ESSAYS ON STRATEGIC FIRMS, VERTICAL CONTRACTS AND HORIZONTAL AGREEMENTS

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Abstract

Inspired by some newly emerged topics from the real world, this thesis comprises of four essays that study firms' strategic incentives, as well as the vertical and horizontal agreements between firms.

The first essay assesses theoretically firms' incentives to engage in quality proliferation. We show that it is possible for vertical proliferation to be completely undesirable in the absence of entry threats, therefore proliferation of any level might be anticompetitive. Nevertheless, when proliferation is optimally conducted, it always benefits consumers.

The second and third essays focus on vertical contracts between successive stages of production. The second essay places the controversial agency model involved in the e-book case in the context of antitrust treatment to vertical restraints, and examines its effects on competition and welfare relative to the wholesale model.

The third essay goes beyond and develops a framework allowing us to clarify the *ceteris paribus* effects of changing each of the two key elements written in a vertical contract: decision roles and forms of the transfer payment. Based on this framework, we show that it is meaningful to distinguish between *classic RRM*, by which a manufacturer sets the transfer payment as well as the retail price, and *agency RPM*, by which a retailer is able to set the transfer payment before a manufacturer set the retail price.

The final essay focuses on horizontal cartel agreements and experimentally investigates the effects of endogenous enforcement on cartel prices. We highlight the strategic uncertainty in cartel coordination as a channel of composition deterrence, as well as the potential trade-off between frequency and composition deterrence.

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Chapter 1

Introduction

This thesis is broadly related to firms' strategic incentives and inter-firm agreements. The progress of information technology has drastically shaped the strategies adopted by firms in competition and the ways in which firms interact with each other in the markets. While some of the changes are well attended by practitioners and academics, some are largely unaddressed, hence the relevant effects on competition and welfare remain unclear. This thesis seeks to enhance our understanding of selected topics of such.

The main body of the thesis presents four independent essays. The first three essays theoretically assess the topics of interest, with Chapters 3 and 4 being closely linked. The final essay uses experimental methodology, although a theoretical background is provided. All four essays offer relevant policy implications. In particular, Chapters 3 and 4 are related to the antitrust treatment of vertical restraints, and Chapter 5 is related to the design of antitrust enforcement.

Chapter 2 is motivated by the high-street and luxury collaborations in the fashion apparel and sportswear industry.[1] While such collaboration may be understood as a type of quality

[1] For example, Hennes & Mauritz (H&M) alone has collaborated with more than 10 designer brands. See http://about.hm.com/en/About/facts-about-hm/fashion-for-all/collections/collaborations.html.

proliferation given that high-street and luxury brands are perceived as vertically differentiated, the literature on quality proliferation is *per se* sparse. Specifically, among many strategic incentives, proliferation has mainly been examined for two – to increase profit and to deter entry. In contrast to the intense investigation regarding both in horizontal differentiation settings, the same in vertical differentiation settings receives far less attention. We therefore wish to take some initial steps to fill in the gap.

In a model of vertical maximal differentiation where firms compete in quality and price, we analyse the incentive of an established high quality firm to proliferate without and with entry threats. We show that the high quality firm would only be able to locate a middle quality product if it allows that product to be an independent unit. Such proliferation is not optimal in the absence of entry threats but becomes optimal in the presence of entry threats, when the proliferation cost is sufficiently small. These results highlight the trade-off between softening competition and broadening market segments brought about by proliferation and that even the most moderate level of quality proliferation may be anticompetitive. Interestingly, when proliferation is optimally carried out, it benefits consumers and could even increase total welfare in a way that is more efficient than entry.

Chapter 3 is motivated by the (in) famous *Apple*[2] case and the prevalence of the agency model in some markets in recent years. Complementary to studies on the agency model in a particular market, e.g., the e-book market, we take an alternative approach of trying to understand the nature of the agency model. Through comparing the wholesale model and the agency model characterizing a vertical relation in a bilateral duopoly market, we find that the agency model may be regarded as an example of retailer power resale price maintenance (RPM) which is usually beneficial to retailers. Results further provide an economic view of why restraints of this kind may be evaluated under the rule of reason: while competition is more likely to be undercut under the agency model, relative to the wholesale model, the agency model benefits consumers by offering lower retail prices and higher demand.

[2] U.S. *v*. Apple Inc., *et al*. 12 Civ. 2826 (DLC), the State of Texas, *et al. v*. Penguin Group Inc., *et al*. 12 Civ. 3394 (DLC) (2013). More details about this case can be found in Section 3.1 of Chapter 3.

Chapter 3 notes that, moving from the wholesale model to the agency model, not only the decision roles of manufacturers and retailers are reversed, but also the form of the transfer payment changes from unit-fee to revenue-sharing. In Chapter 4, we seek to separate out the effects of these two changes through comparing across a menu of vertical contracts that differ in decision roles and/or forms of the transfer payment. Based on this framework, we formally distinguish between *classic RRM*, by which a manufacturer sets the transfer payment as well as the retail price, to *agency RPM*, by which a retailer is able to set the transfer payment before the retail price being set by a manufacturer, e.g., the agency model.

In a bilateral monopoly market, we find that the two types of RPM differ substantially in their respective effects on profit division and consumer surplus: classic RPM benefits the manufacturer whereas agency RPM benefits the retailer; classic RPM eliminates double marginalisation whereas agency RPM may fail to do. Furthermore, since there is no horizontal competition under bilateral monopoly, our analysis highlights the neglected role of vertical competition in vertical relations that both the manufacturer and the retailer may have incentives to use RPM for vertical rent shifting, which can also affect consumer surplus. Regarding the *ceteris paribus* effects of reversing decision roles and changing forms of the transfer payment, we find that, for a given form of the transfer payment, reversing decision roles does not affect retail prices and is purely a vertical rent shifting. More interestingly, manufacturer profits are higher when the retail price is set by the retailer and retailer profits are higher when the retail price is set by the manufacturer. For given decision roles, retail prices are always lower under revenue-sharing contracts. Whoever sets the retail price is better off under a unit-fee contract, whereas the other is better off under a revenue-sharing contract.

Chapter 5 focuses on horizontal cartel agreements. A cartel is fundamentally a cooperative game, hence not only the expected profitability, but also the stability and sustainability of an agreement matter. Nevertheless, practitioners and academics seem to focus more on the former (apart from those studying leniency programmes). The literature on cartels and optimal antitrust enforcement, including those using experimental methodologies, has contributed to our understanding of the effects of exogenous cartel enforcement. In particular, how fines and detection probabilities are imposed to alter a cartel’s expected profitability so that frequency deterrence can be achieved. We wish to examine an alternative channel of deterrence, that is, how endogenous enforcement, i.e., fines and detection probabilities that vary with the cartel harm, can aggravate the cartel coordination problem through worsening the strategic uncertainty among cartelists, so that they are deterred from colluding on the risky high cartel price and instead collude on a low cartel price. This mitigation of harm following a reduced cartel overcharge is known as composition deterrence.

We conduct a laboratory experiment on infinitely-repeated noncooperative games in which subjects engage in homogenous goods price competition in groups of three. Subjects can coordinate on prices but face the risk of being detected and fined if they do. The experiment has four treatments, of which the baseline is with exogenous enforcement. In the other three treatments, the implemented endogenous enforcement regime gives rise to payoff–equivalent collusive price equilibria that bear different levels of riskiness of collusion. Our results suggest evidence of composition deterrence: subjects are found to behave strategically and tend to collude on the price with lower riskiness of collusion. Yet, as the low cartel price becomes more desirable in the presence of endogenous enforcement, there is an adverse effect on frequency deterrence, leaving the overall welfare effect of endogenous enforcement unclear.

This thesis goes on to present each of the four essays. Chapter 6 delivers the general conclusion.

Chapter 2

Proliferation and Entry Deterrence in Vertically Differentiated Markets

2.1 Introduction

In vertically differentiated markets with products of the same generic type, firms making quality-price decisions face a trade-off between softening competition and broadening market segments. As a result, proliferation or multi-product strategy (see, e.g., Constantatos and Perrakis, 1997), with which firms typically offer a range of products, could have either procompetitive or anticompetitive effects. On the one hand, by filling in the gaps on a quality spectrum, proliferation increases competition as products available become less differentiated. On the other hand, proliferation enables firms to reach different market segments and better discriminate against consumers.

Ever since Schmalensee (1978) suggests empirically that an incumbent can preempt entry by introducing new products and restricting the market space available to potential entrants, there has been increasing antitrust concerns against excessive proliferation. If one tries to rationalize firms' engagement in proliferation that is not *per se* profitable, the argument might be that it is optimal if some other considerations are taken into account, e.g., entry deterrence.

Proliferation to deter entry has been under intense investigation in horizontal differentiation settings (Judd, 1985; Choi and Scarpa, 1991; Murooka, 2012), but the same analysis in vertical settings is sparse. Given that excessive proliferation is suspicious, one may tempt to assume that moderate proliferation is more likely to be justified on profitability ground thus seemingly causes no harm. In this paper, we show that it is possible for vertical proliferation to be completely undesirable in the absence of entry threats, even in the extreme case of introducing only one additional quality. Therefore proliferation of any level might involve anticompetitive purpose. More interestingly, when proliferation is optimal given entry threats, it always benefits consumers.

In a vertically differentiated market, suppose that consumers have identical ordinal preferences over product quality and differ only in income levels.[1] Then at an equal price, higher quality is preferable. For example, people would generally agree that a Mason Pearson hairbrush is preferable to a hairbrush from Primark.[2] In a simple duopoly market, a series of papers (Gabszewicz and Thisse, 1979; Shaked and Sutton, 1982; Donnenfeld and Weber, 1992) prove the existence of a unique quality-price equilibrium in which two established firms follow the *Principle of Maximal Differentiation*. That is, they first choose distinct qualities and then set distinct prices, so as to dampen competition and increase profits.

It is also common for a single firm to offer quality-differentiated products to consumers. For example, for a given size, Mason Pearson usually offers three types of hairbrush, namely pure bristle, bristle/nylon, and nylon, where bristle is finer and more expensive than nylon as the component of a hairbrush head. Another form of proliferation, namely brands collaboration, is usually conducted jointly by two firms. Similar to a joint venture strategy, brands collaboration is defined by Chun and Niehm (2010) as a strategic and cooperative relationship

[1] Another interpretation of vertical differentiation is by Mussa and Rosen (1978) where consumers differ only in their intensity of preference for quality. The two interpretations are related; if θ is a parameter of intensity of preference for quality, then wealthier consumers have a higher θ and enjoy quality improvement more that less wealthy consumers (See, e.g., Tirole, 1988; Donnenfeld and Weber, 1992).

[2] See http://masonpearson.co.uk/ and http://www.primark.com/en/search/categorised search?q=hairbrush.

where brands devote their own competitive advantages to present products under joint names to consumers.

A good example of vertical brands collaboration is the high-street brands (e.g. Gap and H&M) and luxury brands (e.g. Jimmy Choo and Lanvin) collaborations in the fashion apparel and sportswear industry. The premier case was by Puma and Jil Sander in the late 1990s. Chun and Niehm (2010) suggest that through this collaboration, "the boundaries between genres collapsed." In 2003, Adidas launched its first collaborations with designer brands Stella McCartney and Jeremy Scott. Puma collaborated with Neil Barrett and Alexander McQueen in subsequent years. Nike joined the trend in 2012 and has been collaborating with Liberty.

A more typical case has been the Sweden based clothing retailer Hennes & Mauritz (H&M). In 2004, H&M tied up with Karl Lagerfeld and produced a successful collection. Since then, it has launched 21 collaborations with 16 different designer brands.[3] The average prices of items from H&M collaborations were over £100, with the most expensive collaboration so far being Maison Martin Margiela for H&M (on average £141.61 per item). Despite at much higher prices compared to normal H&M ranges, the collaboration ranges were sold out quickly. Some popular pieces were sold on eBay for five times the original prices. Meanwhile, the prices were lower than the original luxury collections. As reflected by prices, the perceived quality of collaborated ranges seems to be higher than the normal ranges from the high-street stores, although would not be as high as the original designer collections. As a result, quality configuration expands with such joint proliferation.

It is of importance to study proliferation in vertically differentiated markets since the existing studies relating to it is limited and does not keep up pace with the boom of the real world (joint) proliferation cases. Among many strategic incentives, proliferation has mainly been examined for two – to increase profit and to deter entry. While there is a literature on the optimality of proliferation (e.g., Shaked and Sutton, 1982), the specific conditions and

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[3] Collaborations in the last decade included those with Stella McCartney, Viktor & Rolf, Roberto Cavalli, Comme des Garcons, Marimekko, Matthew Williamson, Jimmy Choo, Sonia Rykiel, Lanvin, Versace, Marni, Anna Dello Russo, Maison Martin Margiela, Isabel Marant and Alexander Wang. See http://about.hm.com/en/About/facts-about-hm/people-and-history/history.html.

endogenous proliferation qualities have been largely unaddressed, leaving it difficult to evaluate proliferation even in a simple framework. Since the entry deterrence effect of proliferation in vertical differentiation settings is rarely examined, the relevant welfare effects remain unclear.[4]

Although fully replicating the real world high-street and luxury collaborations is beyond the scope of this paper, we wish to examine how proliferation works in a context that captures this sort of competition. In the absence of entry threats, common expectation of firms on proliferation is to broaden market segments. Whether such expectation can be fulfilled is unclear without knowing how firms wish to locate the additional qualities.

Furthermore, when a firm makes decisions regarding proliferation, it faces a menu of options of how much control it wishes to take. For example, it may wish to take full control over the quality-price decision of any additional product introduced; or any additional product acts as an independent unit that decides its own quality and price, while the parent-firm acts as a shareholder collecting profit from it (i.e., *divisionalisation* in Baye, Crocker and Ju, 1996). Immediately the message is that an entrant would make the same quality-price decision as an independent unit, as the independent unit seeks to maximise its own profit instead of the total profits of its parent-firm.

In a model of maximal differentiation where one firm specializes at the high end of the quality spectrum and Bertrand competitive firms operate at the low end, we show that the high quality firm would only be able to locate a middle quality product if it allows that product to be an independent unit. The quality level of the middle quality product is endogenously determined and is a convex combination of the existing high and low qualities. To be specific, it is 4/7 of that of the high quality product plus 3/7 of that of the low quality product. The price of the middle quality product is 2/7 of the price of the high quality product.[5] Such proliferation

[4] There is a much richer strand of literature on "limit quality" to deter entry (e.g., Lane, 1980; Donnenfeld and Weber, 1995; Noh and Moschini, 2006) than proliferation to deter entry in vertical differentiation model.

[5] This is superficially similar to Choi and Shin (1992)'s results in a duopoly model of vertical differentiation with uncovered market. They find that the quality level of the low quality product is 4/7 of that of the high quality product, and the price of the low quality product is 2/7 of the price of the high quality product. However, in this paper, we have an additional middle quality product.

is not optimal in the absence of entry threats but becomes optimal in the presence of entry threats, when the proliferation cost is sufficiently small.

Moving from the two-quality to the three-quality market, if the fixed cost of introducing the third quality is small enough, then the rise in consumer surplus would outweigh the fall in industry profits, hence total welfare increases. Such increase in welfare could be achieved by the high quality firm through proliferation, or by the entrant if proliferation does not take place. From the welfare point of view, whether the outcome is achieved more efficiently by the established firm or by the entrant depends on their relative cost of introducing the third product. If the high quality firm benefits from the fact that it is already established hence incur lower cost, then not only proliferation can increase welfare, it also does in a way that is more efficient than entry.

The setting considered in this paper is along the similar lines to Tirole (1988), who provides an intuitive yet simple way to solve the model of vertical differentiation. We allow competitive firms in the low quality segment, which is different from the standard duopoly model. This modification, however, is consistent with the distribution of differentiated brands in the real world. For example, in the fashion apparel industry, there are countless high-street brands and far fewer designer luxury brands. Although it is a simplified model, it delivers a comprehensive evaluation of the proliferation strategy.

This paper is close in spirit to Baye *et al*. (1996), who study firms' incentives to add divisions before engaging in Cournot competition. They suggest that the profit generated by a new division may be offset by the fall in the profit of the parent-firm's existing units. Therefore proliferation, however moderate, might fail to fulfil the expectation.

The idea on proliferation location is close to Donnenfeld and Weber (1992), who show in a model of maximal differentiation that a later entrant always selects an intermediate level of quality. But the intermediate quality is not endogenously determined and they do not consider the situation where the intermediate quality is offered by an incumbent. Our result on the quality level of the middle quality product is consistent with the prediction of Choi and Shin (1992), who suggest it to be "just over half that of the established firm".

While Constantatos and Perrakis (1997) also find that proliferation may help an established firm to block entry, their focus is on market coverage. In our model, market coverage is endogenously full with or without proliferation. Proliferation intensifies price competition and reallocates demand: in the presence of the middle quality product, price of the high quality product decreases and demand increases, whereas demand for the low quality product drops significantly.

The paper proceeds as follows. Section 2.2 presents the model for our analysis. Section 2.2.1 provides a two-quality market environment in which one high quality firm and competitive low quality firms compete in price. We characterize the equilibrium as a benchmark for assessing proliferation incentives later. Section 2.2.2 evaluates the profitability of proliferation in the existing two-quality market without threat of entry. We determine endogenously the quality choice of proliferation. Section 2.2.3 examines proliferation as a deterrent when there is threat of entry. Section 2.3 presents welfare analysis. Section 2.4 concludes.

2.2 Model

2.2.1 Two-quality environment

In a market of quality-differentiated products of the same generic type. Product i is of quality s_i and is sold at price p_i, $i \in \{h, l\}$, where $s_h > s_l$ and $p_h > p_l$. Products with high quality s_h are provided by a single firm, H, and products with low quality s_l are provided by at least two firms, L_1 and L_2. H and the low quality segment engage in maximal differentiation: s_h and s_l are fixed at the two ends of the quality spectrum. The difference between s_h and s_l is denoted as d and is therefore the total length of the spectrum. The unit cost of production c is assumed to be the same for both qualities and is normalized to zero. We assume for now that there is no threat of entry.

There is a continuum of consumers who have identical ordinal preferences over product quality but differ in the willingness to pay. They are uniformly distributed over the interval

$[0,\ \overline{\theta}]$ where θ represents their willingness to pay. Each consumer consumes at most one unit of the products and maximises the following utility function

$$U = \begin{cases} \theta s_i - p_i, & if\ consumes, \\ 0, & otherwise. \end{cases} \tag{2.1}$$

The last consumer with the willingness to pay for the high quality product and the low quality product, is represented by $\theta_h = (p_h - p_l)/d$ and $\theta_l = p_l/s_l$, respectively. That is, consumers with $\theta \in [\theta_h, \bar{\theta}]$ buy the high quality products, consumers with $\theta \in [\theta_l, \theta_h)$ buy the low quality products and consumers with $\theta \in [0, \theta_l)$ buy neither of them.

As L_1 and L_2 offer products with the identical quality s_l, the Bertrand (1883) paradox leads to *Lemma 2.1*.

Lemma 2.1 *Price competition drives p_l down to zero. All consumers purchase at least one of the products and the market is covered.*

For H, we can write the optimisation problem as

$$\max_{p_h} \pi_H = \max_{p_h}\ p_h(\overline{\theta} - \theta_h),$$

where $\overline{\theta} - \theta_h$ is the demand for high quality product. To solve this optimisation problem, we derive the first-order condition with respect to p_h and obtain

$$p_h = \overline{\theta}d/2 + p_l/2,$$

$$D_h = \overline{\theta}d + p_l/2d.$$

Together with *Lemma 2.1*, we have the following

Lemma 2.2 *In equilibrium, high and low quality products equally share the market;* $D_h = D_l = \overline{\theta}/2$. *$H$ sets* $p_h = \overline{\theta}d/2$ *and obtains* $\pi_H = \bar{\theta}^2 d/4$, *whereas* L_1 *and* L_2 *obtain zero profit.*

Lemma 2.2 explains firms' price decisions in the vertically differentiated market. Given that d is constant, the price of the high quality product is higher when the distribution of willingness to pay θ is more dispersed. The market is equally and fully covered by the two existing qualities. Unlike the standard non-cooperative duopoly vertical differentiation model where both high and low quality firms enjoy positive surplus, price competition among products of quality s_l in our model leaves no surplus for the low quality segment.

2.2.2 Proliferation environment

This section examines H's incentive to proliferate in the existing two-quality market. Since moderate proliferation is more likely to be justified on profitability ground, we allow H to introduce exactly one additional quality, s_m, and assume that

$$s_m = \beta s_l + (1-\beta)s_h, \beta \in (0,1).$$

The above assumption ensures that s_m is of an intermediate level, where β is the location parameter. Given that s_h and s_l are exogenous, β decides s_m. When $\beta > 0.5$, s_m is closer to s_l than to s_h. We exclude the possibility of equality among qualities which is not profitable for H.

Figure 2.1 illustrates how proliferation may change the market. We know from *Lemmata 2.1* and *2.2* that in the market with two qualities s_l and s_h, all consumers will purchase. Consumers with $\theta \in [\theta_l, \theta_h)$ buy products of s_l and consumers with $\theta \in [\theta_h, \bar{\theta}]$ buy products of s_h. When products of s_m are introduced to the market, as shown by the dashed line in Figure 2.1, consumers face three choices instead of two. *Ceteris paribus*, consumers with $\theta \in [\theta_l, \theta_m)$ buy products of s_l, consumers with $\theta \in [\theta_m, \theta_h{}')$ buy products of s_m, and consumers with $\theta \in [\theta_h{}', \bar{\theta}]$ buy products of s_h.

