed and they can jointly decide prices and qualities (*full collusion*); finally, we look at what happens when firms form intermediate coalitions (*partial mergers*). Since prices are usually more easily adjusted than qualities, it is reasonable to assume that firms define qualities at the second stage (quality stage) and set prices at the third one (price stage).

The game is solved by backward induction. So, we consider first the price stage under the assumption that qualities have been fixed. Then, we move to the quality stage.

3.1 Noncooperative equilibrium

In this section, we briefly summarize price and quantity equilibrium obtained when the three firms compete in the market against each other, while referring the interesting reader to Scarpa

(1998) for further details. We assume that at the first stage, no collusive agreement has been reached so that firms decide their quality and then their price in a fully noncooperative fashion.

3.1.1 Price stage

At the price stage, given that costs are fixed, we can study the noncooperative price behaviour of the three firms by simply characterizing their revenue functions in the quality spectrum: (i) top quality H, (ii) intermediate quality M and (iii) bottom quality L.

Thus differentiating (1), (2) and (3) w.r.t $p_{H,}$ p_M and $p_{L,}$ respectively, we can easily derive all firms' best-replies as:[25]

$$p_H(p_M) = \frac{1}{2}\left(p_M + (v_H - v_M)\right), \tag{4}$$

$$p_M(p_H, p_L) = \frac{1}{2}\frac{p_H(v_M - v_L) + p_L\,(v_H - v_M)}{v_H - v_L} \tag{5}$$

and

$$p_L(p_M) = \frac{1}{2} p_M \frac{v_L}{v_M}. \tag{6}$$

As stressed by Scarpa (1996), the best-reply function of a firm depends on the quality and price of the firm itself and of its neighboring rivals, while products that are farther away in the product space do not play any role. From the above, equilibrium prices p_i at the price stage are obtained as:

$$p_H^*(v_H, v_M, v_L) = \frac{1}{2}\frac{(v_H - v_M)\,(4v_M v_H - v_L v_H - 3v_L v_M)}{\left(4v_M v_H - v_L v_H - 2v_L v_M - v_M^2\right)} \tag{7}$$

$$p_M^*(v_H, v_M, v_L) = \frac{(v_H - v_M)\,(v_M - v_L)\,v_M}{\left(4v_M v_H - v_L v_H - 2v_L v_M - v_M^2\right)} \tag{8}$$

$$p_L^*(v_H, v_M, v_L) = \frac{1}{2}\frac{(v_H - v_M)\,(v_M - v_L)\,v_L}{\left(4v_H v_M - v_H v_L - 2v_L v_M - v_M^2\right)}, \tag{9}$$

with corresponding profits

$$\Pi_H(p^*(v_H, v_M, v_L)) = \frac{1}{4}\frac{(v_H - v_M)\,(v_H v_L - 4v_H v_M + 3v_L v_M)^2}{\left(v_M^2 + v_L v_H - 4v_M v_H + 2v_L v_M\right)^2} - \frac{1}{2}v_H^2 \tag{10}$$

$$\Pi_M(p^*(v_H, v_M, v_L)) = v_M^2\frac{(v_H - v_M)\,(v_M - v_L)\,(v_H - v_L)}{\left(v_M^2 + v_L v_H - 4v_M v_H + 2v_L v_M\right)^2} - \frac{1}{2}v_M^2 \tag{11}$$

[25] Firms' profit functions (1)-(3) are strictly concave in their respective prices.

$$\Pi_L(p^*(v_H,v_M,v_L)) = \frac{1}{4}\frac{v_L\left(v_H-v_M\right)^2\left(v_M-v_L\right)v_M}{\left(v_M^2+v_Lv_H-v_M4v_H+2v_Lv_M\right)^2}-\frac{1}{2}v_L^2, \tag{12}$$

where $p^* = (p_H^*, p_M^*, p_L^*)$ denote the Nash equilibrium prices of firms obtained at the price stage (stage 3). Let us now consider the choice of qualities by firms.

3.1.2 Quality stage

In order to characterize the Nash equilibrium quality choices occurring at the second stage, it suffices to maximize payoff function (10), (11) and (12) w.r.t. quality v_H, v_M, v_L, respectively, thereby getting:[26]

$$v_H^* = 0.2526, \quad v_M^* = 0.0497, \quad v_L^* = 0.0095. \tag{13}$$

Moreover, the corresponding subgame perfect Nash equilibrium prices $p^*(v^*)$ and profits $\Pi_i(p^*(v^*))$, for $v^* = (v_H^*, v_M^*, v_L^*)$, are immediately obtained as:

$$p_H^*(v^*) = 0.10601, \quad p_M^*(v^*) = 0.00912, \quad p_L^*(v^*) = 0.0008, \tag{14}$$

and

$$\Pi_H\left(p_H^*(v^*)\right) = 0.02348, \quad \Pi_M\left(p_H^*(v^*)\right) = 0.00124, \quad \Pi_L\left(p_H^*(v^*)\right) = 0.00005. \tag{15}$$

3.2 Mergers

By definition a collusive binding agreement can either involve the set of all firms, denoted $N = \{H, M, L\}$ (*grand coalition*) or, alternatively, any other nonempty subset $S \subset N$ of them, with $S \in \mathcal{N}$, where $\mathcal{N} = 2^N \backslash \varnothing$ is the set of all nonempty coalitions of the N firms, in this case simply:

$$\mathcal{N} = \left(\{H\}, \{M\}, \{L\}, \{H, M\}, \{H, L\}, \{M, L\}, \{H, M, L\}\right).$$

Thus, while if the firms form the grand coalition they commit irrevocably to jointly set qualities and prices so as to maximize the sum of all firms' profits (full cooperation), in the second scenario (partial collusion), a smaller subset of firms jointly decide qualities and prices, again irrevocably, so as to maximize the sum of their own profits, while competing against a rival(s), if any. In general, we can describe any type of (full or partial) firm collusion or noncooperative

[26] It can be easily checked that all firm second-stage profit functions are strictly concave in their own qualities. In what follows,for ease of exposition, we truncate our numerical results to five decimals.

behaviour by simply indicating the *coalition structure* $C = (S_1, S_2, ..., S_m)$ representing a collection of firms in alliances having null intersection and summing up to N, with $m \leq n$. The set $\mathcal{C}$ of all coalition structures C that can be formed by the three firms is, therefore, simply given by:

$$\mathcal{C} = ((\{H\}, \{M\}, \{L\}), (\{H, M\}, \{L\}), (\{H\}, \{M, L\}), (\{H, L\}, \{M\}), (\{H, M, L\})).$$

The game is solved backward so that we first analyse the price and then the quality stage under the assumption that either the grand coalition or any other intermediate coalition structure have formed at the first stage. After the full characterization of market equilibrium in any of these cases, we wonder which type of collusion (if any) will prevail in equilibrium.

3.3 Full Collusive Agreement

Let us assume that, at the first stage, firms have formed the grand coalition. In the following, we consider the price and then the quality decision.

3.3.1 Price stage

When the grand coalition $\{N\}$ forms, at the price stage each firm maximizes the sum of all firms' payoffs (1)-(3) for arbitrary levels of the quality chosen at the second stage. Thus, by the price maximization of the joint payoff of the grand coalition, the firm *fully-collusive optimal replies* p_L^c, p_M^c and p_H^c are obtained as

$$p_H^c(p_M) = p_M + \frac{1}{2}(v_H - v_M), \tag{16}$$

$$p_M^c(p_H, p_L) = \frac{p_H(v_M - v_L) + p_L(v_H - v_M)}{v_H - v_L}, \tag{17}$$

and

$$p_L^c(p_M) = p_M \frac{v_L}{v_M}. \tag{18}$$

By solving the system (16)-(18), a fully collusive optimal prices profile $p^{\{N\}}(v)$, for $v = (v_H, v_M, v_L)$, is obtained as:

$$p_H^{\{N\}}(v_H) = \tfrac{1}{2}v_H, \quad p_M^{\{N\}}(v_M) = \tfrac{1}{2}v_M, \quad p_L^{\{N\}}(v_L) = \tfrac{1}{2}v_L. \tag{19}$$