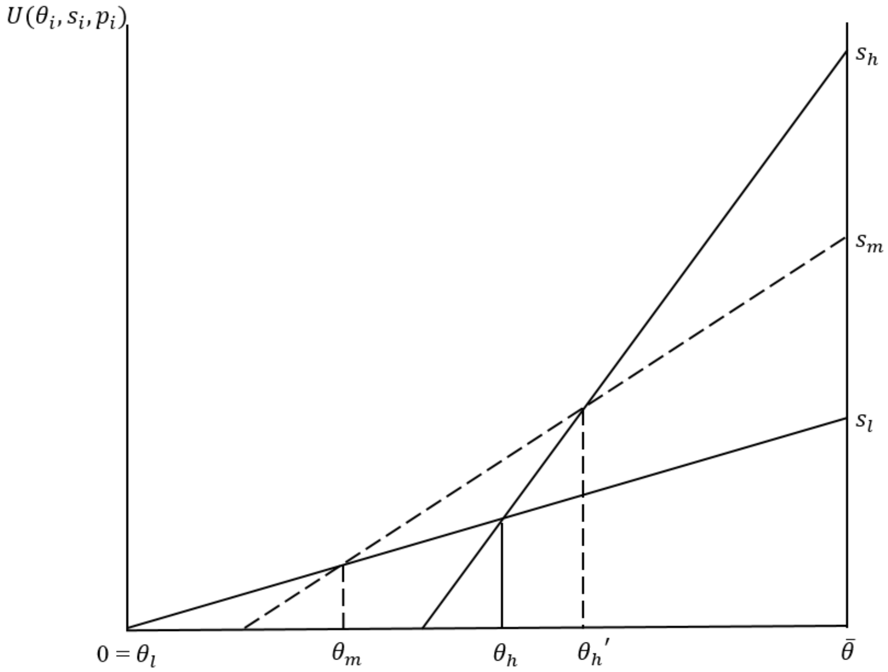

Figure 2.1 Proliferation in the two-quality market

Johnson and Myatt (2003) suggest that when established firms strategically expand on the quality spectrum, they usually do so by introducing a lower quality product.[6] As $s_h > s_m > s_l$, we have H, rather than one of the low quality firms, to offer s_m. Linking it to the real world, reputation of the designer brands seems to be the key factor contributing to the success of H&M's collaborated ranges. Since in the scope of this paper, proliferation is to be conducted by a single firm, not jointly, it can only be credibly conducted by H. H will proliferate by introducing a middle quality to avoid fierce local competition with the existing qualities, as also suggested by Donnenfeld and Weber (1992).

Upon proliferation, H has to incur some fixed cost f, which may be seen as a product-specific-capital, but the unit cost of production is again normalized to zero. Proliferation works like this: first β is chosen and then all three quality products engage in price competition. As

[6] They provide an example from the Indian watch market in which a launch of a high-end brand by a low-end firm was unsuccessful and eventually exited the market.

there are two decisions to be made regarding the middle quality product, quality location and price, H faces options of how much control it wishes to take upon proliferation.

	a. Full Control	**b. Semi-full Control**	**c. Independent Control**
$\boldsymbol{\beta}$ is decided by	H	H	Middle quality as an independent unit
$\boldsymbol{p_m}$ is decided by	H	Middle quality as an independent unit	Middle quality as an independent unit

Table 2.1 Control options of proliferation

As shown in Table 2.1, H can choose from three control options. We specify below the optimisation problem of H with each option respectively.

a. Full Control

$$\max_{\beta, p_h, p_m} \pi_H{}^{pro} = \max_{\beta, p_h, p_m} [\pi_h + \pi_m - f]. \tag{2.2}$$

With this option, H takes full control over proliferation. It sets the quality location and price of the middle quality product, as well as the price of the original high quality product, so as to jointly maximise its total proliferation profits, π_H^{pro}.

b. Semi-full Control

$$\max_{\beta} \pi_H{}^{pro} = \max_{\beta} \left[\left(\max_{p_h} \pi_h + \max_{p_m} \pi_m\right) - f\right], \tag{2.3}$$

where

$$\left.\begin{aligned} \max_{p_h} \pi_h &= \max_{p_h} \ p_h D_h \\ \max_{p_m} \pi_m &= \max_{p_m} \ p_m D_m \end{aligned}\right\}. \tag{2.4}$$

With this option, H sets the location of the middle quality product to maximise total proliferation profits, but does not interfere into price competition. p_h and p_m are chosen to maximise respective unit profits.

c. Independent Control

$$\pi_H{}^{pro} = \max_{p_h} \pi_h + \max_{\beta, p_m} \pi_m - f. \tag{2.5}$$

With this option, the middle quality product acts purely as an independent unit and has freedom to decide its quality location as well as price, whereas H acts as the parent-firm of the middle quality product and collects the profit that it generates.

To determine whether H has an incentive to proliferate and which control option it will choose, we need to compare $\pi_H{}^{pro}$ under options **a**, **b** and **c** to its profit without proliferation, π_H, as solved in Section 2.2.1. Specifically, H will proliferate if $\pi_H{}^{pro} > \pi_H$.

Lemma 2.3 *Under Full Control,* $D_m = 0$ *and* $\pi_H{}^{pro} < \pi_H$ *.* H *has no incentive to proliferate. Any positive* f*, however small, prevents proliferation from being profitable.*

Proof. Appendix A1.

Lemma 2.3 says that the market is unaffected by proliferation under Full Control: demand and profit allocations remain the same as in the two-quality environment. When making quality-price decision jointly, H has no incentive to introduce a quality level that is different from the existing qualities.

Lemma 2.4 *Under Semi-full Control,* $p_m \to 0$ *and* $\pi_H{}^{pro} < \pi_H$ *.* H *has no incentive to proliferate.*

Proof. Appendix A2.

Under Semi-full Control, the profit maximizing level of β is approaching 1. This means that the difference between s_m and s_l is infinitesimally small and the middle quality product in fact joins the Bertrand competition with the low quality segment. As a result, despite positive D_m, π_m is zero. Again, any positive f would lead to a decrease in π_H if proliferation happens.

Lemma 2.5 *Under Independent Control,* $\beta = 3/7$ *and* $s_m = 3s_l/7 + 4s_h/7$. *The middle quality product makes a positive profit.*

Proof. Appendix A2.

The middle quality product is closer to but different from the high quality product, which would never be the case under the first two controls. It is intuitive that given $p_l = 0$, s_m needs to be sufficiently differentiated from s_l in order for the middle quality product to be attractive. Among the three control options, Independent Control is the only option with which proliferation actually expands the quality configuration and the proliferated product generates a positive profit. However, it remains to be checked whether proliferation can increase total profits.

Lemma 2.6 *Under Independent Control,* ${\pi_H}^{pro} = \bar{\theta}^2 d/6 - f < \pi_H$. *H has no incentive to proliferate.*

Proof. Appendix A2.

While ${\pi_H}^{pro} < \pi_H$ for all three control options, Independent Control is the least profitable for H, despite that it is the only option with which $\pi_m > 0$. Table 2.2 puts together equilibrium outcomes from the two-quality environment and the Independent Control in the proliferation environment. Total demand in the proliferation environment is $\overline{\theta}$, so the market is fully covered with and without proliferation. Through the introduction of the middle quality product, H has successfully broadened its market segment by taking away $3\overline{\theta}/8$ out of the total

$4\bar{\theta}/8$ demand that the low quality product would have otherwise captured. Proliferation does not reduce the demand for the high quality product, but p_h is halved as a result, which leads to the fall in H's total profits. Specifically, proliferation creates $\pi_m = \bar{\theta}^2 d/48$ but decreases π_h from $12\bar{\theta}^2 d/48$ to $7\bar{\theta}^2 d/48$, therefore is not desirable for H.

Environment	**Price**			**Demand**			**Profit**		
	$\boldsymbol{p_l}$	$\boldsymbol{p_m}$	$\boldsymbol{p_h}$	$\boldsymbol{D_l}$	$\boldsymbol{D_m}$	$\boldsymbol{D_h}$	$\boldsymbol{\pi_l}$	$\boldsymbol{\pi_m}$	$\boldsymbol{\pi_h}$
Two-quality	0	-	$\bar{\theta}d/2$	$\bar{\theta}/2$	-	$\bar{\theta}/2$	0	-	$\bar{\theta}^2 d/4$
Proliferation (IC)	0	$\bar{\theta}d/14$	$\bar{\theta}d/4$	$\bar{\theta}/8$	$7\bar{\theta}/24$	$7\bar{\theta}/12$	0	$\bar{\theta}^2 d/48$	$7\bar{\theta}^2 d/48$

Table 2.2 Two-quality environment *vs.* proliferation environment with independent control

Lemmata 2.3, 2.4 and *2.6* lead to *Proposition 2.1.*

Proposition 2.1 *In the absence of threat of entry, proliferation is not profitable for H under any level of control. Ceteris paribus, H will not initiate proliferation.*

Given that the most moderate level of proliferation of offering only one additional quality cannot be justified on profitability ground, *Proposition 2.1* also implies the undesirability of excessive proliferation. The result suggests the stability of the principle of maximal differentiation in the market configuration featured in this paper. This is however, conditional on no entry threats. Since proliferation is also a candidate for deterrence, it may be optimal for H to do so when the condition is relaxed.

2.2.3 Entry environment

This section examines H's incentive to proliferate in the existing two-quality market, so as to deter a potential entrant E. Upon entry, E makes quality-price decision to ensure positive post-entry surplus.

Lemma 2.7 *E will enter the market with products of quality $s_E = 3s_l/7 + 4s_h/7$. E sets $p_E = \bar{\theta}d/14$ and obtains $\pi_E = \bar{\theta}^2 d/48 - k$, where $k \in [0, \bar{\theta}^2 d/48]$ is the fixed entry cost.*

Since $\pi_E > 0$, E always has an incentive to enter. The quality-price decision made by E is the same as that under Independent Control in the proliferation environment. This is because when making decisions, the independent unit maximises its own profit (and not the total profits of its parent-firm) just as what an entrant would do. The only difference is that π_m generated under Independent Control contributes to the total profits of the parent-firm, ${\pi_H}^{pro}$, whereas E gets to keep π_E for itself.

Suppose that given the distribution of θ, it is never profitable for E to enter with a fourth quality, then anticipating the quality-price decision of E, H has an incentive to proliferate to deter entry if doing so is more profitable than accommodating entry, i.e., if ${\pi_H}^{pro} > {\pi_H}^{E}$.

Proposition 2.2 *In the presence of threat of entry, H's incentive towards proliferation with Independent Control depends on the value of proliferation cost, f, such that*

- ${\pi_H}^{pro} < {\pi_H}^{E}$ for $f \in (\bar{\theta}^2 d/48, \infty)$, *proliferation is not profitable for H;*
- ${\pi_H}^{pro} > {\pi_H}^{E}$ for $f \in [0, \bar{\theta}^2 d/48)$, *$H$ has an incentive to proliferate and achieve a second best profit.*

Proof: When considering proliferation to deter entry, H will choose Independent Control because with this control option, the proliferated product is of quality $s_m = s_E$, thus can restrict the market space available and make it impossible for E to enter,[7] whereas with the other two control options, proliferation does not change the quality configuration in the market. Table 2.3 represents firms' profits in different environments.

[7] In this paper, we focus on whether the high quality incumbent has the incentive to proliferate to deter entry. See, e.g., Dixit (1980) and Judd (1985) for the issue of credibility in entry deterrence.

Environment	Profit of firms		
	$\boldsymbol{H}$	$\boldsymbol{E}$	$\boldsymbol{L_1}, \boldsymbol{L_2}$
Two-Quality	$12\bar{\theta}^2 d/48$	-	0
Proliferation (IC)	$8\bar{\theta}^2 d/48 - f$	0	0
Entry	$7\bar{\theta}^2 d/48$	$\bar{\theta}^2 d/48 - k$	0

Table 2.3 Firms' profits in two-quality, proliferation (IC) and entry environments

Proposition 2.2 is obtained by comparing H's profit in proliferation environment and entry environment. As shown in Table 2.3, H's incentive to proliferate anticipating the decision of E depends on the magnitude of proliferation cost.

Propositions 2.1 and *2.2* together suggest that, when $f > \bar{\theta}^2 d/48$, proliferation is not profitable for H, regardless of whether there is threat of entry. However, when $f \leq \bar{\theta}^2 d/48$, proliferation becomes optimal only if it is used as an abusive exclusionary conduct. That is, even the most moderate level of proliferation of introducing one additional quality may be anticompetitive.

2.3 Welfare analysis

This section examines how consumer surplus and total welfare change when the market has three instead of two qualities. Consumer surplus is generated from the consumption of each quality. In the two-quality market, consumer surplus consists of CS_h from consumers with $\theta \in [\theta_h, \bar{\theta}]$ and CS_l from consumers with $\theta \in [\theta_l, \theta_h)$, where

$$\left.\begin{aligned} CS_h &= \int_{\theta_h}^{\bar{\theta}} (\theta s_h - p_h)\, d\theta \\ CS_l &= \int_{\theta_l}^{\theta_h} (\theta s_l - p_l) d\theta \end{aligned}\right\}. \tag{2.6}$$

In the three-quality market, consumer surplus consists of CS_h from consumers with $\theta \in [\theta_h, \bar{\theta}]$, CS_m from consumers with $\theta \in [\theta_m, \theta_h)$ and CS_l from consumers with $\theta \in [\theta_l, \theta_m)$, where

$$\left.\begin{aligned} CS_h &= \int_{\theta_h}^{\bar{\theta}} (\theta s_h - p_h)\, d\theta \\ CS_m &= \int_{\theta_m}^{\theta_h} (\theta s_m - p_m)\, d\theta \\ CS_l &= \int_{\theta_l}^{\theta_m} (\theta s_l - p_l) d\theta \end{aligned}\right\}. \tag{2.7}$$

Calculation. See Appendix A3.

Summing up consumer surplus and firms' profits, we are able to compare total welfare in different environments, as shown in Table 2.4. Since the third quality could be offered by proliferation or by the entrant, we include both of them for comparison. Proliferation and entry achieve the same consumer surplus, which is greater than the consumer surplus in the two-quality market, whereas they both decrease industry profits.

Environment	**Welfare Comparison**		
	Consumer surplus	**Industry profits**	**Total welfare**
Two-quality	$\bar{\theta}^2 s_h/8 + 3\bar{\theta}^2 s_l/8$	$\bar{\theta}^2 d/4$	$3\bar{\theta}^2 s_h/8 + \bar{\theta}^2 s_l/8$
Three-quality (Proliferation)	$119\bar{\theta}^2 s_h/288 + 91\bar{\theta}^2 s_m/1152 + \bar{\theta}^2 s_l/128 - \bar{\theta}^2 d/6$	$\bar{\theta}^2 d/6 - f$	$119\bar{\theta}^2 s_h/288 + 91\bar{\theta}^2 s_m/1152 + \bar{\theta}^2 s_l/128 - f$
Three-quality (Entry)	$119\bar{\theta}^2 s_h/288 + 91\bar{\theta}^2 s_m/1152 + \bar{\theta}^2 s_l/128 - \bar{\theta}^2 d/6$	$\bar{\theta}^2 d/6 - k$	$119\bar{\theta}^2 s_h/288 + 91\bar{\theta}^2 s_m/1152 + \bar{\theta}^2 s_l/128 - k$

Table 2.4 Welfare comparison

Lemma 2.7 *Moving from two-quality to three-quality market, consumer surplus strictly increases and industry profits strictly decrease, regardless of values of f and k.*

Proof. Appendix A4.

Following *Lemma 2.7*, whether the rise in consumer surplus outweighs the fall in producer surplus depends on the fixed cost upon having the middle quality product.

Proposition 2.3 *Moving from two-quality to three-quality market, the change in total welfare is such that*

- *When the third quality is introduced through H's proliferation, total welfare increases if and only if* $f \in [0, (44s_h + 91s_m - 135s_l)\overline{\theta}^2/1152)$*;*
- *When the third quality is introduced by* E*, total welfare increases if and only if* $k \in [0, (44s_h + 91s_m - 135s_l)\overline{\theta}^2/1152)$.

Proof. Appendix A4.

When the fixed cost is smaller than the critical threshold, having the middle quality product is welfare-enhancing; otherwise total welfare decreases as a result of a large fall in industry profits. Proliferation and entry affect total welfare in the identical way if $f = k$. From a welfare point of view, whether the third quality should be offered by H or E depends on their relative cost of introducing it. If H benefits from the fact that it is already established therefore incurs lower cost, then not only proliferation can increase welfare, it also does in a way that is more efficient than entry. This leads to an interesting result that, despite being an exclusionary conduct carried out deliberately by a dominant firm facing threat of entry, proliferation always benefits consumers and can even increase total welfare.

2.4 Conclusion

Proliferation in horizontal differentiation markets is well understood. As proliferation is becoming increasingly popular in vertical differentiation markets, and many vertically differentiated brands, especially those in the sportswear and fashion apparel industry, have been repeatedly engaging in joint-proliferations, e.g., H&M collaborations, it seems important to investigate proliferation in vertical differentiation markets. This paper provides some initial steps towards this goal.

We offer an evaluation of proliferation by assessing its effects on profitability, entry deterrence and welfare in a simple yet intuitive framework. We highlight the trade-off between softening competition and broadening market segments brought about by proliferation and show that even the most moderate level of proliferation may be anticompetitive. Nonetheless when proliferation is carried out as a division that competes independently with the parent-firm, it always benefits consumers and could even increase total welfare in a way that is more efficient than entry. In addition, we have extended the literature on entrant choice in duopoly markets following the principle of maximal differentiation by endogenously determining the quality level of the additional middle quality product.

In this paper we focus on proliferation incentives of the high quality firm. The current framework, while useful for addressing our research interests, does not allow the low quality segment to play a positive role. To move closer to the real world and replicate joint-proliferation, future research should introduce competition to the high quality segment and horizontal differentiation among high quality firms and low quality firms, and assess the respective incentives of vertically related firms to collaborate. For example, a low quality firm may find it desirable to collaborate with a high quality firm so as to differentiate itself from other low quality firms.

2.5 Appendices A

A1. Proof of *Lemma 2.3*

Expand H's optimisation problem (2.2),

$$\pi_H^{pro} = p_h\left(\overline{\theta} - \frac{p_h - p_m}{\beta d}\right) + p_m\left[\frac{p_h - p_m}{\beta d} - \frac{p_m}{(1-\beta)d}\right] - f.$$

Derive the first order conditions with respect to p_h and p_m

$$\frac{\partial \pi_H^{pro}}{\partial p_h} = \overline{\theta} - \frac{2p_h}{\beta d} + \frac{2p_m}{\beta d} = 0,$$

$$\frac{\partial \pi_H^{pro}}{\partial p_m} = \frac{2p_h}{\beta d} - \frac{2p_m}{\beta d} - \frac{2p_m}{(1-\beta)d} = 0.$$

The second-order conditions are fulfilled. Prices and demands are $p_h = \bar{\theta}d/2$ and $p_m = \bar{\theta}d(1-\beta)/2$; $D_h = \bar{\theta}/2$, $D_m = 0$ and $D_l = \bar{\theta}/2$. Under Full Control, demand allocation stays the same as in the two-quality environment. □

A2. Proofs of *Lemmata 2.4*, 2.*5* and 2.*6*

We first look at independent price competition as in (2.4). Derive the first-order conditions respectively and solve for prices, demands and profits as functions of β and $\bar{\theta}$

$$p_h = \frac{2\overline{\theta}\beta d}{3+\beta},$$

$$p_m = \frac{\overline{\theta}\beta d(1-\beta)}{3+\beta},$$

$$D_h = \frac{2\overline{\theta}}{3+\beta},$$

$$D_m = \frac{\overline{\theta}}{3+\beta},$$

$$D_l = \frac{\overline{\theta}\beta}{3+\beta},$$

$\pi_h = \frac{4\bar{\theta}^2 \beta d}{(3+\beta)^2}$,

$\pi_m = \frac{\bar{\theta}^2 \beta d(1-\beta)}{(3+\beta)^2}$,

$\pi_l = 0$.

Under Semi-full Control, β is set by H to maximise $\pi_h + \pi_m$. We can find that, for $\beta \in (0, 1)$, $\pi_h + \pi_m$ is increasing in β; $\partial(\pi_h + \pi_m)/\partial\beta = \bar{\theta}^2 d(15 - 11\beta)/(3+\beta)^2 > 0$. Hence $\pi_h + \pi_m$ is maximised at $\beta \to 1$. When $\beta \to 1$, $s_m \to s_l$, $p_h \to \bar{\theta}d/2$, which is the same in the two-quality environment, and $p_m \to 0$.

Under Independent Control, β is set to maximise the unit profit of the middle quality product, not total profits

$$\frac{\partial \pi_m}{\partial \beta} = \frac{(3+\beta)^2(\bar{\theta}^2 d - 2\bar{\theta}^2 \beta d) - 2\bar{\theta}^2 \beta d(1-\beta)(3+\beta)}{(3+\beta)^4} = 0.$$

Solve for the above equation and $\beta = 3/7$. The second-order conditions are fulfilled. The equilibrium outcomes are presented in Table 2.2 in Section 2.2.2. □

A3. Calculation of equations 2.6 and 2.7

Expand and solve for (2.6), in the two-quality market

$$CS_h = \frac{1}{2}\overline{\theta}^2 s_h - \overline{\theta} p_h - \frac{1}{2}\theta_h{}^2 s_h + \theta_h s_h = \frac{3}{8}\overline{\theta}^2 s_h - \frac{1}{4}\overline{\theta}^2 d,$$

$$CS_l = \frac{1}{2}\theta_h{}^2 s_l = \frac{1}{8}\overline{\theta}^2 s_l,$$

$$CS = CS_l + CS_h = \frac{1}{8}\overline{\theta}^2 s_h + \frac{3}{8}\overline{\theta}^2 s_l.$$

Expand and solve for (2.7), in the three-quality market

$$CS_h = \frac{1}{2}\overline{\theta}^2 s_h - \overline{\theta} p_h - \frac{1}{2}\theta_h{}^2 s_h + \theta_h s_h = \frac{119}{288}\overline{\theta}^2 s_h - \frac{7}{48}\overline{\theta}^2 d,$$

$$CS_m = \frac{1}{2}{\theta_h}^2 s_m - \theta_h p_m - \frac{1}{2}{\theta_m}^2 s_m + \theta_m s_m = \frac{91}{1152}\overline{\theta}^2 s_m - \frac{1}{48}\overline{\theta}^2 d,$$

$$CS_l = \frac{1}{2}{\theta_m}^2 s_l = \frac{1}{128}\overline{\theta}^2 s_l,$$

$$CS = CS_l + CS_m + CS_h = \frac{119}{288}\overline{\theta}^2 s_h + \frac{91}{1152}\overline{\theta}^2 s_m + \frac{1}{128}\overline{\theta}^2 s_l - \frac{1}{6}\overline{\theta}^2 d.$$

□

A4. Proofs of *Lemma 2.7* and *Proposition 2.3*

Moving from two-quality to three-quality market, consumer surplus strictly increases if

$$\frac{119}{288}\overline{\theta}^2 s_h + \frac{91}{1152}\overline{\theta}^2 s_m + \frac{1}{128}\overline{\theta}^2 s_l - \frac{1}{6}\overline{\theta}^2 d > \frac{1}{8}\overline{\theta}^2 s_h + \frac{3}{8}\overline{\theta}^2 s_l.$$

That is, if

$$\frac{140}{1152} s_h + \frac{91}{1152} s_m > \frac{231}{1152} s_l,$$

which always holds since

$$\frac{140}{1152} s_h + \frac{91}{1152} s_m > \frac{140}{1152} s_m + \frac{91}{1152} s_m,$$

and

$$\frac{231}{1152} s_m > \frac{231}{1152} s_l.$$

It is straightforward to verify that, moving from two-quality to three-quality market, industry profits decrease. Because $1/4 > 1/6$,

$$\frac{1}{4}\overline{\theta}^2 d > \frac{1}{6}\overline{\theta}^2 d - f,$$

and

$$\frac{1}{4}\overline{\theta}^2 d > \frac{1}{6}\overline{\theta}^2 d - k.$$

Proliferation increases total welfare if

$$\frac{119}{288}\bar{\theta}^2 s_h + \frac{91}{1152}\bar{\theta}^2 s_m + \frac{1}{128}\bar{\theta}^2 s_l - f > \frac{3}{8}\bar{\theta}^2 s_h + \frac{1}{8}\bar{\theta}^2 s_l.$$

That is, if

$$f < \frac{44}{1152}\bar{\theta}^2 s_h + \frac{91}{1152}\bar{\theta}^2 s_m - \frac{135}{1152}\bar{\theta}^2 s_l.$$

It is straightforward to verify that the right hand side of the above inequation is strictly positive.