Given the above prices, the market share of any firm at the price stage, turns out to be:

$$D_H\left(p^{\{N\}}(v)\right)=\tfrac{1}{2},\quad D_M\left(p^{\{N\}}(v)\right)=0,\quad D_L\left(p^{\{N\}}(v)\right)=0. \tag{20}$$

It is immediate to see that, at the prices selected by the grand coalition, consumers are willing to buy only the top quality variant v_H, the demand for the intermediate and bottom variants being nil. Accordingly, the profit accruing to the grand coalition at the price stage are

$$\Pi^{\{N\}}(p^{\{N\}}(v))=\frac{1}{4}v_H-\frac{1}{2}v_H^2.$$

3.3.2 Quality stage

In order to fully characterize the behaviour of the grand coalition, we can easily find its optimal quality, given by $v_H^{\{N\}}=0.25$, so that profit obtains as:

$$\Pi^{\{N\}}\left(p^{\{N\}}(v^{\{N\}})\right)=0.03125. \tag{21}$$

The logic underlying this finding has been well described by Mussa and Rosen (1978): "Serving customers who place smaller valuations on quality creates negative externalities for the monopolist that limit possibilities for capturing consumer surplus from those who do value quality highly. (p.306)".[27] Rather interestingly, this finding does not depend on the initial assumption on the market coverage. Indeed, even if one would develop the above analysis under the alternative assumption that the market is covered, still at the price-quality equilibrium the grand coalition would offer only the top-quality, while serving half of the market.

Finally, it is worth remarking that, under a full collusive behaviour, the level of prices is, for all firms, always higher than under Nash equilibrium. This can be easily checked by the following simple reasoning: (i) Start with the Nash equilibrium price of firm H and let the remaining firms responding using their optimal collusive replies (16)-(17). (ii) Since comparing (4)-(5) with (16)-(17) it turns out that optimal cooperative replies are twice as sloped as the noncooperative best-replies and both upward sloping, as effect of (i) all $N\backslash\{H\}$ firms will increase their prices. (iii) Let now also firm H respond cooperatively using its cooperative

[27] Further discussion on this result are provided by Gabszewicz *et al.* (1982) and by Gabszewicz and Wauthy (2002) under the assumption of zero quality costs. Along the same research line, Acharia (1998) shows that when the cost for quality improvement is not too convex, a multiproduct monopolist offers only the top variant among the ones which *a priori* can be sold in the market. Indeed, if the costs are not so significant, offering the top variant only allows firms to escape from the cannibalization effect which would take place if the more than one variant would be saled at equilibrium. Finally, Lambertini (1997) analyses the Mussa-Rosen's model with quality specific variable costs under the alternative assumption of full market coverage and partial market coverage.

optimal reply (18) and, as a result, it will increase its price. (iv) By continuing the adjustment process of all firms along their collusive optimal replies, since these are all contraction mappings (due to the inequality $v_H > v_M > v_L$), a new price profile $p^{\{N\}}$ will be reached with the property that $p^{\{N\}} \gg p^*$, where p^* is the corresponding profile of noncooperative Nash equilibrium prices.

3.4 Partial mergers

In this section we analyse all market configurations arising when partial mergers take place among firms. We characterize three different market scenarios occurring, in turn, under the following coalition structures: (i) $C_{H,ML} = (\{H\}, \{M, L\})$, (ii) $C_{HL,M} = (\{H, L\}, \{M\})$ and, finally (iii) $C_{HM,L} = (\{H, M\}, \{L\})$.

Before computing in detail prices and qualities of firms under partial mergers, note that from (1)-(3) when either the bottom quality firm or the top quality firm collude in prices with their *direct* competitor, i.e. the intermediate quality firm, they just behave as in the fully collusive case, with optimal replies given by (16) and (18), respectively. On the other hand, when bottom and top quality firms form a coalition, due to the structure of the vertical differentiation model, they set prices exactly as in the noncooperative case, with optimal replies given by (4) and (6). Thus, under a partial merger only the price behaviour of the firm producing the intermediate quality variant v_M (henceforth denoted *intermediate firm*) varies according on whether it is allied either with its left (lower quality) or with its right (higher quality) competitor. In particular, when the intermediate firm coordinates its price with its left competitor, its first-order condition implies

$$\frac{\partial \Pi_M}{\partial p_M} + \frac{\partial \Pi_L}{\partial p_M} = \frac{2p_L - 2p_M}{v_M - v_L} + \frac{p_H - 2p_M}{v_H - v_M} = 0,$$

whereas, when it coordinate its price with its right-competitor, it sets p_M such that

$$\frac{\partial \Pi_M}{\partial p_M} + \frac{\partial \Pi_H}{\partial p_M} = \frac{p_L - 2p_M}{v_M - v_L} + \frac{2p_H - 2p_M}{v_H - v_M} = 0.$$

As a result, the optimal reply of the *intermediate firm*, $p_M^{lc}(p_L, p_H)$ in the left-partial (resp. $p_M^{rc}(p_L, p_H)$ in the right-partial) merger writes as

$$p_M^{lc}(p_L, p_H) = \frac{p_L(v_H - v_M) + \frac{1}{2}p_H(v_M - v_L)}{(v_H - v_L)} \tag{22}$$

$$\text{(resp. } p_M^{rc}(p_L,p_H) = \frac{\frac{1}{2}p_L(v_H - v_M) + p_H(v_M - v_L)}{(v_H - v_L)}\text{).} \tag{23}$$

3.4.1 Partial merger between the intermediate and the bottom quality firm

We consider initially the scenario where at the first stage a merger has occurred between firm M and firm L, with firm H playing as singleton against them. We assume, as a start, that variants v_M and v_L are produced by the colluding firms M and L, respectively. Firm H, outside the collusive agreement, produces the high quality variant v_H. We need to check whether this quality assignment remains optimal at the equilibrium.

Price stage As coalition structure $C_{H,ML} = (\{H\}, \{M,L\})$ forms, prices p_H, p_M and p_L set by firms 1, 2 and 3 at the price stage can be obtained through the maximization of the following objective functions

$$\begin{aligned}
\Pi_H &= \left(1 - \frac{p_H - p_M}{v_H - v_M}\right) p_H \\
\Pi_M + \Pi_L &= \left(\frac{p_H - p_M}{v_H - v_M} - \frac{p_M - p_L}{v_M - v_L}\right) p_M + \left(\frac{p_M - p_L}{v_M - v_L} - \frac{p_L}{v_L}\right) p_L.
\end{aligned}$$

Using (4), (18), and (22), the following optimal replies are obtained, respectively as,

$$\begin{aligned}
p_H^{pc}(p_M) &= \frac{1}{2}\left(p_M + (v_H - v_M)\right) \\
p_M^{pc}(p_H, p_H) &= \frac{p_L(v_H - v_M) + \frac{1}{2}p_H(v_M - v_L)}{(v_H - v_L)} \\
p_L^{pc}(p_M) &= \frac{v_L}{v_M} p_M.
\end{aligned}$$

Therefore, the following equilibrium prices are set by firms:

$$\begin{aligned}
p_H^{(\{H\},\{M,L\})}(v) &= \frac{2v_H\left(v_H - v_M\right)}{4v_H - v_M}, \\
p_M^{(\{H\},\{M,L\})}(v) &= \frac{v_M\left(v_H - v_M\right)}{4v_H - v_M}, \\
p_L^{(\{H\},\{M,L\})}(v) &= \frac{v_L\left(v_H - v_M\right)}{4v_H - v_M},
\end{aligned}$$

where $v = (v_H, v_M, v_L)$, with corresponding profits:

$$\begin{aligned}
\Pi_H(p^{(\{H\},\{M,L\})}(v)) &= 4\frac{v_H^2\,(v_H - v_M)}{(4v_H - v_M)^2} - \frac{1}{2}v_H^2, \\
\Pi_M(p^{(\{H\},\{M,L\})}(v)) &= \frac{v_H\,(v_H - v_M)\,v_M}{(4v_H - v_M)^2} - \frac{1}{2}v_M^2, \\
\Pi_L(p^{(\{H\},\{M,L\})}(v)) &= 0.
\end{aligned}$$

Note that in this case the price of the low quality variant is set so high that no consumer is willing to buy this variant and, therefore, $D_L^{\{M,L\}} = 0$. Thus, firm L ceases to be active in the market: selling the bottom-quality variant would determine a cannibalization effect within the coalition since variant v_L would be in competition only with the adjacent product v_M. Of course, it still plays a role in the coalition as the decision to stop producing benefits the coalition as a whole.[28]