Likewise, entry increases total welfare if

$$k < \frac{44}{1152}\bar{\theta}^2 s_h + \frac{91}{1152}\bar{\theta}^2 s_m - \frac{135}{1152}\bar{\theta}^2 s_l.$$

It follows that, total welfare is higher with proliferation than with entry if and only if $f < k$. □

Chapter 3

A Comparison of the Wholesale Model and the Agency Model in Differentiated Markets

3.1 Introduction

Today individuals shop at high street stores, supermarkets, as well as a variety of online retailers: goods are passing through more elaborate supply and distribution chains. The manufacturer-retailer contracts linking the vertical relations, not surprisingly, are not always identical. Among the various vertical contracts observed in practice, this paper deals with two, the wholesale model and the agency model. Under the wholesale model, a manufacturer sets the wholesale price and sells to a retailer, and the retailer sets the retail price and deals with final consumers. Under the agency model, a retailer specifies the revenue-sharing rate, before selling to final consumers at the retail price set by a manufacturer. The agency model involves resale price maintenance (RPM) because the retail price is set the by the manufacturer, not the retailer.

While the wholesale model remains common in a bricks-and-mortar environment, the agency model becomes predominant in online markets. Some natural questions to ask then would be why a certain vertical contract is chosen against the others, and which contract is beneficial to consumers. These questions appear more relevant given the (in) famous *Apple*[1] case that involved the switch of vertical contracts from the wholesale to the agency model. Plausibly also due to the fact that the agency model has been adopted by several giant online retailers, e.g., Amazon marketplace, Apple, eBay, Google and various booking websites, concerns might arise regarding the nature of such contract, the powerful position of those retailers and whether consumers and market performance are harmed as a consequence. At least the Department of Justice's decision on forcing publishers to move away from the agency model of selling e-books seems to send such a signal.

In fact, *Apple* was not the first antitrust case in which distinctions between the wholesale and agency models were highlighted. In the 1967 *Schwinn*[2] case which involved the adoption of territorial restraints, the U.S. Supreme Court decided that the *per se* illegality of vertical restraints applied to the transactions in which Schwinn sold bicycles to distributors for resale to dealers, i.e., a wholesale model under which the ownership of bicycles was transferred; but those in which Schwinn sold and shipped directly to dealers and paid distributors a commission for taking the order, i.e., an agency model under which Schwinn retained the ownership of bicycles, were legal. That is, the same vertical restraints were treated differently under wholesale and agency models, and the judicial reasoning was the legal ownership of property.

Linking *Apple* and *Schwinn*, the antitrust view towards the agency model seems to be somewhat inconsistent. One may argue that it is due to the different contexts in which the vertical restraints are adopted. *Apple* involved multiple vertical restraints as well as horizontal

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[1] U.S. *v*. Apple Inc., *et al*. 12 Civ. 2826 (DLC), the State of Texas, *et al. v*. Penguin Group Inc., *et al*. 12 Civ. 3394 (DLC) (2013). In April 2010, five large book publishers in the US switched from the wholesale model, which they used to have with Amazon, of selling e-books to the agency model put forward by Apple. Following the price rise of e-books after the switch of vertical contracts, the Department of Justice has lodged a complaint against Apple and publishers for their contractual agreements. The agreement between Apple and publishers also included a price parity provision, the Most Favoured Nation Clause. For details see *Competition Law Journal* Concurrences No.3-2012 on "e-Books and the Boundaries of Antitrust".

[2] U.S. *v*. Arnold, Schwinn & Co. 388 U.S. 365 (1966). From the 1950s, Schwinn adopted a selective distribution system and imposed territorial and customer restraints to its distributors and dealers. Its distributors were only authorized to sell to franchised dealers in their assigned territories, and dealers were only allowed to sell from authorized locations. Meanwhile, its distribution method, the Schwinn Plan, allowed Schwinn to sell and ship bicycles using various ways and not necessarily through its distributors.

conspiracy among the publishers, and the agency model was a complementary device to the price fixing clause used. Yet, the Court's reasoning in *Schwinn* that "…it is unreasonable *without* more for a manufacturer to seek to restrict and confine areas or persons with whom an article may be traded after the manufacturer has parted with dominion over it"[3] was heavily criticized as "it may indicate that such confinement is unlawful absent an acceptable business justification" (ABA Antitrust Section, 1977). In this view, instead of the ownership of property, what should be evaluated is the actual impact of restraints on market performance and how such impact differ under wholesale and agency models.

While the linear price wholesale model is well understood as the basic form of vertical relations in economic theory (Tirole, 1988), recent papers studying the agency model tend to focus more on specific issues related to the e-book market, such as device, e.g. Kindle (Gaudin and White, 2014), the Most Favoured Nation (MFN) clause (Boik and Corts, 2013) and consumer lock-in (Johnson, 2013), rather than the systematic analysis of the agency model *per se*.

In this paper, we seek to examine the agency model and compare it to the wholesale model, which constitutes the basis of understanding some transformations in vertical relations. We do so in a bilateral duopoly framework developed by Dobson and Waterson (1996, 2007) which incorporates both interbrand competition, i.e., competition between manufacturers, and intrabrand competition, i.e., competition between retailers. When making comparisons, we focus on welfare conditions and the relative profitability of the alternative schemes for manufacturers and retailers. We then interpret how results obtained from the comparison are relevant and useful for the understanding of the nature of the agency model, as well as the antitrust treatment of restraints of this kind.

Regarding welfare conditions, we find that in symmetric equilibrium, retail prices are always lower under the agency model relative to the wholesale model. The driving force is double marginalisation: it exists under the wholesale model and disappears under the agency model. Consumer surplus is always higher under the agency model, whereas industry profits

[3] 388 U.S. at 379.

are higher under the wholesale model for a wider range of degrees of product differentiation in the market. Social surplus is higher under the agency model provided that manufacturers' goods are sufficiently differentiated. Given these results, if courts were to distinguish between restraints involved in sale and nonsale transactions, as they did in *Schwinn*, the verdict might be more reasonably based on how welfare impacts of restraints differ in these two scenarios – the agency model is more beneficial to consumers – instead of the legal ownership of property.

Regarding the relative profitability of the alternative schemes for manufacturers and retailers, we find that manufacturer profits are always higher under the wholesale model, whereas retailer profits are higher under the agency model unless manufacturers' goods are close substitutes. This result offers two insights. First, although manufacturers, *ceteris paribus*, have no profit-driven incentive to switch away from the wholesale model, the switch is considerably likely in favour of retailers. The popularity of the agency model in some markets in turn implies the powerful position of retailers in those markets. Second, retailers can benefit from the differentiation at the manufacturer level under the agency model, which contrasts with the inverse association suggested by Steiner (1993) that stronger brands tend to lead to lower retail margins and higher manufacturing margins. Hence manufacturers and retailers' incentives are better aligned under the agency model.

The economic theory on vertical restraints has been traditionally concerned with *manufacturer power* restraints imposed by manufacturers to neutralize potential externalities and induce retail service, assuming that retailers have no market power (e.g., Telser, 1960), or some market power (e.g., Mathewson and Winter, 1984). Relating the above result to this strand of the literature, an interesting question arises as why manufacturers would adopt the agency model. In his re-evaluation of *Schwinn*, Grimes (2007) tells the story behind the case as "an insecure brand seller imposes downstream power restraints."[4] Downstream or *retailer power* restraints, he further defines, "may be imposed by the upstream seller, but the seller acts

[4] He writes, "In 1952, Schwinn had 22.5% of the market…Schwinn's share fell to 12.8% by 1961. It was precisely during this period that Schwinn was actively implementing a selective distribution system designed to insulate retailers from competition and allow them to charge a higher margin. Schwinn was, at this point, an insecure brand seller."

in response to conditions of downstream power." In this view, the agency model may be an example of retailer power RPM, adopted by manufacturers who are in need of brand promotion. While such retail power restraints also serve to induce retail service provision, the underlying assumption of the power relation between manufacturers and retailers is different from the traditional view. This might plausibly also have been part of the story in *Apple*.[5]

Relative to the wholesale model, the higher consumer surplus and better alignment of incentives under the agency model constitute a conflict, which is critical in determining the antitrust status of restraints of this kind: they benefit consumers but undercut competition. The evolution of the antitrust treatment of vertical restraints from *per se* rules to the rule of reason suggests the scope of applying the rule of reason in treating restraints of this kind.[6] While some retailer power restraints do not meaningfully harm consumers or competition, such as those in *Schwinn*, some others do. With the alignment of incentives, the agency model is prone to additional and potentially more harmful restraints, such as the MFN clause involved in *Apple*.[7] Based on our results, we consider the economic analysis of the actual impact of restraints, instead of the ownership of property, to be a better support for applying the rule of reason in treating the agency model.

The paper proceeds as follows. Section 3.2 reviews the related literature. Section 3.3 presents the framework for our analysis, in which we characterize the vertical relation first by the wholesale model and then by the agency model. Section 3.4 compares the symmetric equilibrium outcomes under the two models. Section 3.5 discusses the results. Section 3.6 concludes.

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[5] 12 Civ. 2826 (DLC) (2013). The publishers were upset by Amazon's $9.99 prevailing price policy which they feared that would erode the value and price of books, including hardcover books. They agreed to switch from the wholesale to the agency model upon Apple's proposal. Apple was found to have "played a central role in facilitating and executing that conspiracy. Without Apple's orchestration of this conspiracy, it would not have succeeded as it did in the Spring of 2010."

[6] In 1977, the U.S. Supreme Court applied the rule of reason in *Sylvania* (433 U.S. 36) in deciding the legality of nonprice restraints, which reversed the 10-year-old decision of the *per se* illegality of such restraints in *Schwinn*. In 2007, the Court overruled its decision that RPM was illegal *per se* in *Dr. Miles* (220 U.S. 373) by applying the rule of reason in *Leegin* (551 U.S. 877).

[7] 12 Civ. 2826 (DLC) at 47. "The MFN guaranteed that the e-books in Apple's e-bookstore would be sold for the lowest retailer price available in the marketplace." See Foros, Kind and Shaffer (2015) for an analysis of how the MFN clause can induce the adoption of the agency model.

3.2 Related literature

This paper is related to the law and economics literature on vertical restraints. Vertical restraints are imposed by manufacturers to cope with vertical externalities such as double marginalisation, and horizontal externalities such as pre-sale service underprovision due to intrabrand competition (Tirole, 1988). Restraints, especially those to neutralize horizontal externalities, often allow retailers to capture some of the industry rents. These rents have been used to provide a procompetitive theory of restraints: manufacturers may use these rents to entice retailers to provide promotional efforts which are often costly. For example, Marvel and McCafferty (1996) compare the efficiency of using RPM and exclusive territories to combat free-riding. On the other hand, these rents may be used in anticompetitive ways by facilitating collusion and blocking new entrants. For example, Shaffer (1991) compares RPM and slotting allowances and find that both restraints increase prices and retail profits, and may be seen as practices to facilitate coordination. Asker and Bar-Isaac (2014) suggest that the rents created by restraints for retailers can induce them not to accommodate an entrant to the manufacturer level since entry would reduce those rents.

The above literature suggests that the anticompetitive effects of restraints are mostly likely to arise when they are introduced to dampen intrabrand competition and are not meant to enhance the efficiency of the vertical relation. This may explain why retailer-sponsored "competition-reducing" restraints are almost always considered to increase prices and harm consumers, and thus are presumptively unlawful (Tirole, 1988). For example, Dobson and Waterson (2007) examine the effects of RPM in the presence of countervailing power and find that the social effects of RPM are likely to be negative when retailer power is strong.

In this paper, we show that although the agency model is likely to relax competition and increase retailer profits, it is beneficial to consumers and can be socially desirable. We suggest the agency model to be better understood as an example of retailer power restraints that we mentioned in Section 3.1. A major difference between retailer-sponsored "competition-reducing" restraints and retailer power restraints, as suggested by Grimes (2007), is that retailer power restraints are imposed with genuine business purposes, although intrabrand competition may be reduced as a result. Specifically, strong brands have little incentive to impose restraints that benefit retailers, because retailers who do not promote these brands to increase sales would be worse off. However, weak or insecure manufacturers would have to provide extra incentives to induce retailers to promote their brands, even if it is costly for them to do so. This corresponds to the empirically verified inverse association between the strength of brands and retail margins (Steiner, 1993; Lynch, 2004).

From both law and economics perspectives, contemporary vertical restraint theory recognises retailing as a distinct stage of vertical relations and that it is wrong to neglect the role of intrabrand competition in affecting consumers' choices, as well as the exercise of countervailing power (e.g., Steiner, 1991; Dobson and Waterson, 1999). The understanding of the agency model as retailer power RPM is meaningful as it helps to distinguish the agency model from being perceived as a form of vertical integration which ignores the changing power relation between manufacturers and retailers.[8]

Among the recent studies that compare different vertical contracts, our characterization of the agency model follows Foros, Kind and Shaffer (2013), but the counterparts used for comparison differ in their paper and ours. Their paper compares the agency model to an alternative model in which the revenue sharing rate and the retail price are both set by retailers, whereas our benchmark is the wholesale model. In addition, they focus on the equilibrium contract selection problem of firms and allow different contracts to be used in the same market, whereas we assume common contracts and focus on the different effects of restraint on competition and welfare.

The comparison between the wholesale and the agency models is also made in Johnson (2014), who studies the effects of MFN clauses based on the comparison. Results regarding retailer profits and industry profits in his paper are different from ours and the differences arise because of different demand functions used and different assumptions on market coverage. While he assumes market coverage to be full, changes in demand are important in our paper.

[8] For example, Liu and Shuai (2015) view the agency model as vertical integration and neglect the division of industry profits between manufacturers and retailers.

A further related strand of literature is on markets with intermediaries. Comparisons have been made between the two forms of intermediation: the intermediary buys and resells a product, or simply refers buyers for a fee (Bellaflamme and Peitz, 2010). Condorelli *et al*. (2013) suggest that, when information is asymmetric – the intermediary has privileged information about consumers, efficiency increases when the latter form is used.

3.3 Model

We consider a market with two manufacturers, $j = 1$, 2, and two retailers, $i = 1$, 2. Each manufacturer j produces a single good j and each retailer i presents final consumers with goods from both manufacturers, i.e., $q_i^j > 0$, such that vertical contracts are nonexclusive. Correspondingly, consumers are able to choose from four "final goods" and thus make two decisions: which retailer store to shop and which manufacturer good to buy. This is intuitive as firms in vertically related markets compete not only horizontally with firms at the same level over consumer demand, but also vertically with firms at the other level over their respective shares of retail prices. We assume manufacturer goods and retailer services to be symmetrically differentiated and all production costs to be zero.

Following Dobson and Waterson (1996, 2007) and Gabrielsen and Johansen (2015), we assume the consumers making decisions to maximise

$$U(\boldsymbol{q}) = \sum_{ij} q_i^j - \frac{1}{2}(q_i^j)^2 - \beta\left(q_i^j q_{-i}^j + q_i^{-j} q_{-i}^{-j}\right) - \gamma\left(q_i^j q_i^{-j} + q_{-i}^j q_{-i}^{-j}\right)$$
$$- \beta\gamma\left(q_i^j q_{-i}^{-j} + q_{-i}^j q_i^{-j}\right).$$

This utility function gives rise to the downward sloping inverse demand function

$$p_i^j = 1 - q_i^j - \beta q_{-i}^j - \gamma q_i^{-j} - \beta\gamma q_{-i}^{-j}. \tag{3.1}$$

The parameter $\beta \in [0, 1)$ measures the degree of intrabrand competition between retailers' services and the parameter $\gamma \in [0, 1)$ measures the degree of interbrand competition between goods.[9] Retailers' services are perceived to be perfectly differentiated when $\beta = 0$ and become closer substitutes as $\beta \to 1$. Likewise, when $\gamma = 0$, the two goods are viewed as perfectly differentiated and demand-unrelated, as $\gamma \to 1$, they become closer substitutes. We assume that firms behave non-cooperatively. The direct demand function is given by

$$q_i^j = \frac{(1-\beta)(1-\gamma)-p_i^j+\gamma p_i^{-j}+\beta(p_{-i}^j-\gamma p_{-i}^{-j})}{(1-\beta^2)(1-\gamma^2)}. \tag{3.2}$$

The quantity demanded for good j at retailer i is a function of own price, p_i^j, prices of two relatively closer substitutes, p_i^{-j} and p_{-i}^j, and the price of another substitute that is further away in the product space, p_{-i}^{-j}. Given the ranges of parameters, it can be easily verified that own-price effect dominates each cross-price effect.

The above direct demand system has two features worth highlighting. First, the cross-price effect between different goods presented by different retailers is negative; $\partial q_i^j / \partial p_{-i}^{-j} = -\beta\gamma/(1-\beta^2)(1-\gamma^2) < 0$, which contrasts to our knowledge that as the price of one good increases, the demand of its substitute increases. Gabrielsen and Johansen (2015) suggest that the negative cross-price effect can be explained as a "second-order effect". More specifically, as p_{-i}^{-j} increases, consumers would optimally switch away from good $(-i, -j)$ and demand more $(i, -j)$ and $(-i, j)$, as these two are relatively closer substitutes to $(-i, -j)$. However, as more $(i, -j)$ and $(-i, j)$ are consumed, being relatively closer substitutes to them, (i, j) would consequently be demanded less. This negative "second-order effect" dominates the direct substitution effect, leading to a negative cross-price effect.

Second, demand is decided by two countervailing effects: a price effect and a market size effect. For a common price, demand becomes $(1-p)/\,(1+\beta)(1+\gamma)$, which is increasing

[9] Dobson and Waterson (1996) assume $\gamma \in (-1, 1)$ where a negative γ indicates that the goods are complements. We do not consider this case in this paper.

in degrees of differentiation in the market. This means that high demand may be driven by low prices or highly differentiated products. Some studies consider vertical restraints that increase demand to be presumptively procompetitive (e.g., Bork, 1978), some others argue that consumers may "end up with the wrong product at the wrong price" (Grimes, 2007). Overall this demand system allows for differentiation at both levels of the vertically related market to be parameterised in a convenient form, offering clear and tractable solutions.

Suppose that manufacturers cannot directly reach final consumers, we characterise the vertical relation first under the wholesale model and then under the agency model. We focus on symmetric equilibrium throughout the analysis.

3.3.1 The wholesale model

The timing under the wholesale model is as follows

1. Manufacturers set wholesale prices simultaneously. The wholesale price set by manufacturer j to retailer i is w_i^j,
2. Retailers set retail prices simultaneously. The price set by retailer i for good j is p_i^j.

Retailer i, denoted as R_i, faces the following optimisation problem

$$\max_{p_i^1,\ p_i^2} \pi_{R_i} = \max_{p_i^1,\ p_i^2} [(p_i^1 - w_i^1)q_i^1 + (p_i^2 - w_i^2)q_i^2]. \tag{3.3}$$

The corresponding first-order condition is given by

$$\frac{\partial \pi_{R_i}}{\partial p_i^1} = q_i^1 + \left(p_i^1 - w_i^1\right)\frac{\partial q_i^1}{\partial p_i^1} + \left(p_i^2 - w_i^2\right)\frac{\partial q_i^2}{\partial p_i^1} = 0. \tag{3.4}$$

From (3.4), we get

$$p_1^1 = \frac{(1-\beta)(1-\gamma)+\beta\left(p_2^1-\gamma p_2^2\right)+2\gamma p_1^2+w_1^1-\gamma w_1^2}{2},$$

$$p_2^1 = \frac{(1-\beta)(1-\gamma)+\beta\left(p_1^1-\gamma p_1^2\right)+2\gamma p_2^2+w_2^1-\gamma w_2^2}{2},$$

$$p_1^2 = \frac{(1-\beta)(1-\gamma)+\beta\left(p_2^2-\gamma p_2^1\right)+2\gamma p_1^1+w_1^2-\gamma w_1^1}{2},$$

$$p_2^2 = \frac{(1-\beta)(1-\gamma)+\beta\left(p_1^2-\gamma p_1^1\right)+2\gamma p_2^1+w_2^2-\gamma w_2^1}{2}.$$

Solve for the above

$$p_1^1 = \frac{(2+\beta)(1-\beta)+2w_1^1+\beta w_2^1}{4-\beta^2},$$

$$p_2^1 = \frac{(2+\beta)(1-\beta)+2w_2^1+\beta w_1'^1}{4-\beta^2},$$

$$p_1^2 = \frac{(2+\beta)(1-\beta)+2w_1^2+\beta w_2^2}{4-\beta^2},$$

$$p_2^2 = \frac{(2+\beta)(1-\beta)+2w_2^2+\beta w_1^2}{4-\beta^2}.$$

Substitute the equilibrium second-stage prices into the direct demand function (3.2), we get the second-stage quantities demand

$$q_1^1 = \frac{\beta\left(w_2^1-\gamma w_2^2\right)-(2-\beta^2)(w_1^1-\gamma w_1^2)}{(4-\beta^2)(1-\beta^2)(1-\gamma^2)} + \frac{1}{(2-\beta)(1+\beta)(1+\gamma)},$$

$$q_2^1 = \frac{\beta\left(w_1^1-\gamma w_1^2\right)-\left(2-\beta^2\right)\left(w_2^1-\gamma w_2^2\right)}{(4-\beta^2)(1-\beta^2)(1-\gamma^2)} + \frac{1}{(2-\beta)(1+\beta)(1+\gamma)},$$

$$q_1^2 = \frac{\beta(w_2^2-\gamma w_2^1)-(2-\beta^2)(w_1^2-\gamma w_1^1)}{(4-\beta^2)(1-\beta^2)(1-\gamma^2)} + \frac{1}{(2-\beta)(1+\beta)(1+\gamma)},$$

$$q_2^2 = \frac{\beta(w_1^2-\gamma w_1^1)-(2-\beta^2)(w_2^2-\gamma w_2^1)}{(4-\beta^2)(1-\beta^2)(1-\gamma^2)} + \frac{1}{(2-\beta)(1+\beta)(1+\gamma)}.$$

Manufacturer j, denoted as S^j, faces

$$\max_{w_1^j, w_2^j} \pi^j = \max_{w_1^j, w_2^j} w_1^j q_1^j + w_2^j q_2^j. \tag{3.5}$$

The corresponding first-order condition is given by

$$\frac{\partial \pi^j}{\partial w_1^j} = q_1^j + w_1^j \frac{\partial q_1^j}{\partial w_1^j} + w_2^j \frac{\partial q_2^j}{\partial w_1^j} = 0. \tag{3.6}$$

From (3.6), we get

$$w_1^1 = \frac{(2-\beta^2)\gamma w_1^2 + 2\beta w_2^1 - \beta\gamma w_2^2 + (2+\beta)(1-\beta)(1-\gamma)}{2(2-\beta^2)},$$

$$w_2^1 = \frac{(2-\beta^2)\gamma w_2^2 + 2\beta w_1^1 - \beta\gamma w_1^2 + (2+\beta)(1-\beta)(1-\gamma)}{2(2-\beta^2)},$$

$$w_1^2 = \frac{(2-\beta^2)\gamma w_1^1 + 2\beta w_2^2 - \beta\gamma w_2^1 + (2+\beta)(1-\beta)(1-\gamma)}{2(2-\beta^2)},$$

$$w_2^2 = \frac{(2-\beta^2)\gamma w_2^1 + 2\beta w_1^2 - \beta\gamma w_1^1 + (2+\beta)(1-\beta)(1-\gamma)}{2(2-\beta^2)}.$$

Imposing symmetry, the equilibrium wholesale prices, denoted as w^*, are therefore

$$w^* = \frac{1-\gamma}{2-\gamma}. \tag{3.7}$$

The symmetric equilibrium retail prices and demand, denoted as p^* and q^*respectively, are given by

$$p^* = \frac{(1-\beta)(2-\gamma)+1-\gamma}{(2-\beta)(2-\gamma)},$$

$$q^* = \frac{1}{(1+\beta)(2-\beta)(1+\gamma)(2-\gamma)}.$$

p^* decreases in β and γ: higher values of β and γ mean lower degrees of differentiation between goods and services, thus lower prices. q^* initially decreases and then increases in β and γ. This is because, as we mentioned earlier, demand is decided by two countervailing effects. As β and γ increase, on the one hand, goods and services become less differentiated and demand falls; on the other hand, price decreases and demand increases. Whether demand increases or decreases in β and γ thus depends on which effect is stronger.

We present the complete set of symmetric equilibrium results under the wholesale model, including firms' profits in the following lemma.

Lemma 3.1 *Under the wholesale model, there exists a symmetric equilibrium in which*

- $w^* = (1-\gamma)/(2-\gamma)$;
- $p^* = [(1-\beta)(2-\gamma)+1-\gamma]/(2-\beta)(2-\gamma)$;
- $q^* = 1/(1+\beta)(2-\beta)(1+\gamma)(2-\gamma)$;
- $\pi^j = 2(1-\gamma)/(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)^2$;
- $\pi_i = 2(1-\beta)/(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2$.

3.3.2 The agency model

The timing under the agency model is as follows

1. Retailers declare revenue sharing rates simultaneously. The revenue sharing rate set by retailer i is $\alpha_i \in [0,1)$, with manufacturers retaining $(1 - \alpha_i)$ of the revenue.[10]
2. Manufacturers set retail prices simultaneously. The price set by manufacturer j to retailer i is p_i^j.

Under this model, S^j controls the retail price and faces the following optimisation problem

$$\max_{p_1^j,\, p_2^j} \pi^{S^j} = \max_{p_1^j,\, p_2^j} [(1 - \alpha_1)p_1^j q_1^j + (1 - \alpha_2)p_2^j q_2^j]. \tag{3.8}$$

The corresponding first-order condition is given by

$$\frac{\partial \pi^{S^j}}{\partial p_1^j} = (1 - \alpha_1)(q_1^j + p_1^j \frac{\partial q_1^j}{\partial p_1^j}) + (1 - \alpha_2)p_2^j \frac{\partial q_2^j}{\partial p_1^j} = 0. \tag{3.9}$$

Given symmetry, we get

$$p_i = \frac{(1-\beta)(1-\gamma)\left[(2-\gamma)+\beta(1-\gamma)+\frac{\beta(1-\alpha_{-i})}{1-\alpha_i}\right]}{(2-\gamma)^2-\beta^2\left[1+(1-\gamma)^2+\frac{(1-\gamma)[(1-\alpha_i)^2+(1-\alpha_{-i})^2]}{(1-\alpha_i)(1-\alpha_{-i})}\right]},$$

$$q_i = \frac{(2-\gamma)^2-\beta^2\left[1+(1-\gamma)^2+\frac{(1-\gamma)[(1-\alpha_i)^2+(1-\alpha_{-i})^2]}{(1-\alpha_i)(1-\alpha_{-i})}\right]-(1-\gamma)\left[(1-\beta)+(1-\beta^2)(1-\gamma)+\beta(\frac{1-\alpha_{-i}}{1-\alpha_i}-\frac{\beta(1-\alpha_i)}{1-\alpha_{-i}})\right]}{(2-\gamma)^2(1+\beta)(1+\gamma)-\beta^2\left[1+(1-\gamma)^2+\frac{(1-\gamma)[(1-\alpha_i)^2+(1-\alpha_{-i})^2]}{(1-\alpha_i)(1-\alpha_{-i})}\right](1+\beta)(1+\gamma)}.$$

R_i faces the following optimisation problem

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[10] We allow retailers to specify one sharing rate that applies to both manufacturers, and this does not conflict with what we observe in real life. For example, Apple claimed the same rate to all book publishers and Google claims the same rate to all apps developers.

$$\max_{\alpha_i} \pi_{R_i} = \max_{\alpha_i} \alpha_i(p_i^1 q_i^1 + p_i^2 q_i^2), \tag{3.10}$$

which is solved in Foros *et al*. (2013)[11]. Given their results, the symmetric equilibrium revenue sharing rates are, denoted as α^*

$$\alpha^* = \frac{(2-\gamma)(1-\beta^2)}{2-\gamma(1+\beta)}. \tag{3.11}$$

The symmetric equilibrium retail prices and demand under the agency model, denoted as p_A^* and q_A^* respectively, are given by

$$p_A^* = \frac{1-\gamma}{2-\gamma},$$

$$q_A^* = \frac{1}{(1+\beta)(1+\gamma)(2-\gamma)}.$$

p_A^* decreases in γ. q_A^* and γ exhibit a U-shape relationship for the same reason as under the wholesale model: demand is decided by two countervailing effects. However, under the agency model, β does not affect p_A^*, hence it affects demand only through the negative market size effect.

The following lemma summarises the complete set of symmetric equilibrium results under the agency model.

Lemma 3.2 *Under the agency model, there exists a symmetric equilibrium in which*

- $\alpha^* = (2-\gamma)(1-\beta^2)/[2-\gamma(1+\beta)]$*;*
- $p_A^* = (1-\gamma)/(2-\gamma)$*;*
- $q_A^* = 1/(1+\beta)(1+\gamma)(2-\gamma)$*;*

[11] Our analysis of retailers' optimisation problems under the agency model is analogous to Foros *et al*. (2013).

- $\pi_A^j = 2\beta(1-\gamma)[2\beta - \gamma(1+\beta)]/(1+\beta)(1+\gamma)(2-\gamma)^2[2-\gamma(1+\beta)]$;
- $\pi_{iA} = 2(1-\beta)(1-\gamma)/(1+\gamma)(2-\gamma)[2-\gamma(1+\beta)]$.

3.4 Comparison

In this section we compare the symmetric equilibrium outcomes under the two models. We start with the following proposition.

Proposition 3.1 *In equilibrium, retail prices are lower, quantities demanded are higher and consumer surplus is higher under the agency model than under the wholesale model.*

Proof. Appendix B1.

Proposition 3.1 is driven by the elimination of double marginalisation under the agency model. To show this, we write p^* as the sum of two mark-ups[12]

$$\underbrace{w^*}_{1st} + \underbrace{p^* - w^*}_{2nd} = \underbrace{\frac{1-\gamma}{2-\gamma}}_{1st} + \underbrace{\frac{1-\beta}{(2-\beta)(2-\gamma)}}_{2nd}. \tag{3.12}$$

As $p_A^* = (1-\gamma)/(2-\gamma) = w^*$, the total mark-up under the agency model is equivalent to the first mark-up under the wholesale model.

Double marginalisation as the driving force indicates that when the second mark-up under the wholesale model becomes zero, there should not be any difference between the equilibrium outcomes under the two models. This is indeed the case as $\beta \to 1$ and $(1-\beta)/\,(2-\beta)(2-\gamma) \to 0$. The intuition is, when retailers' services are close substitutes, retailers are neither able to price above costs (i.e., w^*) under the wholesale model, nor to demand positive shares from the manufacturers under the agency model. Hence, some degrees of differentiation between retailers are essential for us to distinguish between the equilibrium outcomes under

[12] The first mark-up is w^* as we assume that firms incur zero marginal costs.

the two models. As long as β is smaller than one, we are able to rank the two sets of equilibrium outcomes.

Proposition 3.2 *In equilibrium, there exists a* $\gamma' \in [0,1)$ *such that social surplus is higher under the agency model than under the wholesale model if* $\gamma \in [0, \gamma')$.

Proof. Appendix B2.

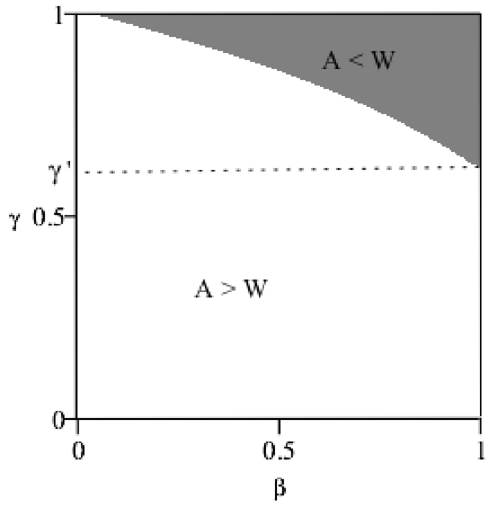

Figure 3.1 Social surplus

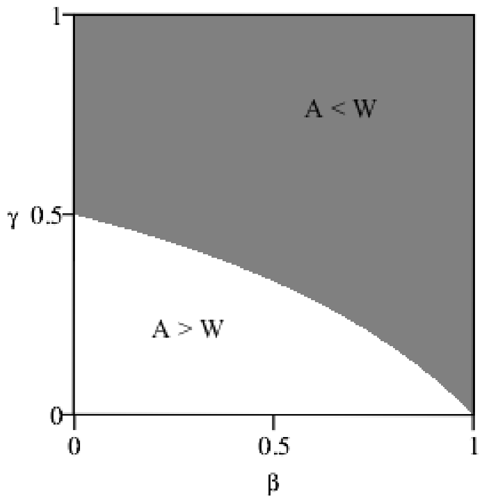

Figure 3.2 Industry profits

Proposition 3.2 says that the agency model is socially desirable given that manufacturers' goods are sufficiently differentiated. We illustrate the comparison of social surplus between the two models in Figure 3.1 to complement *Proposition 3.2*. As we observe, when the condition $\gamma \in [0, \gamma')$ is not satisfied, it is still possible for social surplus to be higher under the agency model, but would place additional conditions on β, e.g., as γ is close to one, β needs to be close to zero for social surplus to be higher under the agency model. It follows that the difference in social surplus between the two models is more responsive to changes in differentiation at the manufacturer level.

The results on consumer surplus and social surplus from *Propositions 3.1* and 3*.2* imply that the rank of equilibrium industry profits under the two models depends on values of β and γ. Figure 3.1 and Figure 3.2 together offers two more observations worth highlighting. First, suppose that both β and γ are independently and equally likely to take up any value over the interval $[0,1)$. Then there are more pairs of β and γ such that industry profits are lower and social surplus is higher under the agency model than under the wholesale model.

Second, when goods and services are approximately homogenous, i.e., $\beta \to 1$ and $\gamma \to 1$, industry profits and social surplus are both relatively higher under the wholesale model. However, when social surplus becomes higher under the agency model but industry profits remain higher under the wholesale model, policy concerns might arise if the wholesale model is adopted. The higher industry profits obtained are at the expense of using the "wrong" vertical contract, especially given *Propositions 3.1* that consumer surplus is always higher under the agency model.

We now compare how industry profits are divided between manufacturers and retailers under the two models. This not only helps to explain the observed comparison of industry profits, but also offers insights on how the power relations between manufacturers and retailers differ under the two models. As vertical restraints theory distinguishes between restraints imposed under manufacturer and retailer power, understanding the division of profits is therefore useful in determining the nature of a particular restraint.

Proposition 3.3 *In equilibrium, manufacturer profits are lower under the agency model than under the wholesale model, whereas there exists a* $\gamma'' \in (\gamma', 1)$ *such that retailer profits are higher under the agency model than under the wholesale model if* $\gamma \in [0, \gamma'')$*.*

Proof. Appendix B3.

Under the wholesale model, manufacturers' per-unit profits are precisely $w^* = (1 - \gamma)/(2 - \gamma)$, whereas under the agency model, their per-unit profits are their shares of p_A^*, $(1 - \alpha)(1 - \gamma)/(2 - \gamma)$, which are strictly lower than w^*. Overall for manufacturers, the effect of relatively higher per-unit profits under the wholesale model always outweighs the effect of relatively higher demand under the agency model. In contrast, retailer profits, as illustrated in Figure 3.3, are relatively higher under the agency model as along as manufacturers' goods are sufficiently differentiated, i.e., γ is not too high, regardless of degrees of differentiation at their own level.

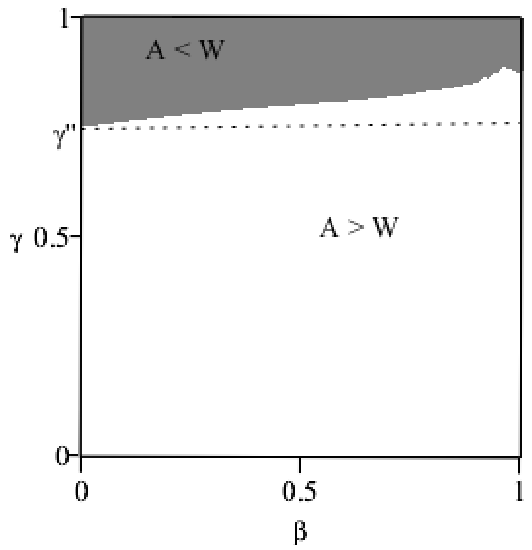

Figure 3.3 Retailer profits

Proposition 3.3 has two implications. First, moving from the wholesale to the agency model, manufacturers are clearly worse off, therefore the agency model is never preferred by manufacturers. Instead, the agency model, *per se* a form of RPM, is likely to be in favour of retailers. Second, retailers can benefit from high degrees of differentiation at the manufacturer level, implying that the two parties' incentives are better aligned.

We explain the second implication further. As we assume that firms behave non-cooperatively, they would usually benefit from high degrees of differentiation at their own level and low degrees of differentiation at the other level of the vertically related market, such that they can exercise countervailing power and appropriate a higher portion of the industry rent. It follows that a highly differentiated brand would leave thin margins to retailers and high margins to manufacturers (see, Steiner, 1993).

It is straightforward to verify that this is the case under the wholesale model. The second mark-up in (3.14), $(1-\beta)/(2-\beta)(2-\gamma)$, increases in γ, meaning that retail margin increases as manufacturers' goods become less differentiated under the wholesale model. Under the agency model, however, retail margin $\alpha(1-\gamma)/(2-\gamma)$ is positively correlated with degrees of differentiation between goods for any given revenue sharing rate. When the revenue sharing rate is endogenous, the relationship is determined by a trade-off: a higher degree of differentiation between manufacturers can reduce retail margin as it reduces the revenue sharing rate and can increase retail margin as it increases the retail price (which are set by manufacturers). The combined effect may not be the same as under the wholesale model. In fact, for $\gamma \in [0, \gamma'')$, as stated in *Proposition 3.3,* retailers under the agency model actually prefer it when the differentiation between manufacturers' goods is high.

3.5 Discussion

In this section we explain how results obtained from the comparison between the wholesale and the agency models are useful for understanding the agency model and the antitrust treatment of restrains of this kind.

First, our results suggest that the agency model may be understood as a retailer power restraint. Retailer power restraints, as introduced in Section 3.1, are usually imposed by insecure manufacturers (Grimes, 2007). *Ceteris paribus*, the agency model is not an option for manufacturers as they earn more under the wholesale model. By choosing the agency model over the wholesale model, manufacturers deliberately create incentives for retailers, at the expense of their own. Although strong manufacturers have no incentive to do so, insecure manufactures may use restraints of this kind to induce retail service and brand promotion. Moving from the wholesale to the agency model, two things change: retail prices are set by manufacturers instead of retailers and transfer payments are revenue shares instead of unit fees.

As a result, retailers do not have to compete over prices and the vertical competition between manufacturers and retailers is relaxed, leaving retailers with higher rents.

Second, with regard to welfare, consumers are better off under the agency model. It follows that if courts were to treat restraints involved in sale and nonsale transactions differently, e.g., in *Schwinn* the former was illegal whereas the latter was legal, then having the verdict based on the actual impact of restraints on consumer surplus (and on how such impact differs in sale and nonsale transactions) seems to be more consistent with the definition of the rule of reason,[13] instead of the legal ownership of property.

The better position of consumers under the agency model further explains, from the end welfare point of view, why Grimes (2007) might consider that some loose forms of "inducement" offered by insecure manufacturers to retailers are "probably presumptively lawful." Nevertheless, he retains two concerns over vertical restraints for brand promotion. One is whether such promotion involves deception about product quality that would eventually harm consumers[14] and the other is whether intrabrand competition is undercut too much to "maintain the competitive distribution of strong brands." While the first concern is an additional dimension of the problem that the current paper does not deal with, the second concern arises naturally given two possible conflicts: one is between the motive and the impact of a restraint and the other is between the restraint's impact on welfare and on competition.

Our final interpretation of results therefore addresses the above conflicts and relates them to antitrust treatment of vertical restraints. Antitrust authorities and courts may frequently face the first conflict. For example, in *Schwinn*, the Court accepted that the distribution program was for business purpose which enabled Schwinn to "compete more effectively in the marketplace,"[15] but the question remained was whether "the effect upon competition in the

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[13] "The rule of reason is (127 S. Ct. 2712) 'the accepted standard for testing whether a practice restrains trade in violation of § 1,' and in application amounts to 'an inquiry into market power and market structure designed to assess [a restraint's] actual effect'" (Martin, 2009).

[14] Grimes (2007) writes "…the consumer is unaware that a vertical restraint has given the retailer an incentive to promote a particular seller's product" and that products with "superior characteristics" may "no longer require the promotion incentives of a vertical restraint."

[15] 388 U.S. at 374.

marketplace is substantially adverse."[16] This appears to signal that courts attach more weight to the impact.

Within the analysis of the impact of vertical restraints, the second conflict has been controversial alongside the evolution of antitrust treatment. Such conflict is appealing under the agency model given the proceeding discussion: while consumers clearly benefit from it, the agency model is evidently more likely to undercut competition with the alignment of incentives. While this does not mean that the agency model would necessarily harm competition substantially, the lack of incentives for firms to compete may itself constitute a major concern of antitrust authorities and courts. The series of vertical restraint cases suggest that, as highlighted by Martin (2009), if a restraint generates conflicting impacts on competition and consumer surplus, precedence goes to consumer surplus. This implies that, in treating vertical restraints of this kind, the rule of reason may be more appropriate as impacts of such restraints may differ, depending on the context in which they are used and the additional restraints used in conjunction, among others.

Moving from the *per se* rule to the rule of reason further urges the recognition of the importance of intrabrand competition and the powerful position of retailers in some industries. This is because many vertical restraints, including RPM, may not be a means through which manufacturers exercise power, but manufacturers act in response of retailer power. The role of retailers therefore is crucial in determining the status of retailer power restraints, and in particular, identifying cases in which a genuine business purpose is lacking and the restraint is mostly likely to be dictated by retailers.

3.6 Conclusion

The agency model is popular in some markets in recent years. However, it is not new and involved debatable court decisions. Complementary to studies on the agency model in a particular market, we take an alternative approach to understand the nature of the agency

[16] 388 U.S. at 375.

model through comparing it to the wholesale model, as well as through placing it in the context of antitrust treatment of vertical restraints.

In a bilateral duopoly model with product differentiation at both the manufacturer level and the retailer level of the market, we first find that, relative to the wholesale model, the agency model benefits consumers with lower retail prices as it eliminates double marginalisation. Hence an economic view would suggest that the legality of restraints involved in the agency distribution in *Schwinn* may be better supported by the impact of restraints on consumer surplus rather than the legal ownership of property.

Second, as manufacturers are strictly better off under the wholesale model whereas retailers are more likely to be better off under the agency model, the agency model may be an example of retailer power RPM, imposed by insecure manufacturers to incentivise retailers to promote their brands. Furthermore, stronger brands do not tend to squeeze retail margin under the agency model, hence the incentives of manufacturers and retailers are better aligned under this model. Overall the agency model increases consumer surplus but tends to relax competition, which constitutes a conflict faced by antitrust authorities and courts in treating restraints of this kind. We suggest that they may be evaluated under the rule of reason.

Unlike the traditional views on vertical relations where retailers are often considered to be perfectly competitive and possess little market power, the rise of the agency model implies that, *ceteris paribus*, retailers are in strong position. Understanding the agency model as retailer power RPM is meaningful for recognising the changing power relations in some supply and distribution chains.

The potential better position of retailers under the agency model comes not only from reduced intrabrand competition, but also from relaxed vertical competition given the alignment of incentives. In contrast to the extensive literature on how restraints affect horizontal competition in vertically related markets, i.e., interbrand and intrabrand competiton, the same regarding vertical competition is scarce. While the current paper does not separate effects coming from the two dimensions, it may be a relevant topic for future research.