Quality stage Then, moving to the quality stage and using the best reply functions, it is immediate to see that top variant and intermediate variant are, respectively,

$$v_H^{(\{H\},\{M,L\})} = 0.25331, \quad v_M^{(\{H\},\{M,L\})} = 0.04823. \tag{24}$$

Given the above values, we can easily find the equilibrium prices as

$$p_H^{(\{H\},\{M,L\})} = 0.10766, \quad p_M^{(\{H\},\{M,L\})} = 0.01025, \tag{25}$$

and the corresponding equilibrium profits:

$$\Pi_H^{(\{H\},\{M,L\})} = 0.02443, \quad \Pi_{\{M,L\}}^{(\{H\},\{M,L\})} = 0.00152. \tag{26}$$

It is easy to see that, at equilibrium, firm H continues to produce the top quality while coalition $\{M, L\}$ sells the intermediate quality only. Note also that the above findings coincide with those emerging, for instance, in Motta (1992) where only two firms compete in a traditional duopoly setting. Indeed, coalition $\{M, L\}$ behaves like a multiproduct firm: since it withdraws from the market one of its variant, *it is as if only* two single-product firms would be active in the market, each of them setting noncooperatively their quality and price. We resume these results in the next proposition.

[28] Its role will be clarified at the alliance formation stage.

Proposition 1 *When the intermediate and bottom quality firm merge against the top quality firm (playing as singleton), namely under coalition structure $C_{H,ML} = (\{H\}, \{M, L\})$, at the price stage colluding firms set a price so high for the low quality variant that no consumer is willing to buy it. Thus, at the price-stage only two variants are marketed and the equilibrium configuration in terms of quality and price coincides with that occurring in a traditional duopoly setting.*

Proof. It directly follows by expressions (24) and (25) and by their comparison with results obtained, for instance, in Motta (1992). ■

Finally, it is worth remarking that this merger benefits both the merging firms and the rival H which plays as a singleton. Indeed, not only the lowest quality variant is dropped out from the market, but also the gap between variants in the market is now larger than the one emerging in the noncooperative setting with three independent firms: under partial collusion, the optimal quality of the intermediate variant is lower (and the top quality higher) than the corresponding levels set noncooperatively. This relaxes price competition between firms, thereby increasing the resulting profits.

3.4.2 Partial merger between the top and the bottom quality firm

Let us move now to the case in which at the first stage firms H and L have merged, whereas firm M plays as singleton. As usual, we have to verify whether this quality assignment holds at the SPE.

Price stage To obtain the optimal prices decided by the merging firms H and L and by firm M alone, we need to take into account the fact that colluding firms H and L maximize the sum of their profits $\Pi_H + \Pi_L$, while M is only concerned with its own profit function Π_M. However, since firm H and L are not direct price competitor and are separated by firm M, at the price stage their equilibrium prices and profits coincides with those obtained in the noncooperative case (cfr. Section 3.1).

Quality stage We can now move to the quality stage. In order to identify the optimal qualities, notice that the revenue of coalition $\{H, L\}$ is monotonically decreasing in v_L, as

$$\frac{\partial \left(\Pi_H^{(\{H,L\},\{M\})} + \Pi_L^{(\{H,L\},\{M\})}\right)}{\partial v_L} = \frac{1}{4} v_M^2 \frac{(v_H - v_M)^2 \left(v_M^2 + v_H v_L + 20 v_M v_H - 22 v_M v_L\right)}{\left(v_M^2 + v_H v_L - 4 v_H v_M + 2 v_M v_L\right)^3} < 0.$$

Accordingly, at the quality stage for colluding firms H and L it is profitable to set $v_L = 0$, whatever the quality chosen by the intermediate rival M. The economic intuition underlying this finding is that the low quality variant and the intermediate variant are strategic complements. So, if the merging firm increases v_L, the independent firm producing v_M would increase its quality variant, thereby making tighter the competition with the top quality producer.[29] Since the profit loss suffered by firm L when decreasing its quality level is lower than the gain obtained by firm H (since the competition between v_M and v_H relaxes), the merging firms will optimally set $v_L = 0$ restricting their production only to the high quality variant v_H.

As a result, from the first-order conditions obtained maximizing, in turn, the profit of coalition $\{H, L\}$ w.r.t to v_H and the profit of rival M w.r.t v_M, namely

$$\frac{\partial\left(\Pi_H + \Pi_L\right)}{\partial v_H} = \frac{\left(v_H v_M^3 - 64v_H^4 + 48v_H^3 v_M + 16v_H^3 - 12v_H^2 v_M^2 + 8v_H v_M^2 - 12v_H^2 v_M\right)}{\left(4v_H - v_M\right)^3} = 0$$
$$\frac{\partial \Pi_M}{\partial v_M} = \frac{\left(v_M^4 - 12v_H v_M^3 - 64v_H^3 v_M + 4v_H^3 + 48v_H^2 v_M^2 - 7v_H^2 v_M\right)}{\left(4v_H - v_M\right)^3} = 0$$

given that, at equilibrium $v_L^{(\{H,L\},\{M\})} = 0$, we obtain the following equilibrium qualities, prices and profits under $C_{HL,M} = (\{H, L\}, \{M\})$:

$$v_H^{(\{H,L\},\{M\})} = 0.25331, \quad v_M^{(\{H,L\},\{M\})} = 0.04823, \tag{27}$$

$$p_H^{(\{H,L\},\{M\})} = 0.10766, \quad p_M^{(\{H,L\},\{M\})} = 0.01025, \tag{28}$$

and

$$\Pi_{\{H,L\}}^{(\{H,L\},\{M\})} = 0.02443, \quad \Pi_M^{(\{H,L\},\{M\})} = 0.00152. \tag{29}$$

Proposition 2 *When the top and the bottom quality firm merge whereas the intermediate firm remains singleton, namely under coalition structure $C_{HL,M} = (\{H, L\}, \{M\})$, at the quality stage the low quality variant is set equal to zero. Prices and qualities offered in equilibrium coincide with those observed under $C_{H,ML} = (\{H\}, \{M, L\})$.*

Proof. It directly follows by comparing expressions (24) and (25) with (27) and (28). ■

[29] See also Scarpa (1998), p. 669 for the same effect in a three-firm noncooperative setting.

It is worth noting that from a market structure viewpoint, the formation of coalition structures $C_{H,ML}$ and $C_{HL,M}$ are equivalent, as both of them entail a duopoly structure with the same quality gap between variants. Still, the *rationale* underlying the equilibrium configuration in coalition $C_{H,ML}$ cannot be extended to $C_{HL,M}$. In the former case, namely when the intermediate and bottom quality firm compete against the top quality one, the colluding firms decide to set a price so high for the bottom variant that no consumer is willing to buy it, whatever its quality. So, this finding would be observed even if firms would unable to define endogenously the quality of their products. This is the case, for instance, in a collusive agreement between an intermediate and a bottom quality producer, where firms have no reason to maintain a fighting brand. Variant v_L is adjacent only to variant v_M and, if kept in the market, would reap consumers only to the other colluding player without playing any role in the competition against the top quality firm. Rather, in the latter scenario top and bottom quality firms can decide to reduce the bottom quality to such an extent that the corresponding market share for this variant turns out to be nil. When the coalition decides to withdraw variant v_L from the market, it takes into account two different effects. On one hand, since the low quality variant is adjacent to the intermediate variant, *ceteris paribus*, increasing its quality can enable the coalition to gain market share from the competitor producing variant v_M and, thus, to benefit from the higher profits obtained by the bottom quality firm. On other hand, as these two variants v_M and v_L are strategic complements, the higher quality of the bottom quality variant boosts the quality of the intermediate variant. The latter variant is, in turn, in direct competition with the top variant: since the lower the quality gap, the fiercer price competition between players, the higher the intermediate quality, the lower, *ceteris paribus*, will be the profit accruing to the top quality firm. Since the loss for this player when the low quality is produced is higher than the gain obtained by the bottom producer, coalition $\{H, L\}$ will stop producing this variant.