3.7 Appendices B

B1. Proof of *Proposition 3.1*

Given *Lemmata 3.1* and *3.2*, it is straightforward that $p^* > p_A^*$ and $q^* < q_A^*$ for $\beta, \gamma \in [0, 1)$. Denoting the equilibrium consumer surplus under the wholesale model as CS and that under the agency model as CS_A, we find that

$$CS = \frac{4}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)} - \frac{1}{2(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2} - \frac{2\beta}{(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2} - \frac{2\gamma}{(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2} - \frac{2\beta\gamma}{(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2},$$

$$CS_A = \frac{4}{(1+\beta)(1+\gamma)(2-\gamma)} - \frac{1}{2(1+\beta)^2(1+\gamma)^2(2-\gamma)^2} - \frac{2\beta}{(1+\beta)^2(1+\gamma)^2(2-\gamma)^2} - \frac{2\gamma}{(1+\beta)^2(1+\gamma)^2(2-\gamma)^2} - \frac{2\beta\gamma}{(1+\beta)^2(1+\gamma)^2(2-\gamma)^2}.$$

Consumer surplus is relatively higher under the agency model if

$$CS_A - CS = \frac{(1-\beta)\left(8\beta^2\gamma^2 - 4\beta^2\gamma - 8\beta\gamma^2 - 12\beta^2 - 16\gamma^2 + 5\beta + 4\gamma + 29\right)}{2(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2} > 0.$$

Since $(1-\beta)/2(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2$ is positive, it follows that $CS_A - CS > 0$ if

$$8\beta^2\gamma^2 - 4\beta^2\gamma - 8\beta\gamma^2 - 12\beta^2 - 16\gamma^2 + 5\beta + 4\gamma + 29 > 0.$$

The above is equivalent to

$$(1-\beta)[4\gamma(1-\beta\gamma) + 4\beta\gamma(1-\gamma)] + 12(1-\beta^2) + 16(1-\gamma^2) + 5\beta + 1 > 0,$$

which can be easily verified to hold for $\beta, \gamma \in [0, 1)$. □

B2. Proof of *Proposition 3.2*

Denoting the equilibrium social surplus under the wholesale model as S and that under the agency model as S_A, we can write $S = 2\pi^{S^j} + 2\,\pi_{R_i} + CS$ and $S_A = 2\pi_A^{S^j} + 2\,\pi_{R_iA} + CS_A$, more specifically,

$$S = \frac{16\beta^2\gamma^2 - 16\beta^2\gamma - 16\beta\gamma^2 - 32\beta^2 + 4\beta\gamma - 32\gamma^2 + 20\beta + 20\gamma + 55}{2(1+\beta)^2(1+\gamma)^2(2-\beta)^2(2-\gamma)^2},$$

$$S_A = \frac{-16\beta\gamma^2 + 4\beta\gamma - 16\gamma^2 + 20\beta + 4\gamma + 23}{2(1+\beta)^2(1+\gamma)^2(2-\gamma)^2}.$$

Given any β, the relationship between $S_A - S$ and γ is illustrated in Figure 3.4. $S_A - S$ is positive for sure for $\gamma \in [0, \gamma')$ whereas it may or may not be positive for $\gamma \in (\gamma', 1)$. $S_A = S$ at $\gamma = \gamma'$. □

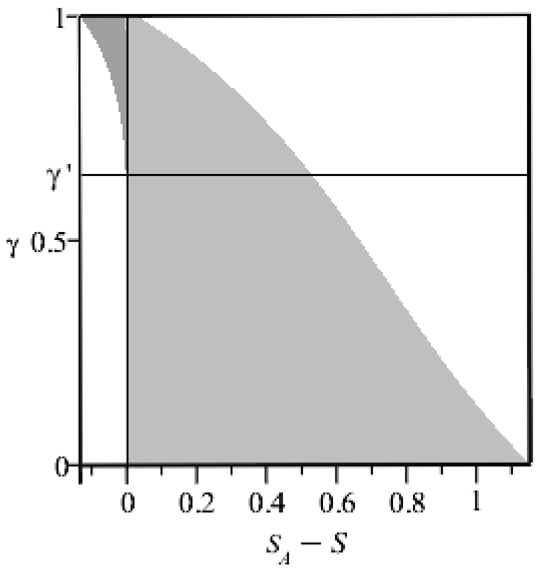

Figure 3.4 The relationship between γ and $(S_A - S)$

B3. Proof of *Proposition 3.3*

We first compare manufacturer profits under the two models. Given *Lemmata 3.1* and *3.2*, $\pi^{S^j} > \pi_A^{S^j}$ if the following holds,

$$\frac{2(1-\gamma)}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)^2(2-\gamma-\beta\gamma)}[2-\gamma(1+\beta)-\beta(2-\beta)(2\beta-\gamma-\beta\gamma)] > 0.$$

Since $2(1-\gamma)/(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)^2(2-\gamma-\beta\gamma)$ is positive, it follows that $\pi^{S^j} - \pi_A^{S^j} > 0$ if

$$2-\gamma(1+\beta)-\beta(2-\beta)(2\beta-\gamma-\beta\gamma) > 0,$$

that is, if $\gamma < 2(1-\beta^2+\beta)/(1-\beta^2)$, which always holds given $\beta, \gamma \in [0,1)$.

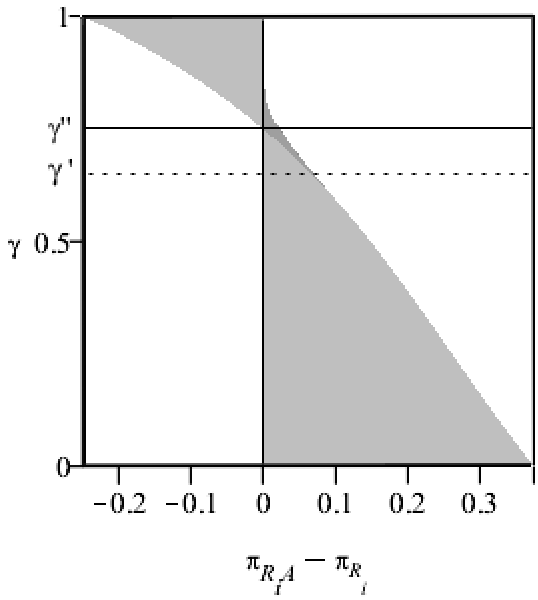

Figure 3.5 The relationship between γ and $(\pi_{R_iA} - \pi_{R_i})$

Next, we compare retailer profits, as illustrated in Figure 3.5, given any β, $\pi_{R_iA} - \pi_{R_i}$ is positive for $\gamma \in [0, \gamma'')$, whereas it is more likely to be negative for $\gamma \in (\gamma'', 1)$. To find γ'', we evaluate $\pi_{R_iA} = \pi_{R_i}$ at β = 0, and obtain $\gamma'' = 3/4$. □

Chapter 4

Two Types of Resale Price Maintenance and Vertical Rent Shifting

4.1 Introduction

Resale price maintenance (RPM) is the practice by which an upstream manufacturer specifies the retail price of a product sold to consumers which, as evaluated by the economic literature, has both pro and anticompetitive effects.[1] RPM has traditionally been viewed as being imposed by upstream manufacturers. Under *classic RPM*, manufacturers set the retail price in addition to their decisions on the transfer payment, e.g., the wholesale price. Retailers typically make no decision. Yet, we often observe in the real world another form of RPM, *agency RPM*, by which retailers set the transfer payment, before manufacturers set the retail price. A recent example of agency RPM was the agency model used by Apple and the book publishers for

[1] RPM can be used to improve the efficiency in vertical relations, while it can also be anticompetitive by dampening competition, facilitating collusion and blocking new entrants. See, Rey and Caballero-Sanz (1996) for a comprehensive survey.

selling e-books under which Apple first specified the revenue-sharing rate and the book publishers set the e-book price.[2]

While there are a number of studies examining the agency model as a type of RPM (e.g., Foros, Kind and Shaffer, 2013) and comparing it to the wholesale model (e.g., Lu, 2016), two concerns arises. First, little is known about how different agency RPM is from classic RPM. Hence it remains unclear whether the two share the common pro and anticompetitive effects. Second, moving from the wholesale model to the agency model, not only the decision roles of manufacturers and retailers are reversed but also the form of the transfer payment changes, i.e., from unit-fee to revenue-sharing. It remains unclear which effect drives the comparison. For example, it can be shown that double marginalisation is eliminated under the agency model. However, since the two features of the agency model, RPM and revenue-sharing, are both potential instruments to neutralize vertical externalities (see, e.g., Tirole, 1988; Dana and Spier, 2001), it is not clear whether double marginalisation is eliminated as a result of RPM, or a result of revenue-sharing, or joint effects of both.

In this paper, we develop a framework to distinguish between the two types of RPM, as well as separate out the effects of reversing decision roles and changing forms of the transfer payment. We compare eight simple vertical contracts including four unit-fee contracts and four revenue-sharing contracts characterising a vertical relation of a monopolist manufacturer and a monopolist retailer.[3] For a given form of the transfer payment, the four contracts differ in who sets the retail price and who sets the amount of the transfer payment: a) the manufacturer sets the transfer payment and the retailer sets the retail price, b) the retailer sets the transfer payment and the manufacturer sets the retail price, c) the manufacturer sets both, and d) the retailer sets both. Among the eight contracts, two involve classic RPM and two involve agency RPM. Many of the featured contracts are, either alone or in combination,

[2] U.S. *v*. Apple Inc., *et al*. 12 Civ. 2826 (DLC), the State of Texas, *et al. v*. Penguin Group Inc., *et al*. 12 Civ. 3394 (DLC) (2013).

[3] Under a unit-fee contract, the transfer payment between the manufacturer and the retailer is proportional to the quantity demanded, e.g., a uniform wholesale price, whereas a revenue-sharing contract is a form of royalties under which the transfer payment is a proportion of the total revenue. The contracts featured in this paper are either unit-fee or revenue-sharing contracts, not any form of combination of the two. See Figure 4.1 in Section 4.3.1 for details.

observed in the real world. For example, Amazon and e-Bay use a combination of unit-fee and revenue-sharing agency RPM to deal with their business sellers[4]; a revenue-sharing contract without RPM is used in the movie industry.[5]

By comparing the contracts, we find that classic RPM and agency RPM can be distinguished in the following aspects. First, while both the manufacturer and the retailer may have incentives to adopt RPM in facing vertical competition, their preferences over RPM differ: classic RPM benefits the manufacturer whereas agency RPM benefits the retailer. Second, the efficiency benefit of the elimination of double marginalisation applies to classic RPM, but not necessarily to agency RPM. Third, agency RPM is better in resembling the freedom of trade appreciated by courts.[6]

Regarding the *ceteris paribus* effects of reversing decision roles and changing forms of the transfer payment, we find that, for a given form of the transfer payment, reversing decision roles, i.e., whether there is agency RPM or not, does not affect retail prices and is purely a vertical rent shifting. More interestingly, manufacturer profits are higher when the retail price is set by the retailer and retailer profits are higher when the retail price is set by the manufacturer. This can be explained by our earlier result that agency RPM empowers the retailer. For given decision roles, retail prices are always lower under revenue-sharing contracts. Whoever sets the retail price is better off under a unit-fee contract, whereas the other is better off under a revenue-sharing contract. We further extend this part of the analysis to the bilateral duopoly market in which we compare symmetric equilibrium outcomes of the four contracts.

Our approach and findings are useful in the following ways. First, we compare across a menu of vertical contracts, which enables us to separate out the effects of the two key elements

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[4] See https://www.amazon.co.uk/gp/help/customer/display.html?nodeId=3517791 for "Selling on Amazon Fee Schedule" and http://sellercentre.ebay.co.uk/fees-business-sellers-0?cat=763 for eBay's "Fees for business seller".
[5] See, e.g., Dana and Spier (2001).
[6] Justice White highlighted the antitrust view of competition as a process of favouring independent decisions by independent firms (433 U.S. 36 at 66-67): "…the reason was rather… the notion in many of our cases involving vertical restraints that independent businessmen should have the freedom to dispose of the goods they own as they see fit."

written in a vertical contract, decision roles and forms of the transfer payment, on retail prices and profit division. Through comparing a given contract with different counterparts, we offer an overview of the baseline preferences of different parties towards vertical contracts, which is helpful for understanding the role of RPM in a particular industry.

Second, we highlight the neglected distinctions between classic RPM and agency RPM, which is important for the assessment of RPM in a specific context, so as to minimise the potential Type I and Type II errors in the antitrust treatment of RPM. One needs to be cautious of the commonly assumed association between RPM and the elimination of double marginalisation, even in the absence of any additional contract terms. Also, RPM that does provide consumers with lower prices might come at the expenses of limited competition.

Third, and in relation to the first two, we clarify that, *ceteris paribus*, reversing decision roles primarily shifts the vertical rents between different levels of the market, whereas changing forms of the transfer payment primarily affects consumer surplus. That is, although the agency model eliminates double marginalisation, this effect is not driven by RPM but by the nature of revenue-sharing contracts.

Furthermore, we show that recognising the role of vertical competition is meaningful. In the model of bilateral monopoly where there is no horizontal competition, the manufacturer and the retailer still have incentives to use RPM for vertical competition. Here RPM increases rents of the firm at one level of the market through vertically suppressing the firm at the other level of the market, and more importantly, it can affect consumer surplus and thus should not be neglected.

The paper proceeds as follows. Section 4.2 reviews the related literature. Section 4.3 presents the framework for our analysis, in which we first characterize the vertical relation by a menu of contracts in bilateral monopoly, and then extend the analysis to bilateral duopoly. Section 4.4 ranks the contracts using different criteria and analyses the results. Section 4.5 concludes.

4.2 Related literature

Unlike the Chicago approach to vertical relations (see, e.g., Bork, 1966), which views firms at successive levels of a supply chain as partners with complementary functions and tends to omit the conflict between them, contemporary vertical restraint theory (e.g., Steiner, 1993) and contract theory (e.g., Aghion and Bolton, 1987) recognise that competition occurs not only horizontally at the same level of the market, but also vertically between different levels. Contracts characterising vertical relations thus can affect the total rents as well as the division rules of those rents.

Despite that the contract is a vertical one, antitrust law seems to only treat firms at the same level as competitors, reflected by the U.S. Supreme Court's statement of "all competitive effects, are by definition, horizontal effects."[7] In analyzing the anticompetitive effects of RPM, the economic literature almost always relies on the horizontal effect of RPM (Giovannett and Stallibrass, 2009). For example, RPM may be adopted to dampen competition (Shaffer, 1991; Dobson and Waterson, 2007), to block entry (Asker and Bar-Isaac, 2014) and to facilitate collusion (Jullien and Rey, 2007), at a particular level of the market. In this context, RPM that empowers firms at a particular level usually does so through relaxing the horizontal competition that the firms are facing. In contract theory, the economics of rent shifting is also horizontal in nature, which is from one seller to another, and the buyer may or may not play a positive role (Marx and Shaffer, 2004).

Contrary to the abundance literature on horizontal competition in vertical relations, vertical competition has received far less attention. One primary reason, as suggested by Steiner (2008), is the doubt on whether vertical competition can affect consumer surplus in the same way as horizontal competition. He highlights this omission and argues that even with "no further horizontal market shares to capture", firms at a particular level can increase their profits through vertically squeezing the margin of firms at other levels of the market. In this paper, we show that RPM could be such a device and that vertical competition can affect

[7] Business Electronics Corp. *v*. Sharp Electronics Corp. 485 U.S. 717, 730 n.4 (1988).

consumer surplus. This is similar to the story of RPM as a commitment device to protect upstream monopoly rents (O'Brien and Shaffer, 1992; Rey and Vergé, 2004), which is possibly so far the only theory of harm that relies on RPM having a vertical effect (Giovannett and Stallibrass, 2009). However, we find that not only upstream manufacturers, but also downstream retailers may have the incentive to use RPM for vertical rent shifting.

Related to the above, as retailers are traditionally viewed as lacking in market power in a vertical relation, despite the rich literature on RPM and the awareness later on that RPM may also be "retailer-sponsored" (Dobson and Waterson, 1999), little attention has been paid to the actual decision role of the retailer. Until recently, and plausibly motivated by Apple's e-book case, some studies start to compare alternative vertical contracts. Foros, *et al*. (2013) focus on the decision role of the retail price in revenue-sharing contracts. Johnson (2014) and Lu (2016) compare the wholesale model to the agency model. Closest in framework to us, Liu and Shuai (2015) include two unit-fee contracts and two revenue-sharing contracts in their comparison and allow the decisions of manufacturers and retailers to reverse, yet they do not clarify the *ceteris paribus* effects of changing one thing at a time.

This paper is further related to the literature on countervailing power, which primarily examines the effects of buyer power on market configuration and welfare. In addition to studies on whether buyer power would lead to exclusion (e.g., Marx and Shaffer, 2007; Gabrielsen and Johansen, 2015), reduction of wholesale prices (Chen, 2003), and promotion of retailers' own-label brands instead of manufacturers' brands (Dobson and Waterson, 1999), our results offer an additional device of exercising buyer power: to use RPM to extract rents from the manufacturer.

4.3 Model

We consider a market with two manufacturers, $j = A, B$ and two retailers, $i = 1, 2$. Each manufacturer j produces a single good j and distributes to both retailers, i.e., $q_i^j > 0$, such that vertical contracts are nonexclusive. That is, there are four "final goods" competing in the downstream market, $\{A1, B1, A2, B2\}$. We assume production costs of all firms to be zero.

We use the linear demand following Dobson and Waterson (1996, 2007)

$$p_i^j = 1 - q_i^j - \beta q_{-i}^j - \gamma q_i^{-j} - \beta\gamma q_{-i}^{-j}, \tag{4.1}$$

which gives rise to the following direct demand function

$$q_i^j = \frac{(1-\beta)(1-\gamma) - p_i^j + \gamma p_i^{-j} + \beta(p_{-i}^j - \gamma p_{-i}^{-j})}{(1-\beta^2)(1-\gamma^2)}. \tag{4.2}$$

The quantity demanded for good j at retailer i depends on its own price, prices of the competing goods and two parameters. The parameter $\beta \in [0, 1)$ measures the degree of competition between retailers and the parameter $\gamma \in [0, 1)$ measures the degree of competition between manufacturers. As values of the parameters increase, competition in the associated market level becomes more intense.

4.3.1 Bilateral monopoly

The direct demand function in (4.2) is valid when all four "final goods" are presented in the market, but it can be modified to model other market configurations. To model bilateral monopoly, we simply set $\beta = \gamma = 0$ in (4.1) and obtain $p = 1 - q$. This is as if the manufacturers' goods and the retailers' services are perceived to be perfectly differentiated and thus not in competition.

In this sub-section, we consider a monopolist manufacturer, M, who produces a single good and distributes to the monopolist retailer, R, who then serves consumers. In this framework, we compare eight vertical contracts as shown in Figure 4.1. Contracts 1-4 are unit-fee based (in squares) and contracts 5-8 are revenue-sharing based (in circles). Each contract involves decisions on the retail price, p, and the amount of the transfer payment between M

and R, w or α, where w is the linear tariff in unit-fee contracts and $\alpha \in [0, 1]$ is the revenue-sharing rate in revenue-sharing contacts. w can be straightforwardly interpreted as the wholesale price when decided by M and can be interpreted as a service fee when charged by R. Under revenue-sharing contracts, the firm setting α obtains α of the total revenue and the other firm obtains $(1 - \alpha)$ of the total revenue.

Our baseline is contract 2, the standard wholesale model, which involves unit-fee transfer payments and no RPM. Given the baseline, we distinguish between two types of RPM: classic RPM under which M has sole control over both decisions (contracts 1 and 5), and agency RPM under which whereas R first sets w (contract 3) or α (contract 7, commonly known as the agency model) and then M sets p. That is, although both types allow M to set the retail price, the decision role of R differs. The remaining contracts 4, 6 and 8 do not involve RPM. R has sole control over both decisions in 4 and 8, and under 6, M decides the proportions of total revenue to retain, before R sets p.

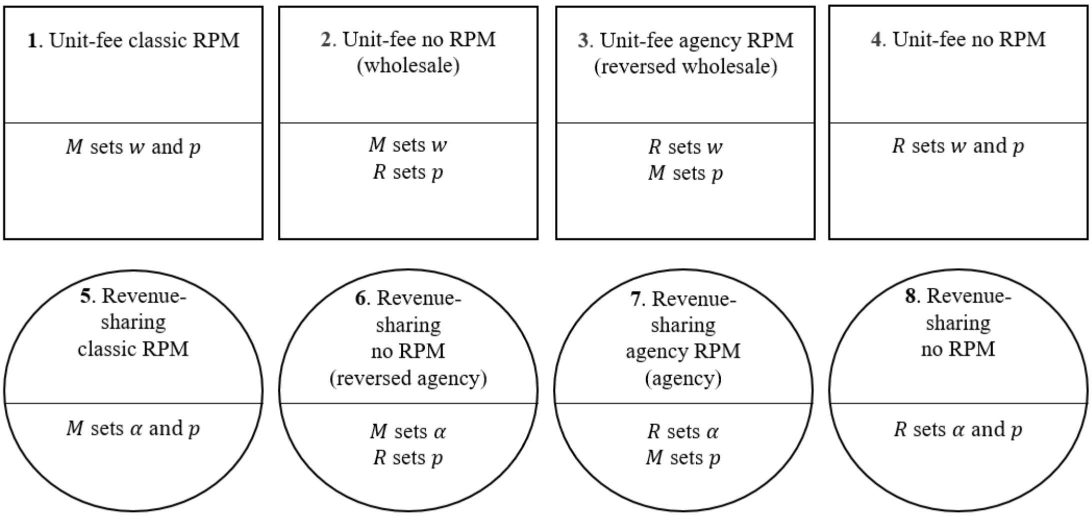


Figure 4.1 A menu of vertical contracts – bilateral monopoly

We assume that under each contract, all terms are final and are not subject to renegotiation, and M and R make the allocated decisions to maximise their profits. Table 4.1 presents the equilibrium outcomes of different contracts[8], including transfer payments (w or α), retail prices (p), quantity demanded (q), manufacturer profits (π^M), retailer profits (π_R) and total profits (π). Contract 0 represents the monopoly outcomes when M and R integrate, which are useful for our analysis later. More specifically, we compare across contracts 1-8 to examine whether M and R would each have an incentive to adopt RPM in facing vertical competition and how the two types of RPM differ, and then restrict the comparison to contracts 2, 3, 6 and 7 to identify the *ceteris paribus* effects of reversing decision roles and changing forms of the transfer payment. Note that, in the restricted comparison, contracts 2, 3, 6 and 7 are typically referred as models of wholesale, reversed wholesale, reversed agency and agency to facilitate understanding.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
RPM	-	Classic	No	Agency	No	Classic	No	Agency	No
$\boldsymbol{w}$	-	$1/2$	$1/2$	$1/2$	0	-	-	-	-
$\boldsymbol{\alpha}$	-	-	-	-	-	1	1	1	1
$\boldsymbol{p}$	$1/2$	$1/2$	$3/4$	$3/4$	$1/2$	$1/2$	$1/2$	$1/2$	$1/2$
$\boldsymbol{q}$	$1/2$	$1/2$	$1/4$	$1/4$	$1/2$	$1/2$	$1/2$	$1/2$	$1/2$
$\boldsymbol{\pi^M}$	-	$1/4$	$1/8$	$1/16$	0	1/4	$1/4$	0	0
$\boldsymbol{\pi_R}$	-	0	$1/16$	$1/8$	$1/4$	0	0	$1/4$	$1/4$
$\boldsymbol{\pi}$	$1/4$	$1/4$	$3/16$	$3/16$	$1/4$	$1/4$	$1/4$	$1/4$	$1/4$

Table 4.1 Equilibrium outcomes – bilateral monopoly

4.3.2 Bilateral duopoly

In this sub-section we relax the imposition of $\beta = \gamma = 0$ and are back to the direct demand function (4.2) of modelling two competing manufacturers and two competing retailers. Now the vertically related market features both horizontal and vertical competition.