3.4.3 Partial merger between the top and the intermediate quality firm

We finally characterize the equilibrium configuration when the top and the intermediate quality firm decide to merge, with the bottom quality rival playing as singleton.

Price stage At the price stage, firms top and intermediate quality firms maximize the sum of their own profits, namely $\Pi_H + \Pi_M$, whereas the bottom quality firm is playing independently. Using (6), (16) and (23), the optimal replies under coalition structure $C_{HM,L} = (\{H, M\}, \{L\})$ are obtained, respectively, as

$$
\begin{aligned}
p_H^{pc}(p_M) &= p_M + \frac{1}{2}(v_H - v_M) \\
p_M^{pc}(p_L, p_H) &= \frac{\frac{1}{2}p_L(v_H - v_M) + p_H(v_M - v_L)}{(v_H - v_L)} \\
p_L^{pc}(p_M) &= \frac{1}{2}\frac{v_L}{v_M}p_M.
\end{aligned}
$$

Thus, the last stage equilibrium prices can be easily found as:

$$
\begin{aligned}
p_H^{((\{H,M\},\{L\}))}(v_H, v_M, v_L) &= \frac{(4v_H v_M - v_H v_L - 3v_L v_M)}{2\,(4v_M - v_L)}, \\
p_M^{((\{H,M\},\{L\}))}(v_H, v_M, v_L) &= \frac{2v_M\,(v_M - v_L)}{4v_M - v_L}, \\
p_L^{((\{H,M\},\{L\}))}(v_H, v_M, v_L) &= \frac{v_L\,(v_M - v_L)}{4v_M - v_L},
\end{aligned}
$$

with corresponding profits,

$$
\begin{aligned}
\Pi_H^{((\{H,M\},\{L\}))} &= \frac{1}{4}\frac{(4v_H v_M - v_H v_L - 3v_L v_M)}{(4v_M - v_L)} - \frac{1}{2}v_H^2, \\
\Pi_M^{((\{H,M\},\{L\}))} &= \frac{v_L v_M\,(v_M - v_L)}{(4v_M - v_L)^2} - \frac{1}{2}v_M^2, \\
\Pi_L^{((\{H,M\},\{L\}))} &= \frac{v_L v_M\,(v_M - v_L)}{(4v_M - v_L)^2} - \frac{1}{2}v_L^2.
\end{aligned}
$$

Quality stage We saw above that, at the price stage, when the coalition structure $C_{12,3} = (\{1,2\},\{3\})$ forms, no variant is withdrawn from the market. Still, at the quality stage, it can be proved that a case of *quality reversal* occurs. This is done in the next proposition.

Proposition 3 *In order to escape from the cannibalization taking place between adjacent variants, merging top and intermediate quality firms enhance maximal differentiation between their products by putting the intermediate quality at the bottom of the quality ladder. The rival L "leapfrogs" the intermediate quality firm, thereby producing a variant which lies now in the middle of the quality ladder.*

Proof. See the Appendix. ■

Notice that now, profit $\Pi_L^{((\{H,M\},\{L\}))}$ coincides with that obtained by firm M when producing variant v_M in coalition structure $C_{H,ML} = (\{H\},\{M,L\})$, namely $\Pi_M^{((\{H\},\{M,L\}))}$. Thus, the variant produced by the merging firms coincide now with those produced under coalition structure $C_{H,ML} = (\{H\}, \{M, L\})$ where intermediate and bottom quality firms were colluding. Moreover, in $C_{HM,L} = ((\{H, M\}, \{L\}))$ the independent firm produces now the variant that in the the previous scenarios was sold by the intermediate quality firm. In line with the analysis performed in the previous case, the optimal variants are immediately obtained here as:

$$v_H^{(\{H,M\},\{L\})} = 0.25331, \quad v_M^{(\{H,M\},\{L\})} = 0 \quad v_L^{(\{H,M\},\{L\})} = 0.04823, \tag{30}$$

while the equilibrium profits write as:

$$\begin{aligned} \Pi_{\{H,M\}}^{(\{H,M\},\{L\})} &= 0.02443, \\ \Pi_L^{(\{H,M\},\{L\})} &= 0.00152. \end{aligned} \tag{31}$$

Thus, one can state the following proposition.

Proposition 4 *When the top and intermediate quality firms merge whereas the bottom quality firm remains as singleton, namely under coalition structure $C_{HM,L} = ((\{H, M\}, \{L\}))$, at the quality stage the firm initially producing the bottom quality firm leapfrogs the adjacent rival whose variant is no longer on sale in the market. The obtained qualities coincide with those occurring under the alternative coalition structures $C_{H,ML} = ((\{H\}, \{M, L\}))$ and $C_{HL,M} = (\{H, L\}, \{M\})$.*

Proof. This follows directly by Proposition 3 and by the comparison of (27), (24) and (30). ■

For ease of exposition, we summarize in the following table the payoffs accruing to each firm or coalition in each feasible coalition structure.

$(\{H\}, \{M\}, \{L\})$	$\Pi_H^* = 0.02348$	$\Pi_M^* = 0.00124$	$\Pi_L^* = 0.00005$
$\{N\}$	$\Pi_{(\{H,M,L\})}^{\{N\}} = 0.03125$		
$(\{H\}, \{M, L\})$	$\Pi_H^{(\{H\},\{M,L\})} = 0.02443$	$\Pi_{\{M,L\}}^{(\{H\},\{M,L\})} = 0.00152$	
$(\{H, L\}, \{M\})$	$\Pi_{\{H,L\}}^{(\{H,L\},\{M\})} = 0.02443$	$\Pi_M^{(\{H,L\},\{M\})} = 0.00152$	
$(\{H, M\}, \{L\})$	$\Pi_{\{H,M\}}^{(\{H,M\},\{L\})} = 0.02443$	$\Pi_L^{(\{H,M\},\{L\})} = 0.00152$	

Table 1 - Firm payoffs in every coalition structure.

It is worth remarking that the market structure (duopoly) arising in all *partial mergers* does not vary with the coalition structure induced by the firms. Still, the profits accruing to firms depend on the coalitions to (against) which they belong (compete).

4 Equilibrium Analysis: Alliance Structures

4.1 The profitability and cooperative stability of the grand coalition

Table 1 shows that, in terms of total payoffs, the grand coalition of firms, i.e. the merger giving rise to the whole market monopoly is, not surprisingly, the most profitable coalition structure obtainable in the vertical differentiated market. Before starting the analysis of the stability of coalition structures in the sequential game, we may wonder whether the grand coalition is, in general, robust against coalitional deviations. More specifically, we wonder whether there are feasible allocations of the monopoly profit belonging to the *core* of the transferable utility game associated to our simple model. An accurate analysis shows that the answer to this question crucially depends on the initial assumptions of the game. In particular, if the players (firms) are assumed *ex ante* identical and (contrarily to our case) there is not any pre-assigned level of quality among them when the negotiation starts, the *core* of the corresponding cooperative game in partition function form, turns out to be *empty.* Even worse than this, no other intermediate coalition structure is stable even against individual deviations.

4.1.1 The core is empty with ex ante identical firms

The emptiness of the *core* with *ex ante* identical firms can be easily shown as follows: it is natural to think that three *ex ante* identical firms $i = 1, 2, 3$ would equally divide the monopoly profit obtained producing only the top quality good, thus obtaining $\Pi_i = \frac{\Pi^{\{N\}}}{3} = \frac{0.03125}{3} = 0.0104$. In this case, at least one of them could decide to break the agreement and start producing alone variant v_H, thus obtaining $\Pi_H^{(\{H\},\{M,L\})} = 0.02443$ if the remaining firms jointly produce in response the intermediate quality variant (and a duopoly forms);[30] alternatively, if the remaining firms split up into singletons and a triopoly forms, the firm leaving the merger would obtain $\Pi_H^{(\{H\},\{M\},\{L\})} = 0.02348$. In both cases the deviation is profitable and the efficient equally-split monopoly payoff is not sufficient to prevent that at least one of the firms breaks the cooperative agreement to become the top-quality producer. Analogously, all partial mergers are *unstable.* In fact, inside every partial merger $\{i, j\}$ jointly selling either H or M against an independent rival, at least one of the two firms could always