Unlike in bilateral monopoly where eight vertical contracts are considered, in this framework, we compare four contracts: wholesale (2), reversed wholesale (3), reversed agency

[8] Proof see Appendix C1.

(6) and agency (7). The reason for not including the contracts in which both decisions are made by firms at the same level of the market, i.e., contracts 1, 4, 5 and 8, is that there exists no pure strategy equilibrium in those contracts in the presence of horizontal competition. For example, if we allow the two manufacturers, A and B, to make both decisions, then A may have an incentive to offer retailers positive payments in order to induce the exclusion of B from the market.

We focus on symmetric equilibrium in this sub-section. Table 4.2 presents the equilibrium outcomes of the four contracts in bilateral duopoly[9], including transfer payments (w or α), retail prices (p), quantity demanded per final good (q), manufacturer profits per firm (π^j), retailer profits per firm (π_i) and total profits (π). Since the four contracts included feature only agency RPM, we cannot comment on the differences between the two types of RPM in this framework. However, extending the analysis to bilateral duopoly provides useful robustness check on the other results from bilateral monopoly, i.e., whether they hold in the presence of horizontal competition.

4.4 Analysis

Given the equilibrium outcomes of the different vertical contracts, in this section we rank the contracts using a number of criteria, namely, maximising manufacturer profits, maximising retailer profits, maximising consumer surplus, as well as best resembling the notion of independent decisions by independent firms appreciated by courts. By comparing and ranking the contracts accordingly, we seek to address the research questions set up in the preceding sections.

[9] Proof see Appendix C2.

	2. Wholesale	**3. Reversed whole**	**6. Reversed agency**	**7. Agency**
RPM	No	Agency	No	Agency
$\boldsymbol{w}$	$\frac{1-\gamma}{2-\gamma}$	$\frac{1-\beta}{2-\beta}$	-	-
$\boldsymbol{\alpha}$	-	-	$\frac{(2-\beta)(1-\gamma^2)}{2-\beta(1+\gamma)}$	$\frac{(2-\gamma)(1-\beta^2)}{2-\gamma(1+\beta)}$
$\boldsymbol{p}$	$\frac{(1-\beta)(2-\gamma)+(1-\gamma)}{(2-\beta)(2-\gamma)}$	$\frac{(1-\beta)(2-\gamma)+(1-\gamma)}{(2-\beta)(2-\gamma)}$	$\frac{1-\beta}{2-\beta}$	$\frac{1-\gamma}{2-\gamma}$
$\boldsymbol{q}$	$\frac{1}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)}$	$\frac{1}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)}$	$\frac{1}{(1+\beta)(1+\gamma)(2-\beta)}$	$\frac{1}{(1+\beta)(1+\gamma)(2-\gamma)}$
$\boldsymbol{\pi^j}$	$\frac{2(1-\gamma)}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)^2}$	$\frac{2(1-\gamma)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2}$	$\frac{2(1-\beta)(1-\gamma)}{(1+\beta)(2-\beta)[2-\beta(1+\gamma)]}$	$\frac{2\beta(1-\gamma)[2\beta-\gamma(1+\beta)]}{(1+\beta)(1+\gamma)(2-\gamma)^2[2-\gamma(1+\beta)]}$
$\boldsymbol{\pi_i}$	$\frac{2(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2}$	$\frac{2(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)}$	$\frac{2\gamma(1-\beta)[2\gamma-\beta(1+\gamma)]}{(1+\beta)(1+\gamma)(2-\beta)^2[2-\beta(1+\gamma)]}$	$\frac{2(1-\beta)(1-\gamma)}{(1+\gamma)(2-\gamma)[2-\gamma(1+\beta)]}$
$\boldsymbol{\pi}$	$\frac{4(1-\gamma)(2-\beta)+4(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2}$	$\frac{4(1-\gamma)(2-\beta)+4(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2}$	$\frac{4(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2}$	$\frac{4(1-\gamma)}{(1+\beta)(1+\gamma)(2-\gamma)^2}$

Table 4.2 Symmetric equilibrium outcomes – bilateral duopoly

4.4.1 Bilateral monopoly

We first compare the equilibrium outcomes in the bilateral monopoly market. Table 4.3 presents the rankings of contracts using our variables of interest, π^M, π_R and p. Contracts denoted in squares are unit-fee based and those in circles are revenue-sharing based. Our baseline wholesale model (contract 2) is denoted in bold.

	Ranking
$\boldsymbol{\pi^M}$	$\boxed{1}$ ⑤ ⑥ > $\boxed{\mathbf{2}}$ > $\boxed{3}$ > $\boxed{4}$ ⑦ ⑧
$\boldsymbol{\pi_R}$	$\boxed{4}$ ⑦ ⑧ > $\boxed{3}$ > $\boxed{\mathbf{2}}$ > $\boxed{1}$ ⑤ ⑥
$\boldsymbol{p}$	$\boxed{1}$ $\boxed{4}$ ⑤ ⑥ ⑦ ⑧ < $\boxed{\mathbf{2}}$ $\boxed{3}$

Table 4.3 Rankings of contracts – bilateral monopoly

We start with π^M and π_R. As table 4.3 shows, among all contracts, π^M is maximised in 1, 5, and 6 and minimised in 4, 7 and 8. It is not surprising that M prefers to take sole control of the decisions (in 1 and 5), and is exploited when R makes both decisions (in 4 and 8), regardless of the contract form. The additional insight comes from that he likes contract 6 as much as contract 5. That is, being able to decide the revenue-sharing rate is as if being able to make both decisions. The intuition is, although R sets the retail price in contract 6, she has no incentive to set a price that does not maximise the total revenue. No matter how little revenue share M offers her, R would set a price to maximise that share, which is equivalent to maximise the total revenue. The preferences of R is the opposite of those of M due to the vertical conflict between them on the division of total revenue.

Lemma 4.1 *Suppose that a revenue-sharing contract is written between M and R. Ceteris paribus, whoever decides the revenue-sharing rate earns more, whereas the decision role of the retail price is irrelevant.*

Foros *et al*. (2013) find that when retailers set the revenue-sharing rate, they would like manufacturers to set the retail price if $\beta > \gamma$ to avoid fierce horizontal competition. *Lemma 4.1* complements this finding by adding the baseline scenario of $\beta = \gamma = 0$. Regardless of who sets the revenue-sharing rate, M or R are indifferent between whether or not setting the retail price. More importantly, *Lemma 4.1* emphasizes the revenue-sharing rate as the key element affecting the respective profits of M or R. Although we use a simple model, the results indicate that, among a number of possible reasons explaining why many giant retailers would like to use the agency model, the key reason seems to be, it allows them to set the revenue-sharing rate, and they are content to delegate price decisions to sellers.

To examine M and R's incentives of adopting RPM, we need to find out whether RPM can increase π^M and π_R, respectively. Results suggest that, compared to the baseline contract (2), there are three alternative contracts (1, 5 and 6) that can make M better off, among which two involve RPM (1 and 5); there are four contracts (4, 7, 8 and 3) that can make R better off, among which two involve RPM. That is, while RPM is not the only way to increase π^M or π_R, it can be such a device.

More interestingly, it is clear from Table 4.3 that when M or R was to use RPM for higher rents, the types of RPM that he or she would choose are different. Typically, classic RPM benefits M and agency RPM benefits R. Furthermore, while both unit-fee and revenue-sharing classic RPM (1 and 5) enable M to extract the monopoly rents and thus M is indifferent between the two, revenue-sharing agency RPM (7) provides R with monopoly rents and unit-fee agency RPM (3) benefits R to a smaller extent.

Note that such incentive of adopting RPM is purely driven by the vertical competition between M and R that each of them is strictly better off obtaining more of the total rents. The results suggest that RPM can be a device of vertical rent shifting, and the type of RPM adopted is, *ceteris paribus*, useful in telling whether the rent is shifted from M to R, or *vice versa*.

Lemma 4.2 *Compared to the baseline wholesale model (2), ceteris paribus, classic RPM benefits M and agency RPM benefits R.*

We then examine how such vertical effects of RPM affect consumer surplus. First, as shown in Table 4.3, retail prices are identical among contracts 1, 4, 5, 6, 7 and 8, and are identical between contracts 2 and 3. Consumers are worse off under contracts 2 and 3 that involve double marginalisation and thus higher retail prices. The message here is, despite that RPM may reduce prices and benefit consumers, similar effects can be achieved without RPM. Second, not all contracts involving RPM affect consumer surplus in the identical way. The two classic RPM and revenue-sharing agency RPM indeed benefit consumers by eliminating double marginalisation and providing lower retail prices, such efficiency benefit does not realise under unit-fee agency RPM.

Lemma 4.3 *Compared to the baseline wholesale model (2), classic RPM offers lower retail prices by eliminating double marginalisation, whereas agency RRM achieves such efficiency benefit if the form of contract is revenue-sharing.*

Lemma 4.3 offers two implications. First, one needs to be cautious of the commonly assumed association between RPM and the elimination of double marginalisation. While such association is *ceteris paribus* true for classic RPM, it is not necessarily true for agency RPM. Second, vertical competition should not be neglected as it can benefit consumers. Relative to the baseline, three out of the total four contracts involving RPM change consumer surplus, which demonstrates the relevance of vertical competition.

Antitrust authorities and courts also consider whether vertical restraints limit competition by restricting firms' freedom of trade. For example, in deciding the illegality of RPM in *Dr Miles*[10], the Supreme Court stated that it restricted the freedom of firms in trading what they own. We therefore further distinguish between the two types of RPM from this perspective.

Table 4.4 includes the baseline contract and the contracts with RPM, and lists whether the ownership of goods is transferred from M to R, and whether M and R have the freedom to make independent decisions under these contracts. The different combinations of answers to

[10] Dr. Miles Co. *v*. John D. Parke & Sons Co. 220 U.S. 373 (1911).

these two questions, i.e., Yes/No under unit-fee classic RPM (1), No/No under revenue-sharing classic RPM (5) and No/Yes under the two agency RPM (3 and 7) suggest that different RPM may restrict the freedom of trade to different extents.

	1	**2**	**3**	**5**	**7**
RPM	Classic	No	Agency	Classic	Agency
Transfer of ownership	Yes	Yes	No	No	No
Freedom of trade	No	Yes	Yes	No	Yes

Table 4.4 Freedom of trade – bilateral monopoly

Among the five contracts, unit-fee classic RPM (1) seems to least resemble the "antitrust view of competition as a process of favoring independent decisions by independent firms" (Martin, 2009), as it involves the transfer of ownership of goods from M to R and yet R has no freedom in setting the retail price. On the other hand, agency RPM (3 and 7) is by definition better in respecting the freedom of the retailer.

Overall, we can conclude that it is necessary and meaningful to distinguish between the two types of RPM, as stated in the following proposition.

Proposition 4.1 *In a bilateral monopoly market, classic RPM and agency RPM differ in their respective effects on profit division, consumer surplus and freedom of trade*

- *Classic RPM benefits the manufacturer whereas agency RPM benefits the retailer;*
- *Classic RPM eliminates double marginalisation whereas agency RPM may fail to;*
- *Classic RPM restricts the freedom of trade whereas agency RPM allows the retailer to make independent decisions.*

Note that there are potential conflicts when different criteria are used. For example, consumers would prefer unit-fee classic RPM to unit-fee agency RPM, but the former strictly restricts the retailer's freedom of trade and thus overall competition. Since *Leegin*[11] in which the *per se* illegality of RPM was overruled in the U.S., comprehensive evaluations of RPM, including its impacts on competition as well as on consumer surplus, have become more relevant for the antitrust treatment of RPM. *Proposition 4.1* suggests that even in a simple framework, RPM of different types can have substantially different impacts. Hence there may be cases in which it is necessary to view RPM in a specific context before deciding the form of antitrust intervention to avoid Type I and Type II errors.

We next move on to examine the *ceteris paribus* effects of reversing decision roles of M and R, and changing forms of the transfer payment between them. For this purpose we restrict the comparison to four contracts that allow both M and R to make independent decisions: wholesale (2), reversed wholesale (3), reversed agency (6) and agency (7). Among the four contracts, contracts of reversed wholesale and agency involve agency RPM.

In a bilateral monopoly market, the comparison has been made between the wholesale and the agency models, based on which welfare implications are drawn (Gaudin and White, 2014). However, since moving from wholesale to agency, not only decision roles of M and R are reversed, but also the form of the transfer payment changes, it would be difficult to identify the driving force of the comparison without capturing the effects of changing one thing at a time.

As presented in Table 4.5, we examine the effect of reversing decision roles by holding the form of the transfer payment constant, and then examine the effect of changing the form of the transfer payment by holding the decision roles constant. For a given form of transfer payments, we first find that reversing decision roles does not change retail prices: p is identical between contracts 2 and 3, and between 6 and 7. Second, while reversing decision roles does not change the total profits either, it redistributes the total profits between M and R. Interestingly π^M is higher under contracts 2 and 6, both with the retailer setting the retail price,

[11] Leegin *v*. PSKS. Inc. 127 S. Ct. 2705 (2007).

and π_R is higher under contracts 3 and 7, which we know from earlier results that involve agency RPM.

For given decision roles, changing the form of the transfer payment changes p. Retail prices are lower and total profits are higher under revenue-sharing contracts (6 and 7), irrespective of the decision roles. Furthermore, and in line with *Lemma 4.1*, whoever sets the retail price is better off under a unit-fee contract, whereas the other is better off under a revenue-sharing contract. We summaries these findings as follows.

	For a given form of transfer payment		**For given decision roles**	
	Unit-fee	Revenue-sharing	M sets w/α R sets p	R sets w/α M sets p
$\boldsymbol{\pi^M}$	$\boxed{2} > \boxed{3}$	$6 > 7$	$\boxed{2} < 6$	$\boxed{3} > 7$
$\boldsymbol{\pi_R}$	$\boxed{2} < \boxed{3}$	$6 < 7$	$\boxed{2} > 6$	$\boxed{3} < 7$
$\boldsymbol{p}$	$\boxed{2} = \boxed{3}$	$6 = 7$	$\boxed{2} > 6$	$\boxed{3} > 7$
$\boldsymbol{\pi}$	$\boxed{2} = \boxed{3}$	$6 = 7$	$\boxed{2} < 6$	$\boxed{3} < 7$

Table 4.5 Reversing decision roles and changing forms of transfer payments – bilateral monopoly

Proposition 4.2 *In a bilateral monopoly market, the ceteris paribus effects of reversing decision roles of the manufacturer and the retailer, and changing forms of the transfer payment between them are such that*

- **a.** *For a given form of the transfer payment, retail prices are the same, irrespective of the decision roles;*
- **b.** *For a given form of the transfer payment, the manufacturer and the retailer each would like the other to set the retail price;*
- **c.** *For given decision roles, retail prices are lower under revenue-sharing contracts;*
- **d.** *For given decision roles, the one who sets the retail price would like a unit-fee contract, whereas the one who sets the amount of the transfer payment would like a revenue-sharing contract.*

Proposition 4.2 is useful as it clarifies the driving forces of the differences in the retail price and profit division across featured vertical contracts: *ceteris paribus*, reversing decision roles changes profit division between M and R, whereas changing the form of the transfer payment changes the retail price. We discuss the implications further below.

First, while the agency model eliminates double marginalisation, it does so through a channel different from classic RPM. The theoretical rationale of using RPM to solve the double marginalisation problem is that RPM leads to the same allocation as vertical integration. However, under agency RPM where the retailer is free to set the amount of the transfer payment, as stated in *Proposition 4.1*, such rationale may not hold. Under the agency model, the elimination of double marginalisation is not driven by the retail price being set by the manufacturer, i.e., RPM, but by the nature of revenue-sharing contracts. It follows that, the efficiency effect of the agency model involving RPM can be equally achieved by alternative vertical contracts without RPM.

Second, it seems counterintuitive that, regardless of the contract form, neither the manufacturer nor the retailer would wish to maintain control over the retail price. In fact, this is due to different reasons under different forms of contracts. *Lemma 4.1* has explained the reason under a revenue-sharing contract: the one setting the revenue-sharing rate is as if making both decisions and is able to extract full rents. Under a unit-fee contract, whoever moves first, i.e., setting the wholesale price, has an advantage because the second mover has to take into account the first mover's decision. When demand is elastic and cost pass-though is incomplete, the increase in the wholesale price by the first mover will have to be partly absorbed by the second mover who sets the retail price and is thus worse off. Hence, when decision roles are fixed, the one setting the retail price prefer a unit-fee contract to guarantee positive earnings, as he/she would only obtain ε under a revenue-sharing contract.

4.4.2 Bilateral duopoly

We extend the comparison of contracts wholesale (2), reversed wholesale (3), reversed agency (6) and agency (7) to a vertical market of two competing manufacturers and two competing retailers.[12] This extension is directly relevant to the analysis of the effects of reversing decision roles and changing forms of the transfer payment. It provides robustness check on whether *Proposition 4.2* obtained in a bilateral monopoly market can be carried over. This market configuration with both horizontal and vertical competition is also closer to the real world. Furthermore, since it includes two contracts with no RPM and two contracts with agency RPM, we are able to examine whether agency RPM remains beneficial to retailers in this setting.

By comparing the symmetric equilibrium outcomes presented in Table 4.2, we obtain the following proposition.

Proposition 4.3 *In a bilateral duopoly market, the ceteris paribus effects of reversing decision roles of manufacturers and retailers, and changing forms of the transfer payment between them are such that*

- ***c.** from **Proposition 4.2** holds;*
- *Under unit-fee contracts, **a. b. and d.** from **Proposition 4.2** hold;*
- *Under revenue-sharing contracts, whether **a. b.** and **d.** from **Proposition 4.2** hold depends on values of β and γ.*

Although some results obtained under revenue-sharing contracts in the bilateral monopoly market do not hold straightforwardly in the bilateral duopoly market, the essence holds: *ceteris paribus*, reversing decision roles changes profit division, whereas changing the form of the

[12] Comparisons of these four vertical contracts in a bilateral duopoly market have been made in Liu and Shuai (2015), who primarily focus on welfare comparisons between alternative contracts and do not discuss profit division nor issues of RPM. For this reason, although the four contracts are considered, the *ceteris paribus* effects of changing one element at a time remain unclear. Furthermore, while their results from comparing reversed agency and agency contracts are similar to ours, we obtain different results regarding the comparison between wholesale and reversed wholesale contracts.

transfer payment changes the retail price. This is because, in the bilateral duopoly market, retail prices remain lower under revenue-sharing contracts, regardless of decision roles, and agency RPM remains beneficial to retailers among the four contracts.

In the bilateral duopoly market, reversing decision roles under revenue-sharing contracts, in addition to the change in profit division, can change retail prices. Compared to reversed agency model (6) which does not involve RPM, the agency model (7) would increase retail prices if the degree of competition intensity is relatively higher between retailers than between manufacturers, i.e., $\beta > \gamma$. As a result, under revenue-sharing contracts, the comparison of $\pi^j(\pi_i)$ given different decision roles is not as straightforward as under the bilateral monopoly case and is dependent on β and γ. However, as we mentioned above, when we compare across all four contracts, π^j is higher under either wholesale model (2) or reversed agency model (6), both with retailers setting the retail price; π_i is higher under either reversed wholesale model (3) or agency model (7), both involve agency RPM.

Note that, under unit-fee contracts, reversing decision roles typically shifts some rents from one level of the market to the other without changing the total profits, whereas under revenue-sharing contracts, there can be additional rents from an increased total profits following changes in the retail price.

In the absence of horizontal competition, vertical competition in bilateral monopoly can help to restore the vertical integration outcome (contract 0); whereas moving to the bilateral duopoly market, horizontal competition in addition can help to decrease the retail price below the monopoly level. For example, the equilibrium retail prices under either one of the featured revenue-sharing contracts are strictly lower than the integrated monopoly retail prices; $(1-\beta)/(2-\beta) < 1/2$ and $(1-\gamma)/(2-\gamma) < 1/2$, for $\beta, \gamma \in [0, 1)$.

4.5 Conclusion

Vertical relations in economics are often modelled on the basis that upstream manufacturers set the wholesale price and downstream retailers set the retail price. However, this is oversimplistic. A number of other complexities have been included in models over time, e.g., allowing for the manufacturers charging, or being charged, a fixed fee, as well as allowing for various royalty schemes. These complexities may further affect the adoption of vertical restraints such as RPM.

In this paper, we consider the implications of relaxing two key elements written in a vertical contract, decision roles of manufacturers and retailers, i.e., who sets the retail price and who sets the amount of the transfer payment, as well as forms of the transfer payment between them, i.e., unit-fee or revenue-sharing. We do so by comparing eight vertical contracts covering the possible combinations of the variants of the two key elements. This framework of analysis enables us to distinguish between two types of RPM: classic RPM by which a manufacturer sets both the transfer payment and the retail price, and agency RPM by which a retailer sets the transfer payment before the retail price being set by a manufacturer.

In a bilateral monopoly market, we find that the two types of RPM differ substantially in their respective effects on profit division, consumer surplus and freedom of trade. *Ceteris paribus*, classic RPM benefits the manufacturer whereas agency RPM benefits the retailer; classic RPM eliminates double marginalisation whereas agency RPM may fail to do. Furthermore, since there is no horizontal competition under bilateral monopoly, our analysis highlights the neglected role of vertical competition in vertical relations that both the manufacturer and the retailer may have incentives to use RPM for vertical rent shifting, which may affect consumer surplus.

Moreover, we separate out the effects of reversing decision roles and changing forms of the transfer payment. The former changes profit division whereas the latter changes retail prices. For a given form of the transfer payment, retail prices are the same irrespective of decision roles, and both the manufacturer and the retailer prefer not to set the retail price. For given decision roles, retail prices are lower under revenue-sharing contracts, and the one setting the retail price would like a unit-fee contract whereas the other would like a revenue-sharing contract.

Our approach and findings suggest that it is important to evaluate RPM in a particular context, as the motives, the driving forces and the associated welfare effects of RPM can differ substantially. Understanding each simple two-level vertical contract is also crucial for the assessment of combined contracts and/or multi-level supply and distribution chains.