[30] Inside the monopoly at least one of the three firms are producing the top quality good. Therefore, this firm could decide to produce it alone. The core is rather silent on the behaviour of players inside or outside the cooperative agreement. In line with the literature on endogenous coalition formation, we presume here a Nash behaviour for all coalitions after the breakdown of the grand coalition. Note however that, if the core is empty under a Nash behaviour, it must be so also under minmax or maxmin behaviour of remaining players after coalition deviations from the grand coalition.

try to break the agreement and selling, independently, either H or M. Thus, since an *ex ante* identical firm i in a partial merger receives either $\Pi_{\{i,j\}}^{(\{i,j\}\{h\})}/2 = 0.0122$ when the merger produces H or $\Pi_{\{i,j\}}^{(\{h\},\{ij\})}/2 = 0.00076$ when it produces M, these payoffs are largely dominated, respectively, by $\Pi_{H}^{(\{i\},\{j\},\{h\})} = 0.02348$ and $\Pi_{M}^{(\{i\},\{j\},\{h\})} = 0.00124$. The same result would arise in a sequential bargaining protocol, since the first firm along the sequence would always announce its willingness to remain singleton to produce v_H, the second to remain singleton to produce v_M and the third, similarly, would remain alone producing v_L. As a result, in a vertically differentiated market in which firms are *ex ante* identical and free to select their qualities and prices in a two-stage market game, any negotiation would always yields a coalition structure in which all firms remain independent. This outcome, by the way, it is the starting point of our coalition formation game. Before any merger can take place, firms are characterized by pre-assigned quality levels, due to their previous history: say, they are either Volkswagen or Skoda. However, as in our model, once entered an alliance, they can jointly adjust their quality-price combinations.

4.1.2 The core is nonempty with ex ante heterogeneous firms

If firms are assumed, as in our game, *ex ante* heterogeneous, since at the beginning they produce noncooperatively three different variants, it can be proved that the core is *nonempty*. This is because now the monopoly profit can be allocated asymmetrically according to the initial identities (and outside options) of the players, i.e., H, M and L. Formally, we can associate to the vertically differentiated market a *partition function game* $\rho = (N, v(S, C(S)))$, where N is the set of firms and $v(S, C(S)) \in \mathcal{R}$ is the worth associated to every coalition of firms $S \subset N$ *embedded* in a given coalition structure $C \in \mathcal{C}$ of which S is part. In our model, when an alliance $S \subset N$ forms, its maximal payoff obtains when the remaining firms stick together in the complementary coalition $\{N \backslash S\}$.[31] Therefore, if the core of the partition function game ρ exists when every $S \subset N$ is embedded in $C = (\{S\}, \{N \backslash S\})$, it will *a fortiori* exist in any other coalition structure containing S. Let us formally state this result.

Definition 3 *The core of the partition function game $\rho = (N, v(S, C))$ consists of all efficient profit allocations $\Pi \in \mathcal{R}_{+}^{|N|}$ such that $\sum_{k \in S} \Pi_i \geq v(S, C(S))$ for all $S \subset N$ and for all $C(S)$ in*

[31] With only three firms, the behaviour outside a coalition S matters only for $S = \{i\}$, i.e. when an individual firm i is competing with the remaining firms in $N \backslash \{i\}$, which, in turn, can either stay together, or paly as singletons. Moreover, from Section 3 we know that whenever two firms form a coalition they eliminate one of the variant either at the quality or at the price stage. Therefore, a firm playing as singleton prefers that its competitiors merge rather than compete independently in the market: in game-theoretic terms there are *positive coalition externalities* (see, for instance, Yi, 1997 and 2003).

which S can be embedded.

Thus, we can prove the following result.

Proposition 5 *In the three-firm vertically differentiated market with ex ante heterogeneous firms H, M, L and endogenous qualities and prices, the core of the corresponding partition function game $\rho = (N, v(S, C))$ is nonempty.*

Proof. See the Appendix. ∎

The above result simply says that in a vertical differentiated market with three firms initially competing noncooperatively in prices and qualities, there would always be room for *cooperative* agreements between them. This is because, starting from their initial outside options (in turn, Π_H, Π_M and Π_L), there exist divisions of the monopoly payoff that cannot be improved upon by any coalition of firms, which includes their departure as singletons. The grand coalition of firms would also be the outcome of an infinite-horizon sequential coalition formation game with *ex ante* heterogeneous players, where for a sufficiently high discount rate there would always be room for cooperation.[32] However, as we show in the next section, if the bargaining process is sequential and in each period the firms possess only a *finite* set of possibilities to propose coalitions and divisions of the joint profit to the rivals and if the game possesses a finite-horizon, the grand coalition cannot be enforced in equilibrium.[33] In particular, we show that only *intermediate coalition structures* (partial mergers) can be sustained as subgame perfect equilibria of the alliance formation game. The study of *which*, among all feasible partial mergers, are more likely to ariese in the three-firm negotiation, it is the purpose of the next section.

4.2 Stable Alliances Structures

In this section we characterize the equilibria of the sequential game of alliance formation. Since this game is sensitive to the identity of the initial player, we consider, in turn, the outcomes obtained by the game when either firm H, M and L starts the bargaining process. Let us first

[32] In Bloch (1996) it is proved that if a coalition structure is core-stable it can also be sustained as a subgame perfect equilibria of the infinite-horizon sequential game of coalition formation (with a fixed allocation rule).

[33] In the real world there is also an additional, reason why the grand coalition is unfeasible: anti-trust authorities would always prevent a monopoly to form. This somehow justifies the great deal of attention we devote to the stability of partial agreements among firms.

consider the case in which the firm producing the top-quality good (firm H) is the initiator of the coalition formation game.

It can be proved the following:

Proposition 6 *When firm H is the initiator of the sequential alliance formation game, the only stable coalition structure is $C_{H,ML} = (\{H\}, \{M, L\})$, where firm H continues to produce variant v_H and the two remaining firms M and L only market variant v_M.*

Proof. See the Appendix. ■

Applying the same *rationale* as above, in the next proposition, we can easily show that, when firm M is the initial player, $C_{HL,M} = (\{H, L\}, \{M\})$ is the *only stable coalition structure.*

Proposition 7 *When firm M is the initiator of the sequential alliance formation game, the only stable coalition structure is $C_{HL,M} = (\{H, L\}, \{M\})$, where firm H and L jointly produce variant v_H and firm M produces variant v_M.*

Proof. See the Appendix. ■

Notice that, in both cases the initiator of the game is never part of an alliance in equilibrium. Indeed, as shown in detail in the proofs of Proposition 6 and 7, the payoff of a firm when remaining singleton (and rationally expecting that the other firms will prefer to merge) dominates that of being part of the grand coalition, since in this case the distribution of profits will be unfavourable for the initial proposer. The equilibrium profit accruing to either firm H or M when initiating the game and competing against an alliance is, therefore, larger than when they are part of the alliance itself. The optimal strategy is, therefore, to induce the remaining firms to merge.

A different result arises when firm L (the bottom quality one) begins the negotiation process. The reason is that, in this case, firm L cannot credibly commit to remain independent when the remaining firms (H and M) prefer to play as singletons rather than forming an alliance (see Table 1). This is due to the fact that the alliance between firm H and M is problematic because in this circumstance M optimally leapfrogs the bottom quality firm, and ends up sharing the top quality firm duopoly payoff, which is lower than the sum of their profits under triopoly (cf. section 3.4.3). Knowing in advance the infeasibility of coalition $\{H, M\}$, firm L will prefer to let firm H playing independently, and form an alliance with firm M. This is shown in the next proposition.

Proposition 8 *When firm L is the initiator of the sequential alliance formation game, the only stable coalition structure is $C_{H,ML} = (\{H\}, \{M, L\})$, where firm H produces variant v_H and M and L jointly produce variant v_M.*

Proof. See the Appendix. ■

It is worth noting that if the game initiator would be selected at random, the most likely outcome of the alliance formation game would be that in which the coalition structure $C_{H,ML} = (\{H\}, \{M, L\})$ forms, the other possible outcome implying the formation of $C_{HL,M} = (\{H, L\}, \{M\})$. Moreover, although at equilibrium the same coalition structure $C_{H,ML}$ forms both when either firm H or L starts the negotiation, there is a difference in term of rent extraction, in the two cases, for colluding firms M and L: when firm H is the one starting the negotiation, firm M in alliance $\{M, L\}$ only receives its outside option $\Pi_M = \Pi_M^* = 0.00124$, whereas firm L is able to get a profit $\Pi_L^{(\{H\},\{M,L\})} = \Pi_{\{M,L\}}^{(\{H\},\{M,L\})} - \Pi_M^* = 0.00027 > \Pi_L^*$, exploiting its last-mover advantage in the sequential game. When, on the other hand, it is firm L to start the game, firm M in alliance $\{M, L\}$ receives $\Pi_M^{(\{H\},\{M,L\})} - \Pi_L^* = 0.00147 > \Pi_M^* = 0.00124$, while firm L only receives its noncooperative payoff $\Pi_L^* = 0.00005$. In both cases, firm H receives its duopoly payoff $\Pi_H = 0.02443$.

Quite surprisingly, in the alliance formation game firm M enjoys a first-mover advantage, just because, when it starts the negotiation, it is able to enforce $C_{HL,M} = (\{H, L\}, \{M\})$ extracting a profit of $\Pi_M^{(\{H,L\},\{M\})} = 0.00152$ higher than in all other cases. Moreover, this comes at expense of firm H, which in coalition structure $C_{HL,M}$ only receives its noncooperative payoff $\Pi_H^* = 0.02348$.

Finally, it can be noticed that, since for any order of play our one-shot coalition formation game always sustains only one equilibrium alliance structure, the subgame perfect equilibrium of the *finite* repeated version of the game will generate the same outcome period after period. We condense this conclusion in the next corollary.

Corollary 1 *If the alliance formation game is repeated for a finite number of periods, the coalition structures which are stable in the one-shot game will continue to be so in the finite-horizon repeated version of the game, sustained by the same SPE strategy profile repeated at each period.*

Therefore, even in a repeated finite-horizon framework, the stability of $C_{H,ML}$ and $C_{HL,M}$ would continue to hold.

The results of our coalition formation game, confirms that the most likely type of merger is the one occurring between intermediate and bottom-quality producers, with the premium quality brands preferably running alone. This is the case, for instance, of some top car producer as Daimler-Benz, whose only participation was in the production of Smart, initially started as a joint venture with Nicolas Hayek, the inventor (and producer) of Swatch. What the stylized results of our model indicate, is that the mergers between intermediate and bottom quality firms, as those occurring between Volkswagen and Skoda, or between Fiat and Chrysler in the automotive industry, should be the norm. In these cases the intermediate quality product is withdrawn from the market, which can be interpreted by saying that of all products sold by the merger possess a tendency to converge towards the level of quality of their premium brand products. Our model also highlights how the mergers between top and bottom quality firms are also likely as, for instance, those occurring between generics manufacturers and premium brand pharmaceutical companies. In this case we see how the low quality products can be profitably withdrawn from the market, in order to soften the existing competition among remaining goods.

5 Concluding Remarks

We have investigated the endogenous formation of mergers in vertically differentiated markets in which full or partial binding agreements among initially heterogenous firms can be signed over prices and qualities of the products. We have shown that despite of the profitability of the full collusive agreement (i.e. the one signed by all firms in the market), such an arrangement is not obtained in a (finite horizon) sequential negotiation process requiring the unanimity of firms. Conversely, we found that the sequential bargaining process enforces only partial collusive agreements, namely those involving subsets of firms. In particular, stable associations of firms always include the firm producing the bottom quality variant, which is, however, never sold by the coalition at equilibrium. Further, whatever the coalition structure arising at the equilibrium, the market moves from a triopoly to a duopoly with only two variants on sale. The rationale underlying this result can be found in the nature of competition among vertically differentiated firms. Indeed, in a partial merger, the optimal set of products to market is defined by balancing *the cannibalization effect* within the coalition and the *stealing effect* occurring between the coalition and the firm outside. When the bottom quality is kept for sale in the market under a collusive agreement, the former effect always dominates the latter. As immediate consequence, this variant is withdrawn from the market and the equilibrium configuration coincides with that observed in the case of a duopoly in terms of price and quality gap between variants. In a complementary perspective, we can state that moving from a triopoly (observed in the noncooperative scenario) to a duopoly under partial collusion, firms can soften price competition in the market and magnify the quality differentiation between the variants kept on sale. This view is in line with the empirical findings, where mergers emphasize "product differentiation" among merging firms and also with respect to the rivals. Partial mergers are, thus, as a means to enhance *dynamic* competition *for* the market, while decreasing *static* competition in the market.

6 Appendix: Omitted Proofs

A.1 Proof of Proposition 3

Proposition 3. In order to escape from the cannibalization taking place between adjacent variants, merging top and intermediate quality firms enhance maximal differentiation between their products by putting the intermediate quality at the bottom of the quality ladder. The rival L "leapfrogs" the intermediate quality firm, thereby producing a variant which lies now in the middle of the quality ladder.

Proof. At the quality stage, firms' profits are:

$$\begin{aligned}
\pi_H^{(\{H,M\},\{L\})} &= \frac{1}{4}\frac{(4v_H v_M - v_H v_L - 3v_L v_M)}{(4v_M - v_L)} - \frac{1}{2}v_H^2 \\
\pi_M^{(\{H,M\},\{L\})} &= \frac{v_L v_M (v_M - v_L)}{(4v_M - v_L)^2} - \frac{1}{2}v_M^2 \\
\pi_L^{(\{H,M\},\{L\})} &= \frac{v_L v_M (v_M - v_L)}{(4v_M - v_L)^2} - \frac{1}{2}v_L^2
\end{aligned}$$

It is easy to see that, the joint profit of merger$\{H, M\}$ is monotonically decreasing in v_M, as

$$\frac{\partial\left(\pi_H^{(\{H,M\},\{L\})} + \pi_M^{(\{H,M\},\{L\})}\right)}{\partial v_M} = \frac{\left(4v_L^3 v_M + v_L^3 - 48 v_L^2 v_M^2 + 20 v_L^2 v_M + 192 v_L v_M^3 - 256 v_M^4\right)}{4(v_L - 4v_M)^3} < 0.$$

Thus, the merging firms find it profitable to set the quality of the intermediate variant at the minimum admissible value, say 0. By doing this, they choose to produce a variant which is at the bottom of the quality ladder. If the competitor L would keep its own variant at the same quality level, then it would obtain nil profits. Rather, choosing to produce an intermediate variant $v_M > 0$ would yield positive equilibrium profits equal to

$$\pi_L^{(\{H,M\},\{L\})} = \frac{v_M^2 (v_H - v_L)(v_M - v_L)(v_H - v_M)}{\left(v_M^2 + v_H v_L - 4 v_H v_M + 2 v_M v_L\right)^2} > 0 \ .$$

As this profit $\pi_L^{(\{H,M\},\{L\})}$ is strictly positive for any $v_H > v_M > v_L = 0$, one can conclude that firm L finds it profitable to leapfrog rival M. ■

A.2 Proof of Proposition 5

Proposition 5. *In the three-firm vertically differentiated market with ex ante heterogeneous firms and endogenous qualities and prices, the core of the partition function game $\rho = (N, v(S, C))$ is nonempty*