The current framework may be extended to include costs and to model more complex vertical arrangements in a particular industry. Furthermore, given the different preferences of different parties towards these vertical contracts, it is important for future research to study the equilibrium contract selection problem.

4.6 Appendices C

C1. Equilibrium outcomes under bilateral monopoly

Recall that the direct demand function under bilateral monopoly is

$q = 1 - p.$

Under contract 0, M and R integrate and the monopolist's payoff is $p(1-p)$. Solving the first-order condition, we can find that the equilibrium retail price is given by

$p_0 = \frac{1}{2}.$

The equilibrium demand and profits are therefore

$q_0 = 1 - \frac{1}{2} = \frac{1}{2},$

$\pi_0 = \frac{1}{2}(1 - \frac{1}{2}) = \frac{1}{4}.$

We next move on to our baseline wholesale model (contract 2). Under this contract, the optimisation problems of M and R are, assuming zero marginal costs, respectively

$\max_{w} \pi^M = \max_{w} wq,$

$\max_{p} \pi_R = \max_{p} (p - w)q.$

In stage 2, from the corresponding first-order condition, we can find R's payoff-maximising retail prices as a function of w, and it is given by

$p = \frac{1}{2} + \frac{w}{2}.$

In stage 1, M maximises $w(1 - 1/2 - w/2)$ and the equilibrium wholesale price is

$w_2 = \frac{1}{2}.$

The equilibrium retail price and demand are therefore

$p_2 = \frac{3}{4}$,

$q_2 = \frac{1}{4}$.

$p_2 > p_0$, which is due to double marginalisation. The equilibrium profits are

$\pi_2^M = \frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$,

$\pi_{R_2} = \frac{\left(\frac{3}{4} - \frac{1}{2}\right)}{4} = \frac{1}{16}$,

$\pi_2 = \pi_2^M + \pi_{R_2} = \frac{3}{16}$.

Under contract 1, unit-fee contract with classic RPM, M sets both p and w. He will optimally set p to achieve the vertical integration outcome and then take away the full monopoly rent by charging $w = p$. That is

$w_1 = p_1 = p_0 = \frac{1}{2}$,

$q_1 = q_0 = \frac{1}{2}$.

Unit-fee classic RPM eliminates double mark-ups. However, unlike a vertically-integrated monopolist, R has to pay w to M under bilateral monopoly, their respective profits are hence

$\pi_1^M = \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$,

$\pi_{R_1} = \frac{\left(\frac{1}{2} - \frac{1}{2}\right)}{2} = 0$.

Under reversed wholesale model (contract 3), relative to contract 2, the decision roles of M and R are reversed, therefore their optimisation problems are

$\max_w \pi_R = \max_w wq$,

$$\max_p \pi^M = \max_p (p-w)q.$$

The equilibrium w and p stay the same as under contract 2, but π^M and π_R change

$$w_3 = w_2 = \frac{1}{2},$$

$$p_3 = p_2 = \frac{3}{4},$$

$$\pi_3^M = \frac{\left(\frac{3}{4}-\frac{1}{2}\right)}{4} = \frac{1}{16},$$

$$\pi_{R_3} = \frac{1}{2} \times \frac{1}{4} = \frac{1}{8},$$

$$\pi_3 = \pi_2 = \frac{3}{16}.$$

As we can see, although M sets the retail price, i.e., RPM, double marginalisation persists under contract 3. While total profits stay the same as under contract 2, π^M and π_R are reversed as a result of reversing decision roles.

The last unit-fee contract included in our analysis is contract 4, under which R sets both p and w. Symmetric to the idea of proving the equilibrium outcomes under contract 1, under contract 4, R will optimally set p to achieve the monopoly outcome and then take away the full rent by charging $w = 0$. That is

$$w_4 = 0,$$

$$p_4 = p_0 = \frac{1}{2},$$

$$q_4 = q_0 = \frac{1}{2}.$$

M and R's respective profits are

$$\pi_4^M = 0 \times \frac{1}{2} = 0,$$

$$\pi_{R_4} = \frac{\left(\frac{1}{2}-0\right)}{2} = \frac{1}{4}.$$

We now examine the four revenue-sharing contracts. We start with the most popular contract among the four, the agency model (contract 7). Under this contract, the optimisation problems of M and R are, assuming zero marginal costs, respectively

$$\max_{\alpha} \pi_R = \max_{\alpha} \alpha pq,$$

$$\max_{p} \pi^M = \max_{p} (1-\alpha)pq.$$

In stage 2, from the corresponding first-order condition, we can obtain that M's payoff-maximising retail price is given by

$$p = \frac{1}{2}.$$

Note that unlike the stage 2 equilibrium price under the wholesale model (contract 2) which is a function of the wholesale price w, here the revenue-sharing rate α does not appear in the equation of stage 2 equilibrium price. The reason is that, as discussed also in the first part of Section 4.4.1, for M, maximising the payoff $(1-\alpha)pq$ is equivalent to maximising pq, hence he would set p to maximise the total rent, regardless of the value of α. For the same reason, R has no incentive to set α below 1: *ceteris paribus*, M would set $p = 1/2$, no matter how little $(1-\alpha)$ is. In the absence of any other contract terms, the party setting α under revenue-sharing contracts can obtain the full monopoly rent. That is

$$\pi_7^M = (1-1) \times \frac{1}{2} \times \frac{1}{2} = 0,$$

$$\pi_{R_7} = 1 \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}.$$

Likewise, it is straightforward to obtain outcomes under contract 6. Since α is set by M under this contract, we have

$\pi_6^M = 1 \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$,

$\pi_{R_6} = (1-1) \times \frac{1}{2} \times \frac{1}{2} = 0$.

The idea of proof for contract 5 is analogous to that for contract 1, except that when M takes the full monopoly rent under contract 5, he does so by setting the revenue-sharing rate $\alpha = 1$. Likewise, under contract 8, R sets both p and α, she will optimally do the same and take 100% of the monopoly rent. So we have

$\pi_5^M = 1 \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$,

$\pi_{R_5} = (1-1) \times \frac{1}{2} \times \frac{1}{2} = 0$,

$\pi_8^M = (1-1) \times \frac{1}{2} \times \frac{1}{2} = 0$,

$\pi_{R_8} = 1 \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$.

□

C2. Equilibrium outcomes under bilateral duopoly

Our analysis of the wholesale model (contract 2) and the agency model (contract 7) in the framework of bilateral duopoly is analogous to Lu (2016) and Foros *et al*. (2013), respectively. The symmetric equilibrium outcomes under each are presented in Table 4.2. The proofs are similar for reversed wholesale (contract 3) and reversed agency (contract 6). We present them here for the sake of completeness.

The direct demand function under bilateral duopoly is

$q_i^j = \frac{(1-\beta)(1-\gamma)-p_i^j+\gamma p_i^{-j}+\beta(p_{-i}^j-\gamma p_{-i}^{-j})}{(1-\beta^2)(1-\gamma^2)}$.

Under reversed wholesale model (contract 3), in stage 2, manufacturer j solves

$$\max_{p_1^j,\ p_2^j} \pi^j = \max_{p_1^j,\ p_2^j} (p_1^j - w_1^j)q_1^j + \left(p_2^j - w_2^j\right)q_2^j.$$

The corresponding first-order condition is given by

$$\frac{\partial \pi^j}{\partial p_1^j} = q_1^j + \left(p_1^j - w_1^j\right)\frac{\partial q_1^j}{\partial p_1^j} + \left(p_2^j - w_2^j\right)\frac{\partial q_2^j}{\partial p_1^j} = 0.$$

From the above condition, we get

$$p_i^j = \frac{(1-\beta)(1-\gamma)+\gamma\left(p_i^{-j}-\beta p_{-i}^{-j}\right)+2\beta p_{-i}^j+w_i^j-\beta w_{-i}^j}{2}.$$

Solve for the stage 2 equilibrium retail price

$$p_i^j = \frac{(2+\gamma)(1-\gamma)+2w_i^j+\gamma w_i^{-j}}{4-\gamma^2}.$$

Substitute the above into (4.2), we can obtain the stage 2 quantities demand

$$q_i^j = \frac{\gamma^2 w_i^j-2w_i^j+2\beta w_{-i}^j-\beta\gamma^2 w_{-i}^j+\gamma w_i^{-j}-\beta\gamma w_{-i}^{-j}+\beta\gamma^2+\beta\gamma+2-\gamma^2-2\beta-\gamma}{(4-\gamma^2)(1-\gamma^2)(1-\beta^2)}.$$

In stage 1, retailer i solves

$$\max_{w_i^1, w_i^2} \pi_i = \max_{w_i^1, w_i^2} w_i^1 q_i^1 + w_i^2 q_i^2.$$

The corresponding first-order condition is given by

$$\frac{\partial \pi_i}{\partial w_i^1} = q_i^1 + w_i^1\frac{\partial q_i^1}{\partial w_i^1} + w_i^2\frac{\partial q_i^2}{\partial w_i^1} = 0.$$

Imposing symmetry, the symmetric equilibrium unit-fee transfers under reversed wholesale model (contract 3) in bilateral duopoly, denoted as w_{rw}, are given by

$$w_{rw} = \frac{1-\beta}{2-\beta}.$$

The equilibrium retail prices, demand and profits are therefore

$$p_{rw} = \frac{(1-\beta)(2-\gamma)+(1-\gamma)}{(2-\beta)(2-\gamma)},$$

$$q_{rw} = \frac{1}{(1+\beta)(1+\gamma)(2-\beta)(2-\gamma)},$$

$$\pi_{rw}^{j} = 2(p_{rw} - w_{rw})q_{rw} = \frac{2(1-\gamma)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2},$$

$$\pi_{i_{rw}} = 2w_{rw}q_{rw} = \frac{2(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)},$$

$$\pi_{rw} = \pi_{rw}^{j} + \pi_{i_{rw}} = \frac{4(1-\beta)(2-\gamma)+4(1-\gamma)}{(1+\beta)(1+\gamma)(2-\beta)^2(2-\gamma)^2}.$$

Under reversed agency model (contract 6), in stage 2, retailer i solves

$$\max_{p_i^1,\, p_i^2} \pi_i = \max_{p_i^1,\, p_i^2} \ (1-\alpha^1)p_i^1 q_i^1 + (1-\alpha^2)p_i^2 q_i^2.$$

The corresponding first-order condition is given by

$$\frac{\partial \pi_i}{\partial p_i^1} = (1-\alpha^1)\left(q_i^1 + p_i^1 \frac{\partial q_i^1}{\partial p_i^1}\right) + (1-\alpha^2)p_i^2 \frac{\partial q_i^2}{\partial p_i^1} = 0.$$

From the above condition, we get

$$p_i^j = \frac{(1-\alpha^j)\left[(1-\beta)(1-\gamma)+\gamma p_i^{-j}+\beta\left(p_{-i}^j-\gamma p_{-i}^{-j}\right)\right]+(1-\alpha^{-j})\gamma p_i^{-j}}{2(1-\delta^j)},$$

Solve for the stage 2 equilibrium retail prices and quantities demand

$$p^j = \frac{\gamma(1-\beta)(1-\gamma)(1-\alpha^{-j})[(1-\beta)(1-\alpha^j)+(1-\alpha^{-j})]+(1-\beta)(1-\gamma)(2-\beta)(1-\alpha^j)(1-\alpha^{-j})}{(2-\beta)^2(1-\alpha^j)(1-\alpha)-\gamma^2[(1-\alpha^{-j})+(1-\beta)(1-\alpha^j)][(1-\alpha^j)+(1-\beta)(1-\alpha^{-j})]},$$

$$q^j = \frac{A-(1-\beta)[(1-\gamma)+(1-\beta)(1-\gamma^2)+\gamma(\frac{1-\alpha^{-j}}{1-\alpha^j}-\gamma\frac{1-\alpha^j}{1-\alpha^{-j}})}{A(1+\beta)(1+\gamma)},$$

where

$$A = (2-\beta)^2 - \gamma^2\left[1 + (1-\beta)^2 + (1-\beta)\frac{(1-\alpha^j)^2+(1-\alpha^{-j})^2}{(1-\alpha^j)(1-\alpha^{-j})}\right].$$

In stage 1, manufacturer j solves

$$\max_{\alpha^j} \pi^j = \max_{\alpha^j} 2\alpha^j p^j q^j.$$

The corresponding first-order condition is given by

$$\frac{\partial \pi^j}{\partial \alpha^j} = 2p^j q^j + 2\alpha^j [p^j \frac{\partial q^j}{\partial \alpha^j} + q^j \frac{\partial p^j}{\partial \alpha^j}] = 0.$$

Imposing symmetry, the symmetric equilibrium revenue-sharing rates under reversed agency model (contract 6) in bilateral duopoly, denoted as α_{ra}, is given by

$$\alpha_{ra} = \frac{(2-\beta)(1-\gamma^2)}{2-\beta(1+\gamma)}.$$

The equilibrium retail prices, demand and profits are therefore

$$p_{ra} = \frac{1-\beta}{2-\beta},$$

$$q_{ra} = \frac{1}{(1+\beta)(1+\gamma)(2-\beta)},$$

$$\pi_{ra}^j = 2\, \alpha_{ra}\, p_{ra}\, q_{ra} = \frac{2(1-\beta)(1-\gamma)}{(1+\beta)(2-\beta)[2-\beta(1+\gamma)]},$$

$$\pi_{i_{ra}} = 2(1-\ \alpha_{ra}) p_{ra} q_{ra} = \frac{2\gamma(1-\beta)[2\gamma-\beta(1+\gamma)]}{(1+\beta)(1+\gamma)(2-\beta)^2[2-\beta(1+\gamma)]},$$

$$\pi_{ra} = \pi_{ra}^j + \pi_{i_{ra}} = \frac{4(1-\beta)}{(1+\beta)(1+\gamma)(2-\beta)^2}.$$

□

Chapter 5

The Effects of Endogenous Enforcement on Strategic Uncertainty and Cartel Deterrence

5.1 Introduction

The fight against cartels fixing prices or allocating customers remains a priority of antitrust authorities around the globe. The main tool of antitrust authorities to deter cartels is to punish detected cartelists with fines featuring both fixed and variable elements. On the one hand, cartels are prosecuted for their wrongdoings *per se*, i.e. they receive an exogenous, fixed fine for the mere attempt to collude irrespective of the actual cartel harm. On the other hand, parts of the fines are adjusted to the magnitude of harm induced by the cartel.[1] Furthermore, a substantial part of costs of detection for cartelists stems from private damage actions, in which damages are awarded based on estimated overcharges, and therefore are endogenous.

[1] Revenue-based fines is in practice in major jurisdictions including the EU and the US. See Bageri, Katsoulacos and Spagnolo (2013).

The deterrent effect of antitrust enforcement can be decomposed into two elements: frequency and composition deterrence. Frequency deterrence refers to the prevention of cartel formation and is often measured as the number of cartels that are not formed in the presence of antitrust laws, but would have formed otherwise. Composition deterrence refers to the mitigation of harm caused by a cartel through a reduced cartel overcharge (Block, Nold and Sidak, 1981; Harrington, 2004, 2005; Bos, Davies and Ormosi, 2016). This effect follows from a change in the cartel's optimisation problem in the presence of endogenous enforcement and is usually treated as profitability–driven. Yet, cartel behaviour may not only be influenced by profitability concerns, but also by strategic responses of cartelists to uncertainty about the actions of the other cartel members – we define this as *strategic uncertainty*. Although strategic uncertainty does not influence the expected profitability in the same way as antitrust enforcement does, as the probabilities of the other cartel members' actions are *ex ante* unknown, it may be affected by endogenous enforcement and indirectly contributes to composition deterrence.

In this paper, we seek to determine whether endogenous enforcement can induce composition deterrence through strategic uncertainty in a laboratory experiment on infinitely–repeated non–cooperative games. In doing so, we abstract from the direct profitability–driven effects and focus on the indirect effects induced by antitrust enforcement on strategic uncertainty. We contribute to the experimental literature on collusion in the presence of an antitrust authority by proposing a framework that allows us to study the impact of endogenous enforcement on equilibrium cartel price selection. For this purpose, we allow the expected punishment to increase with the cartel price, so that cartels formed on a high price and a low price are identical in expected profitability but different in the *riskiness of collusion* (Blonski, Ockenfels and Spagnolo, 2011; Blonski and Spagnolo, 2015) or the *level of trust required* for collusion (Bigoni, Fridolfsson, Le Coq and Spagnolo, 2015). As a result, the two collusive equilibria are equally payoff–dominant, but the low cartel price is with lower riskiness of collusion

Yet, while we expect endogenous enforcement to induce composition deterrence, it may produce adverse effects on frequency deterrence. The enforcement regime featured in our design renders the low cartel price a more desirable collusive equilibrium, and thus may encourage more collusive agreements on the low cartel price as well as stabilise such agreements. That is, endogenous enforcement may produce frequency and composition deterrence that go in opposite directions. This potential trade–off may have important consequences for the optimal design of antitrust enforcement, which warrants the study of the overall effect of endogenous enforcement.

Our findings suggest that, consistent with our theoretical predictions, endogenous enforcement produces composition deterrence through its effect on strategic uncertainty. As a result, more cartels are formed on the low cartel price that is attached with the lower riskiness of collusion. Yet, we find an adverse effect on frequency deterrence due to the increased stability of cartels formed on the low price. Due to the trade-off, the overall effect of endogenous enforcement on market outcomes is unclear. This might plausibly also be driven by the aggravated strategic uncertainty under endogenous enforcement, which *ceteris paribus* worsens the cartel coordination problem and thus mitigate the adverse effect on frequency deterrence. Furthermore our results show that subjects' preferences over cartel prices are not driven by their risk attitudes, suggesting that subjects behave strategically. Moreover, cartel price choices are insensitive to different combinations of fines and detection probabilities that feature the same expected punishment.

The paper proceeds as follows. Section 5.2 reviews the relevant literature. Section 5.3 describes the experimental design, and provides the theoretical background and the hypotheses. Section 5.4 presents the results. Section 5.5 concludes.

5.2 Literature review

Until now, most cartel experiments that explore how enforcement regimes affect frequency deterrence focus on the impact of exogenous fines and detection probabilities on collusion. Examples include the studies on the effects of leniency programmes by Hamaguchi, Kawagoe and Shibata (2009), Bigoni *et al.* (2012, 2015), Clemens and Rau (2014), and Hinloopen and

Onderstal (2014), but also on other aspects such as the substitutability of fines and detection probabilities (Chowdhury and Wandschneider, 2015), avoidance activities of cartels (Chowdhury, Crede and Wandschneider, 2016), and tacit collusion induced by previous cartel activities (Chowdhury and Crede, 2015). Exceptions are Apesteguia, Dufwenberg and Selten (2007) and Hinloopen and Soetevent (2008) studying the effects of leniency programmes, and Fonseca and Normann (2014), who study how firm numbers affect the necessity to engage in repeated communication to preserve collusion. In these three papers, fines are endogenous and depend on the chosen cartel price and/or the preceding collusive history. Yet, they do not study how the endogeneity of fines affects cartel prices or stability, hence the issue of composition deterrence remains unaddressed. To the authors' knowledge, endogenous detection probabilities (apart from detection triggered by leniency applications) have not yet been experimentally implemented or studied in the context of cartels. However, in the field, cartelists decide not only whether to collude, but also which price to collude on. Although it is reasonable to assume that the risk of detection faced by a cartel increases with the magnitude of its price overcharge (Harrington, 2004, 2005; Harrington and Chen, 2006), cartel experiments so far have forgone to analyse composition deterrence due to the exogenous design of implemented enforcement regimes.

While the breakdown of all–inclusive cartels is, in general, either triggered internally by coordination failure of cartelists or externally through the detection by antitrust authorities, the experimental literature on cartels tends to focus on the latter channel. Recently, Bigoni *et al.* (2015) suggest that deterrence can be achieved not only through imposing severe punishments, but also by worsening the incentive and the trust problems of cartelists. As a cartel is a type of collective crime, when making decisions, each member cares not only about the expected profitability of a collusive agreement, but also its stability and sustainability. As severe coordination complexity might itself render collusion infeasible, whether a cartel can be profitably formed fundamentally depends on the cartelists' ability to reach and sustain cooperative equilibria.

Cooperative games can be loosely divided into two classes: finitely or infinitely–repeated non–cooperative games, and coordination games that are classified according to the access of information. Both strands of literature point out that the Nash equilibrium concept may fail to predict a unique outcome in such games (e.g., Cooper, DeJong, Forsythe and Ross,1990; Fudenberg and Maskin, 1993; Dal Bó and Fréchette, 2011). Coordination failure may arise from the absence of a payoff–dominant cooperative equilibrium, as well as from Nash equilibria that are not self–enforcing (Van Huyck, Battalio and Beil, 1990). The multiplicity of equilibria calls for equilibrium refinement criteria to select equilibria that are most likely to arise. While Harsanyi and Selten (1988) suggest payoff dominance should take precedence over alternative deductive selection criteria, more recent theoretical and experimental studies (e.g. Van Huyck *et al.*, 1990) tend to support the risk dominance criterion. The underlying reason for coordination failure, as suggested by Van Huyck *et al.* (1990) and developed by Heinemann, Nagel and Ockenfels (2009), is strategic uncertainty that arises in a socially interactive decision situation.

Knight (1921) distinguishes between risk and uncertainty. The former is usually referred to as Knightian uncertainty or exogenous uncertainty, whereas the latter is referred to as strategic uncertainty or endogenous uncertainty. Heinemann *et al.* (2009) define exogenous uncertainty as "*a priori* given and known probabilities for all possible states of the world". In the context of cartel experiments, the detection probability imposed by the antitrust authority belongs to this source of uncertainty. Strategic uncertainty, on the other hand, describes situations in which the probabilities with which the states occur are not exogenously given or known *a priori*. Each subject is uncertain about the strategies and actions of the others within the same group, and thus has to make decisions according to subjectively assigned probabilities based on beliefs. This is where the trustworthiness of the others becomes crucial. Based on the behavioural definition of trust and betrayal aversion, Fehr (2009) suggests that trust is captured by preferences and beliefs of individuals, as well as those generated from social interactions. Intuitively, as the degree of strategic uncertainty faced by decision makers increases, it becomes more difficult to trust, hence actions converge to inefficient but secured ones.