Proof. Core allocations are individually-rational and group-rational profit division $\Pi = (\Pi_H, \Pi_M, \Pi_L)$ of the efficient monopoly payoff $v(N) = \Pi^{\{N\}} = 0.03125$. Thus, the set of $\Pi \in$ Core(ρ) must respect the following inequalities:

$$\begin{aligned}
\sum_{i=H,M,L} \Pi_i &= v(N) = \Pi^{\{N\}} = 0.03125, \\
\Pi_H + \Pi_M &\geq v(\{H,M\}, (\{H,M\}, \{L\})) = \Pi_{\{H,M\}}^{(\{H,M\},\{L\})} = 0.02443 \\
\Pi_H + \Pi_L &\geq v(\{H,L\}, (\{H,L\}, \{M\})) = \Pi_{\{H,M\}}^{(\{H,L\}\{M\})} = 0.02443 \\
\Pi_M + \Pi_L &\geq v(\{M,L\}, (\{H\}, \{M,L\})) = \Pi_{\{H,M\}}^{((H),\{M,L\})} = 0.00152 \\
\Pi_H &\geq v(\{H\}, (\{H\}, \{M,L\})) = \Pi_H^{((H),\{M,L\})} = 0.02443 \\
\Pi_M &\geq v(\{M\}, (\{H,L\}, \{M\})) = \Pi_M^{(\{H,L\}\{M\})} = 0.00152 \\
\Pi_L &\geq v(\{L\}, (\{H,M\}, \{L\})) = \Pi_L^{(\{H,M\},\{L\})} = 0.00152
\end{aligned}$$

which surely hold, since:

$$0.02443 + 0.00152 + 0.00152 = 0.02749 < 0.03125.$$

Note that for every i-th firm, $v(\{i\}, (\{i\}, \{N \backslash \{i\}\})) > v(\{i\}, (\{i\}, \{j\}, \{h\}))$ for every $j, h \in N \backslash \{i\}$, implying that each firm gains more when the remaining firms form a coalition than when playing alone. Thus, the last numerical inequality holds *a fortiori* when, after one firm leaves the grand coalition, the remaining firms split-up in singletons. As a result, all efficient payoff allocations $\Pi = (\Pi_H, \Pi_M, \Pi_L)$ rewarding every firm *at least* its maximal deviating payoff and distributing the remaining surplus Z between the three firms, namely,

$$Z = \Pi^{\{N\}} - \Pi_H^{((H),\{M,L\})} - \Pi_M^{(\{H,L\}\{M\})} - \Pi_L^{(\{H,M\},\{L\})} = 0.0085$$

belong to the core, which is, therefore, nonempty. ■

A.3 Proof of Proposition 6

Proposition 6. When firm H is the initiator of the sequential alliance formation game, the only stable coalition structure is $C_{H,ML} = (\{H\}, \{M, L\})$, where firm H continues to produce variant v_H and the two remaining firms M and L only market variant v_M.

Proof. The game can be solved backward. Firm's H available actions at the initial node (information set $I_H^1 \in \mathcal{I}_H$) are the following (proposals):

$$A_H(I_H^1) = [(\{N\}, \Pi), (\{H, M\}, \Pi), (\{H, L\}, \Pi), (\{H\})].$$

Assume first that firm H proposes the grand coalition $\{N\}$ associated to a given division $\Pi \in \Pi^{\{N\}}$ of the efficient monopoly profit between the three firms. By the order of the game, firm M can either accept or reject. If it rejects the offer, it is its turn to make a proposal and can propose one of the following:

$$A_M(I_M^1) = [(\{N\}, \Pi), (\{H, M\}, \Pi), (\{M, L\}, \Pi), (\{M\})].$$

We know (from Table 1) that, for any associated payoff division, the coalition structure $C_{HM,L} = (\{H, M\}, \{L\})$ is dominated by the choice of firm H and M to play as singletons, since

$$\Pi_{\{H,M\}}^{(\{H,M\},\{L\})} < \Pi_H^* + \Pi_M^*.$$

Therefore, when made by firm M, the proposal $p_M^{HM} = (\{H, M\}, \Pi)$ will always be rejected by firm H. In this event, firm H has no more proposals to make. Thus, firm L can gain its highest payoff by proposing $\{N\}$, offering the noncooperative profits to H and M and get the difference $\Pi^{\{N\}} - \Pi_H^* - \Pi_M^*$, which is its most profitable outcome. To break the ties, we can initially assume that, when gaining equal payoffs all firms prefer being in a coalition than remaining singletons (although the reasoning can be repeated when the alternative case holds). A similar outcome would be reached if, after a rejection, firm M proposes $p_M^{ML} = (\{M, L\}, \Pi)$ or $p_M^N = (\{N\}, \Pi)$ which, in turn, would be both refused by firm L, aiming to propose (as last proposer) the grand coalition, obtaining $\Pi_L = \Pi^{\{N\}} - \Pi_H^* - \Pi_M^*$. Analogously, if firm M accepts to enter the grand coalition when proposed by firm H, it knows that, when it is its turn to play, firm L will always reject such proposal to propose, in turn, the grand coalition with a payoff allocation which assigns to its rivals their Nash equilibrium payoffs. Reasoning backward, firm H knows that, if it proposes the grand coalition, it would obtain at most its Nash equilibrium payoff. For this reason, firm H can try to make alternative offers. Proposing $p_H^{HM} = (\{H, M\}, \Pi)$ is out of question, since player M would always reject it, and the game would return to the situation described above. Another chance for firm H is to propose $p_H^{HL} = (\{H, L\}, \Pi)$ that, in turn, would be rejected by firm L with the aim to propose again $(\{H, L\}, \Pi)$, offering to firm H its noncooperative outside option. Alternative proposals by firm L (after its rejection of $\{H, L\}$ proposed by firm H) involving firm M, as $p_L^N = \{\{N\}, \Pi\}$ or $p_L^{ML} = \{\{M, L\}, \Pi\}$ would similarly be rejected by firm M to enforce, as last proposer, the grand coalition payoff. Thus, at the initial node the most profitable action for firm H is to propose $p_H^H = \{H\}$, signalling the intention to play irrevocably as singleton. By doing this, it is aware that firm M can either propose $p_M^{ML} = (\{M, L\}, \Pi)$ or $p_M = (\{M\})$. In the first case, firm M knows that firm L will reject to propose, in turn, $p_L^{ML} = (\{M, L\}, \Pi)$, offering Π_M^* to firm M and keeping the difference, since: $\Pi_{\{ML\}}^{(\{H\}\{M,L\})} - \Pi_M^* > \Pi_L^*$. In the second case, namely when firm M proposes $p_M^M = \{M\}$, a triopoly arises and firm M obtains Π_M^*. Since with equal payoffs firms prefer by assumption to be in a coalition rather than remaining as singletons, in this subgame the choice of firm M will be $p_M^{ML} = (\{M, L\}, \Pi)$. Therefore, the coalition structure $C_{H,ML} = (\{H\}, \{M, L\})$ is stable because can be sustained by the following SPE strategy profile along the *equilibrium path*:[34]

$$\sigma^* = \left(\sigma_H^* = \{H\}, \sigma_M^* = \left(\{M, L\}, \Pi'\right), \sigma_L^* = \left(\text{No}, \{M, L\}, \Pi''\right)\right),$$

where $\Pi' = (\Pi'_M, \Pi'_L)$, for $\Pi'_M = \Pi_{\{ML\}}^{(\{H\},\{M,L\})} - \Pi_{L,L}^*$, $\Pi'_L = \Pi_L^*$, and $\Pi'' = \left(\Pi''_M, \Pi''_L\right)$, for $\Pi''_M = \Pi_M^*$ and $\Pi''_L = \Pi_{ML}^{(\{H\}\{M,L\})} - \Pi_M^*$. If we assume, to break ties, that with equal payoffs firms prefer to be singletons rather than being in coalition, the same coalition structure $C_{H,ML}$ can be enforced by a SPE of the coalition formation game with the difference that, along the equilibrium path, $\Pi'_M = \Pi_{\{ML\}}^{(\{H\}\{M,L\})} - (\Pi_L^* + \epsilon)$, $\Pi'_L = \Pi_L^* + \epsilon$ and $\Pi''_M = \Pi_M^* + \epsilon$, $\Pi''_L = \Pi_{\{ML\}}^{(\{H\}\{M,L\})} - (\Pi_M^* + \epsilon)$, for $\epsilon > 0$. The same occurs in all other proposals implying the presence of a coalition. The reason is that to convince a firm to join an alliance it must receive

[34] We have verbally described all *out of equilibrium path* actions which compose the SPE strategy profile σ^* and, therefore, for ease of simplicity, we do not repeat it here.

something *more* (an $\epsilon > 0$) than its noncooperative payoff. Therefore, coalition structure $C_{H,ML}$ remains stable (namely supported by a SPE strategy profile of the sequential coalition formation game) for every adopted rule to break ties. Finally, to see that $C_{H,ML}$ is the *only* stable coalition structure arising when firm H is the initiator of the game, note that any alternative strategy profile cannot be SPE just because firm H possesses an incentive to profitably deviate by proposing $p_H = \{H\}$ with the expectation to compete in a duopoly (namely under $C_{H,ML}$) and gaining a payoff $\Pi_H^{((H),(ML))} = 0.02443$ which dominates its triopoly profit $\Pi_H^* = 0.02348$ (or in turn, $\Pi_H^* + \epsilon$). ■

A.4 Proof of Proposition 7

Proposition 7. *When firm M is the initiator of the sequential game of coalition formation, the only stable coalition structure is $C_{HL,M} = (\{H, L\}, \{M\})$.*

Proof. As above, the game can be solved backward. Firm's M available actions at the initial node (information set $I_M^1 \in \mathcal{I}_M$) are:

$$A_M(I_M^1) = [(\{N\}, \Pi), (\{H, M\}, \Pi), (\{M, L\}, \Pi), (\{M\})].$$

Again, if firm M proposes the grand coalition $\{N\}$, with an associated division of the monopoly profit $\Pi \in \Pi^{\{N\}}$, the next player, firm H, would reject the offer to propose, in turn, one of the following:

$$A_H(I_1^1) = [(\{N\}, \Pi), (\{H, M\}, \Pi), (\{H, L\}, \Pi), (\{H\})].$$

Coalition structure $C_{HM,L} = (\{H, M\}, \{L\})$ is dominated by the choice of firm H and M to play as singletons and proposal $p_H^{HM} = (\{H, M\}, \Pi)$ is, therefore, rejected by firm M. If this occurs, firm M has no more proposals and, hence, firm L can propose $\{N\}$, obtaining $\Pi_L = \Pi^{\{N\}} - \Pi_H^* - \Pi_M^*$, which is its most profitable outcome. Similar outcome would be reached if, after a rejection, firm H offers, in turn, $p_H^{HL} = (\{H, L\}, \Pi)$ or $p_H^N = (\{N\}, \Pi)$, which can either be accepted or refused by firm M, but nevertheless the final payoff would, for firm H and M, be their noncooperative outside options. Thus, reasoning backward, firm M knows that by proposing the grand coalition it would receive at most its noncooperative payoff. Its alternative proposals are $p_M^{HM} = (\{H, M\}, \Pi)$ which would be rejected by firm H (so the game would reach the same outcome described above) or $p_M^{ML} = \{\{M, L\}, \Pi\}$ which, in turn, would be rejected by firm L with the aim to propose $p_L = \{\{M, L\}, \Pi\}$, offering firm M its noncooperative outside option, which turns out to be better than any other coalition containing firm H that would, in fact, exploit its last mover advantage. Note that forming alliance $\{M, L\}$

would, for firm L, be better than any other proposal involving firm H, that could exploit its last-mover advantage. Thus, at the initial node, the most profitable action for firm M is to propose $p_M^M = \{M\}$, with the knowledge that firm H prefers to be in coalition than playing as singleton proposing $p_H^{HL} = \{\{H, L\}, \Pi\}$ rather than $p_H^H = \{H\}$. Hence, the proposal p_H^{HL} by firm H would be rejected by firm L, that can counter-offer, in turn, $p_L^{HL} = \{\{H, L\}, \Pi\}$, giving Π_H^* to firm H and keeping the difference for itself, since $\Pi_{HL}^{(\{H,L\}\{M\})} - \Pi_H^* > \Pi_L^*$. As a result, the coalition structure $C_{HL,M} = (\{H, L\}, \{M\})$ is stable since it can be sustained by the following SPE strategy profile along the *equilibrium path*:[35]

$$\sigma^* = \left(\sigma_H^* = \left(\{H, L\}, \Pi^{'}\right), \sigma_M^* = \{M\}, \sigma_L^* = \left(\text{No}, \ \{H, L\}, \Pi^{''}\right)\right),$$

with $\Pi' = (\Pi'_H, \Pi'_L)$, where $\Pi'_H = \Pi_{\{HL\}}^{(\{H,L\}\{M\})} - \Pi_L^*$ and $\Pi'_L = \Pi_L^*$ and $\Pi'' = \left(\Pi''_M, \Pi''_L\right)$, where $\Pi''_H = \Pi_H^*$ and $\Pi''_L = \Pi_{\{HL\}}^{(\{H,L\}\{M\})} - \Pi_H^*$. As in the proof of Proposition 6, if, under equal payoffs, firms prefer to be singletons than being in a coalition, the coalition structure $C_{HL,M}$ can be enforced as a SPE of the coalition formation game for, $\Pi'_H = \Pi_{\{HL\}}^{(\{H,L\},\{M\})} - (\Pi_L^* + \epsilon)$, $\Pi'_L = \Pi_L^* + \epsilon$, $\Pi''_H = \Pi_H^* + \epsilon$ and $\Pi''_L = \Pi_{\{HL\}}^{(\{H,L\},\{M\})} - (\Pi_H^* + \epsilon)$, for $\epsilon > 0$, and, similarly for all other proposal involving coalitions outside the equilibrium path. Finally, $C_{HL,M}$ is the *only* stable coalition structure when firm M is the initiator of the coalition formation game just because in any alternative strategy profile firm M would always prefer to propose $p_M^M = \{M\}$ and compete in a duopoly with a payoff $\Pi_M^{(\{H,L\}\{M\})} = 0.00152$ rather than getting its triopoly profit $\Pi_M^* = 0.00124$ (or in turn, $\Pi_M^* + \epsilon$), which occurs in all other subgames. ■

A.5 Proof of Proposition 8

Proposition 8. *When firm L is the initiator of the sequential coalition formation game, the only stable coalition structure is $C_{ML,H} = (\{M, L\}, \{H\})$.*

Proof. Again in this proof we reason backward. Note that when firm L is the initiator of the game, the line of reasoning is slightly different than in Proposition 6 and 7. Firm's L available actions at the initial node (information set $I_L^1 \in \mathcal{I}_L$) are:

$$A_L(I_L^1) = [(\{N\}, \Pi), (\{H, L\}, \Pi), (\{M, L\}, \Pi), (\{L\})].$$

To break ties assume initially that, with equal payoffs, firms prefer to be in coalition rather than act as singletons. Note first that if firm L proposes $p_L^L = \{L\}$, the turn passes to

[35] Again, for simplicity, we skip the description of all players' out of equilibrium actions.

player H, who can either propose $p_H^H = \{H\}$, in which case the game ends with $C_{H,M,L} = (\{H\}, \{M\}, \{L\})$ or instead $p_H^{HM} = (\{H, M\}, \Pi)$, which again forces the game to end with $C_{H,M,L} = (\{H\}, \{M\}, \{L\})$, since $C_{H,ML} = (\{H\}, \{M, L\})$ is dominated by $C_{H,M,L}$ for both firm H and M (see Table 1). So differently from above, firm L is unable to enforce the formation of its complementary coalition $N \backslash \{L\} = \{H, M\}$ by signalling its willingness to play alone as singleton. Alternatively, if firm L proposes either $p_L^N = (\{N\}, \Pi)$ or $p_L^{HL} = (\{H, L\}, \Pi)$ it always induces the formation of coalition structure $C_{H,ML}$ with $\Pi_H = \Pi_H^{(\{H\},\{M,L\})}$, $\Pi_M = \Pi_M^{(\{H\},\{M,L\})} - \Pi_L^*$ and $\Pi_L = \Pi_L^*$. The reason is that, by the order of play, after both proposals the turn passes to firm H whose optimal strategy is to reject the offer and to announce $p_H^H = \{H\}$, thus inducing proposal $p_M^{ML} = (\{M, L\}, (\Pi))$ by firm M with $\Pi_M = \Pi_M^{(\{H\},\{M,L\})} - \Pi_L^*$ and $\Pi_L = \Pi_L^*$, which firm L will accept. Finally, if firm L proposes at the beginning of the game $p_L^{ML} = (\{M, L\}, \Pi)$, for any profit distribution Π firm M will reject it to propose, in turn, $p_M^{ML} = (\{M, L\}, \Pi)$, again offering $\Pi_L = \Pi_L^*$ to firm L that, in turn, will accept. Therefore, since by assumption with equal payoffs firms prefer to be in coalition, the game possesses as unique outcome the intermediate coalition structure $C_{H,ML} = (\{H\}, \{M, L\})$, which can be sustained as a SPE strategy profiles. Again, it can be easily checked that the game outcome does not change if, to break ties, we assume that under equal payoffs firms prefer to play as singletons rather than being in coalitions. ■

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