In the evolutionary game theory literature, Dal Bó and Fréchette (2011) conclude that the games' fundamentals, which are structural determinants contributing to exogenous uncertainty such as the attractiveness of alternative action choices, length of the games, form of communication and subjects' experience, may affect cooperative behaviour. However, although repeated play of the game allows for inductive selection and learning, selected long run stochastically stable equilibria tend to be those satisfying the concept of risk dominance (Kandori, Mailath and Rob, 1993; Young, 1993). Blonski *et al.* (2011) and Blonski and Spagnolo (2015) introduce the concept of riskiness of collusion of a cooperative equilibrium in infinitely repeated non–cooperative games which is heuristically related to the concept of risk dominance.[2] In doing so, they consider strategic uncertainty by taking cognitive and behavioural determinants into account with a particular emphasis on the sucker's payoff. They take an axiomatic approach and offer a strategic uncertainty based measure of the critical discount factor, which allows for a comparison of the riskiness of different cooperative equilibria.

Cooperative games have been applied in the lab to study illegal activities and the optimal design of enforcement. For example, Berninghaus *et al.* (2013) and Tan and Yim (2014) use coordination games to model corruption and tax evasion. Both studies highlight the role of trust and beliefs, suggesting higher degrees of uncertainty to be an effective device to deter illegal activities. As unlike tax evasion, a cartel is a type of collective crime, the incentive and trust issues seem to be more relevant. Bigoni *et al.* (2015) suggest that a crucial part of the deterrent effect offered by leniency programmes is driven by the "distrust" created, an idea similar to betrayal aversion. They measure the level of trust needed to sustain collusion: the minimum level of trust required is higher as the strategic uncertainty of collusion increases, thus collusion is less likely to be reached.

[2] The riskiness of cooperation measured by Blonski and Spagnolo (2015) is related to strategic uncertainty that we discuss above, rather than exogenous risk, although the term they follow is "strategic risk".

5.3 Experiment

5.3.1 Experimental procedure

The experiment was carried out at the Centre for Behavioural and Experimental Social Science (CBESS) at the University of East Anglia, UK, in February and March 2015. Recruitment of subjects was carried out with hRoot (Bock, Baetge and Nicklisch, 2014) and the experiment was programmed and run with zTree (Fischbacher, 2007). 144 students from a variety of backgrounds and nationalities and without prior experience in oligopoly experiments participated. 36 subjects were allocated in groups of three, providing 12 independent market observations in each of the four treatments. Group composition was fixed throughout the session. At the start of each session, subjects were randomly seated in the laboratory at workstations separated by modular walls. Each subject received a printed copy of the instruction, which was also read aloud by an experimenter and displayed on each computer screen at the beginning of each session. Subjects' understanding of the instructions was tested with a questionnaire before they had to reach decisions.

The experiment consisted of two parts. In the first part, the risk preferences of subjects were tested with a risk elicitation task similar to that in Eckel and Grossman (2008). Subjects indicated the choices of their preferred lotteries on their computers, and then an experimenter determined the outcome of the lottery with a coin toss monitored by a volunteering subject. In the second part, subjects each represented a firm and played an oligopoly game in markets of three firms, as described below in Section 5.3.2 for 20 regular periods. A random stopping rule was implemented to avoid end–game effects as described in Dal Bó (2005): after the regular periods, there was a 20% chance in each additional period that the experiment ends. At the end of each session, subjects filled out an anonymous demographic survey before being called out of the laboratory and paid in private. Earnings are denoted as "experimental points" and each point was converted into 12 pence for cash payment. Based on subjects' performance, payments varied from £4.00 to £13.20 with a mean of £8.19. Sessions lasted between 40 to 60 minutes.[3]

5.3.2 Experimental design

In the experiment, subjects, each representing a firm, engage in competition in a market with two other subjects. The market is defined as a homogeneous goods Bertrand triopoly with (discontinuous) inelastic demand as introduced by Dufwenberg and Gneezy (2000) and market characteristics similar to those in Gillet *et al.* (2011). Previous experimental evidence indicates that three firms are sufficient to ensure that collusion cannot be sustained effectively without communication (Dufwenberg and Gneezy, 2000; Wellford, 2002), but with communication (Fonseca and Normann, 2012).

In each period all firms simultaneously make price decisions by choosing any price p from the choice set $p \in \{40, 41, \ldots, 52\}$. A firm sells one unit of the good and incurs a production cost of 40 if its price is lower than that of any other firm, and does not sell anything nor incur any production cost otherwise. The firm that sells the good at a price lower than its two competitors in a period therefore makes a profit of $p - 40$ whereas the other two firms make zero profit. In case that two or three firms choose the same lowest price, the profit is evenly divided among them. Before engaging in Bertrand competition as described above, in each period firms first have to simultaneously decide whether they wish to enter a non–binding price agreement, and if so, which price to agree on. There are two price agreements to choose from: one on the high cartel price $p_C^h = 52$ and one on the low cartel price $p_C^l = 46$.[4] We allow two cartel prices to facilitate the identification of effects in the econometric analysis of price agreements and to ensure that fines and detection probabilities are transparent to the subjects. Firms wishing to cooperate can choose to suggest their preferred cartel price, or they can suggest both prices if they are indifferent between the two. However, such a price

[3] Sample instructions, including the risk elicitation task, can be found in Appendix D1.
[4] 52 is the highest possible price and 46 is the mean price in the choice set.

agreement can be detected by the computer with positive probability resulting in a fine to be deducted from the profits.

Firms need to indicate their decisions to cooperate by answering the question "Do you want to agree on prices?". If all three firms wish to agree on prices and a unique common price exists among the three firms' suggested cartel prices, an agreement is reached on that price. If all three firms choose both prices, implying that they wish to agree on either price, then in half of the groups in each treatment a price agreement on 46 is reached automatically and in the other half a price agreement on 52 is reached automatically. This is done to control for any potential effect of this protocol on cartel price choice. It is shown in Section 5.4 that this default agreement price rule does not affect subjects' price choices. The default price remains the same within a group throughout the experiment. If there is no common price among the firms' chosen cartel prices, no price agreement is reached, e.g. if two firms choose 46 and one firm chooses 52. If firms do not wish to cooperate, they can express so by choosing the option "No". If at least one firm chooses "No", no price agreement is reached in that period. To avoid any potential effect that the order of items appearing on the screen may have on subjects' choices, their order is randomized across periods.[5]

With our design, we expect coordination complexity arising from endogenous enforcement to render reaching price agreements more difficult. Although a free–form communication protocol may help to facilitate price agreements, we restrict communication to a limited–form protocol for several reasons. First, our focus is to obtain clear measures on subjects' desired price choices rather than to facilitate collusion. Second, limited–form communication prevents the social dimension to influence results (see, e.g. Cooper and Kühn, 2014) and ensures that communication is limited to pure signalling and cheap talk. Furthermore, it allows for a clear identification and econometric analysis of how strategic uncertainty increases the complexity of cartel coordination. Given that in our experiment bargaining is only possible through signalling over the course of several periods of the game, observations on cartel price choices at the subject level may not directly translate into similar

[5] A computer screenshot of the communication protocol can be found in the instructions in Appendix D1.

patterns at the market level. To study the uncertainty–driven behavioural pattern of subjects, we focus primarily on individual subjects' decisions.

The sequence of the market experiment is summarised below:

1. Firms simultaneously indicate their decisions to cooperate by answering the question "Do you want to agree on prices?" Firms willing to cooperate choose "Yes" and the price(s) they wish to agree on and "No" otherwise.
2. Firms learn about whether a price agreement is reached, and if so, the agreement price.
3. Firms simultaneously make price decisions by choosing a price from the choice set $p \in \{40,41,\ldots,52\}$. Any price agreements reached at stage 2 are not binding for the firms' price decisions at this stage.
4. Firms learn about each other's prices and whether they sell a good in the current period.
5. Firms learn about whether they are detected by the computer given that they have reached a price agreement in the current period and/or their price agreements in previous periods have not yet been detected.
6. Finally, firms learn about their profits in the current period minus any potential fines, as well as about their accumulated profits.

This experiment is based on a 2×2 between–subject design. Baseline is the control treatment and serves to capture coordination failure that occurs because certain cooperative actions are not supported by an equilibrium. The other treatments assess the explanatory power of the concept of riskiness of collusion when two cooperative equilibria are payoff equivalent, which is useful to determine the uncertainty–driven channel of composition deterrence. We then compare the three treatments with endogenous enforcement to examine, given a constant expected profitability, whether there is a limited substitutability between fines and detection probabilities that might affect cartel pricing as well as deterrence. The detection probabilities (D) and the fines (F) differ in different treatments as shown in Table 5.1.

	Exogenous detection prob.	Endogenous detection prob.
	Baseline	**EndoD**
Exogenous fine	46: $D = 20\%, F = 12, E(\pi) = -0.4$ 52: $D = 20\%, F = 12, E(\pi) = 1.6$	46: $D = 3.3\%, F = 12, E(\pi) = 1.6$ 52: $D = 20\%, F = 12, E(\pi) = 1.6$
	EndoF	**BothEndo**
Endogenous fine	46: $D = 20\%, F = 2, E(\pi) = 1.6$ 52: $D = 20\%, F = 12, E(\pi) = 1.6$	46: $D = 10\%, F = 4, E(\pi) = 1.6$ 52: $D = 20\%, F = 12, E(\pi) = 1.6$

Table 5.1 Treatments and key parameters

In Baseline, the detection probability (20%) and the fine (12 experimental points) are the same for price agreements on the high price 52 and the low price 46. It represents a typical homogeneous goods Bertrand cartel experiment with exogenous fines and detection probabilities independent of the cartel price. In EndoF, the detection probability is held fixed but fine is endogenous. The magnitude of the fine is a function of the agreed cartel overcharge: collusion on price 52 yields a higher per period profit and hence requires a higher potential fine (12), whereas collusion on price 46 face a lower potential fine (2). Similarly, in EndoD the fine is held fixed but the detection probability increases in the cartel overcharge: collusion on the low price 46 and on the high price 52 feature detection probabilities of 3.3% and 20%, respectively. In BothEndo, the fine and detection probability attached to collusion on 52 are the same as in Baseline, whereas those attached to collusion on 46 are lower (F = 4 and D = 10%), i.e., both elements are endogenous in this treatment. The overcharge is about 27% when firms collude on price 52, which is close to the mean overcharge of 29% of the cartels studied in Connor and Bolotova (2006). Detection probabilities of 10% and 20% are in range of those reported in Ormosi (2014) for cartels prosecuted by the European Commission between 1984 and 2009.

Parameters and the experimental design are chosen such that the expected profitability and the ICCs are equal across the treatments with endogenous enforcement and the two cartel prices. This rules out the profitability–driven effects of endogenous enforcement on cartel behaviour as analysed in Katsoulacos, Motchenkova and Ulph (2015), which is crucial for allowing us to focus on our research question: the uncertainty–driven effects.

5.3.3 Theoretical background

Before we provide the theoretical model that underlines our framework and experimental design, we briefly discuss the main insights from the theoretical literature on endogenous punishment on cartel prices. Consider a homogeneous goods market with $n \geq 2$ firms that face the identical unit costs of production c and demand function $Q(p)$, and compete in prices, where p denotes price and Q is the quantity supplied to the market. The industry profits $\pi(p, c)$ is

$$\pi(p, c) = (p - c)Q(p). \tag{5.1}$$

When price collusion is not possible, price competition gives rise to the unique Bertrand equilibrium in which all firms set $p^B = c$ and each firm earns $\pi^B = 0$. When price collusion is possible and all firms agree to collude, then in the absence of antitrust enforcement, each firm sets $p^M = \arg max_p \pi(p, c)$ and yields a profit of π^M/n.

In this context, the existing literature (e.g. Block *et al*., 1981; Katsoulacos *et al*., 2015) has shown that antitrust enforcement that is increasing in cartel overcharge can mitigate the harm caused by the illegal activity by producing composition deterrence. To illustrate this result, we include an expected punishment of DF where D is the detection probability and F is the penalty imposed upon detection. Let DF be a function of cartel prices and assume $\partial DF/\partial p > 0$ and $\partial^2 DF/\partial p^2 \geq 0$ such that it is weakly convex.[6] With this general functional form, we allow either the fine, the detection probability, or both elements to increase with the cartel overcharge, which is a reasonable assumption given observations from the field. Figure

[6] We consider our findings based on this assumption, in particular the counteracting effects of frequency and composition deterrence, to hold in most cases. However, special scenarios may exist in which the assumption does not hold. See Bos *et al.* (2015) for an example in which antitrust punishment benefits cartels.

5.1 plots the cartel gross profit against the price in the absence of the expected punishment (π^M) as well as the net profit in the presence of the expected punishment (π^{DF}). As Figure 5.1 illustrates, such endogenous antitrust enforcement can lead to composition deterrence by altering the expected profitability of a cartel. As a result, while cartels may not be deterred altogether, they are formed at lower prices, i.e. at p^{DF} instead of p^M.

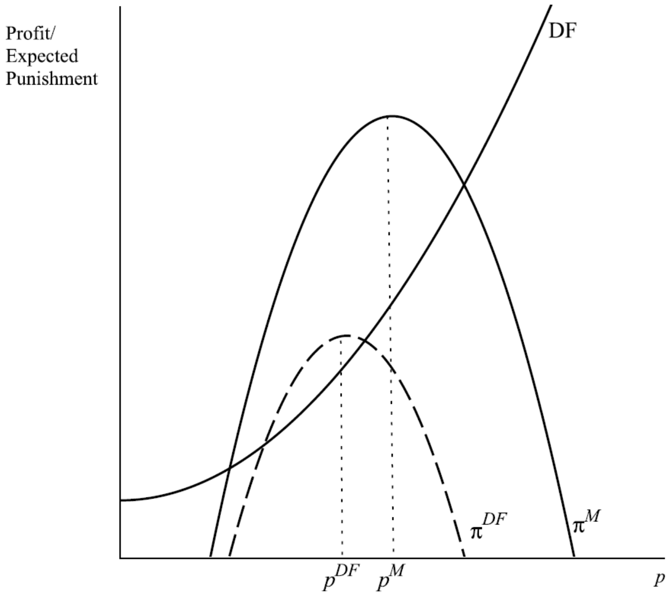


Figure 5.1 Profitability–driven composition deterrence

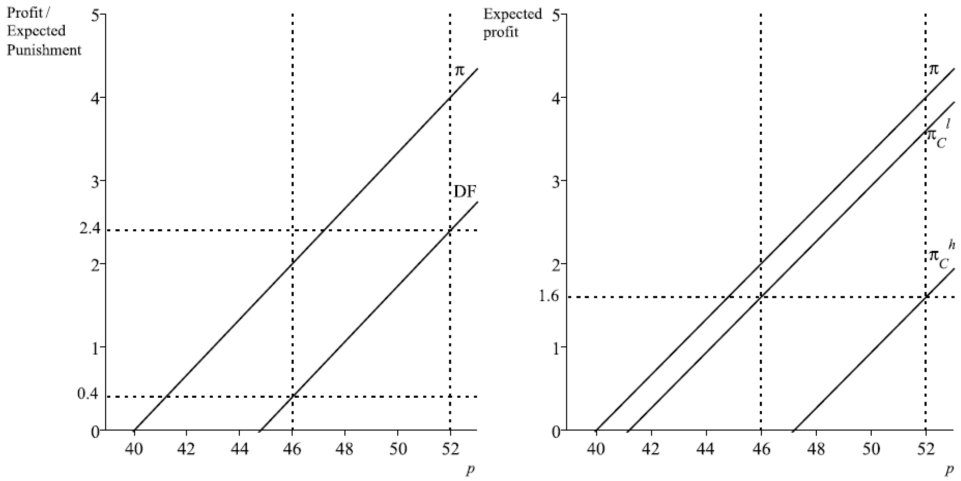
Changing the cartel's optimisation problem, however, is not the only channel through which composition deterrence can be achieved in the presence of endogenous enforcement. Price collusion is in nature a cooperative problem. Therefore, in this study we wish to assess whether pricing below the monopoly level could be an optimal reaction to strategic uncertainty in non–cooperative infinitely repeated games. For this purpose, we introduce an antitrust regime with endogenous punishment in which two cartel prices generate the same cartel profit but carry different levels of riskiness of collusion. As such, we rule out any incentive that arises from the relative size of the expected profitability of a cartel, and makes sure that cartelists' collusive price choices are driven by their behaviour when facing strategic uncertainty. As mentioned in Section 5.3.2, this constitutes the crucial property of our experimental design, which is explained further below.

In this framework, there are multiple equilibria. Yet, the only symmetric non-cooperative equilibrium that tends to dominate in the case of coordination failure is characterized by each firm choosing $p^B = 41$ and obtaining a competitive profit of $\pi^B = (41 - 40)/3 = 0.33$ in each period. However, firms reaching price agreements, depending on which price they have agreed on, can each earn a high or a low cartel profit, $\pi_C^h = (52 - 40)/3 = 4$ or $\pi_C^l = (46 - 40)/3 = 2$, both of which are strictly higher than π^B. In Baseline, the expected punishment is exogenous and fixed at $0.2 \times 12 = 2.4$, therefore the expected payoffs of colluding on the high price and on the low price are respectively

$$E(\pi_C^h) = 4 - 2.4 = 1.6 > \pi^B, \tag{5.2}$$

$$E(\pi_C^l) = 2 - 2.4 = -0.4 < \pi^B. \tag{5.3}$$

The expected payoff of colluding on p_C^h is strictly larger than the payoff associated with the predominant non-cooperative equilibrium, whereas it is negative of collusion on p_C^l. Hence in Baseline, cartels can only be profitably formed on price 52, and rational cartels would – absent other strategic considerations – either collude on price 52 or not collude at all. In treatments EndoF, EndoD and BothEndo, the expected punishment of forming a cartel is endogenous and increasing in the cartel price. Figure 5.2 offers the experimental version of the general cartel optimisation problem as shown in Figure 5.1.



a) Gross profits and exp. punishment **b)** Expected profits

Figure 5.2 Profits and expected punishment in the experiment

Figure 5.2a shows the gross profits and the expected punishment as functions of the cartel price. Figure 5.2b displays the net expected profits of collusion on the high (π_C^h) and low (π_C^l) cartel prices. As Figure 5.2 shows, the expected punishment DF is now different for the two cartel prices: it is lower (0.4) for 46 and higher (2.4) for 52. Consequently, the expect payoffs of colluding on the high and the low cartel prices are the same,

$$E\left(\pi_C^h\right) = 4 - 2.4 = 1.6, \tag{5.4}$$

$$E\left(\pi_C^l\right) = 2 - 0.4 = 1.6. \tag{5.5}$$

The two cartel prices thus represent two payoff-equivalent Pareto-dominant collusive equilibria. In the following, we characterize the equilibrium conditions, which may vary under different treatments and with different cartel prices. Since price agreements are not binding, a firm that slightly undercuts the agreed price can obtain a one shot deviation profit π_{dev}, while the others earn zero profit.

Suppose that firms react to cheating with a grim-trigger strategy (see, Tirole, 1988). The corresponding incentive compatibility constraint (ICC) of sustaining collusion infinitely is given by

$$\frac{\pi_C}{1-\delta} - \frac{DF}{1-\delta(1-D)} > \pi_{dev} + \frac{\delta\pi_B}{1-\delta} - \frac{DF}{1-\delta(1-D)}, \tag{5.6}$$

where δ denotes the discount factor. Note that in the experiment, the punishment is linked to the agreed cartel price, irrespective of whether deviation occurs afterwards or not.[7] As such, the term measuring expected punishment, $DF/[1-\delta(1-D)]$, appears on both sides of the ICC and cancels out. Thus, the ICC is not affected by the variations in fines and detection probabilities and the discount factor derived from the ICC is given by

$$\delta > \frac{\pi_{dev}-\pi_C}{\pi_{dev}-\pi_B}, \tag{5.7}$$

which is almost identical for p_C^h and p_C^l (0.656 and 0.642), such that cartel formation should not be driven by the relative size of the ICCs: when firms are able to cooperate, they should be equally likely to collude on either of the two cartel prices.

However, while the ICCs ensure the existence of a cooperative equilibrium and that firms' incentives are not affected by variations in the exogenous uncertainty DF, the cooperative difficulties and trust issues arising from strategic uncertainty may render collusion infeasible. Thus, firms may not stick to a price agreement even if it represents an equilibrium.

The recent theoretical and experimental literature tends to suggest that risk dominance gives rise to more self-enforcing and sustainable equilibria. Thus, assessing the standard ICCs is not sufficient to explain equilibrium selection in the lab. To exemplify this, we use Blonski and Spagnolo (2015)'s prisoner's other dilemma to compare the riskiness of collusion when

[7] This is in line with fining practices in the field in most jurisdictions, in which the mere attempt to collude is illegal and is fined.

firms collude on different prices. This measure of strategic risk can be calculated as the difference between two squared expressions

$$(\pi_B - \pi_S)^2 - (\pi_C - \pi_{dev})^2. \tag{5.8}$$

This is closely related to the comparison of Nash products in static 2×2 games to determine the risk–dominant equilibrium as proposed by Harsanyi and Selten (1988). Inside the first squared expression is the difference between the predominant non-cooperative equilibrium profit and the profit obtained in case of being cheated upon (π_S), i.e., the incentive to stay out of an agreement to avoid the worse scenario. Inside the second squared expression is the difference between the collusive profit and the deviation profit, i.e., the incentive to enter an agreement. The riskiness of collusion is measured by comparing the two opposing incentives. *Ceteris paribus*, when the former is larger than the latter, the riskiness of a collusive equilibrium is positive. The higher the riskiness of a collusive equilibrium is, the higher the discount factor needs to be to sustain collusion. The corresponding net present value of the riskiness of collusion when the game is repeated infinitely is given by

$$\left(\frac{\pi_B}{1-\delta^*} - \pi_S + \frac{DF}{1-\delta^*(1-D)} - \frac{\delta^*\pi_B}{1-\delta^*}\right)^2 - \left(\frac{\pi_C}{1-\delta^*} - \pi_{dev} - \frac{\delta^*\pi_{dev}}{1-\delta^*}\right)^2. \tag{5.9}$$

where δ^*denotes the discount factor below which the riskiness of a collusive equilibrium is positive and above which it is negative. Equation (5.9) can be used to calculate the riskiness of colluding on different collusive prices in different treatments for any given discount factor of firms.

Figure 5.3 illustrates the riskiness of collusion on the two cartel prices as a function of the discount factor. We obtain the following observations. First, the riskiness of collusion is identical for price 52 in all treatments because of the identical fine and detection probability attached to it across treatments, whereas the riskiness of collusion on price 46 varies. Note that we do not consider collusion on 46 in Baseline, as it is an off–equilibrium option. Second, given the identical payoff, the risk constraint is the tightest for collusion on 52, whereas it does not differ much for collusion on 46 across the included treatments. Third and more importantly, collusion on 46 is subject to a lower level of riskiness than collusion on 52. The high riskiness of collusion on price 52 follows from the fact that collusion on 52 is associated with higher cheating incentives than collusion on 46, whereas the sucker's payoff of 0 remains constant.

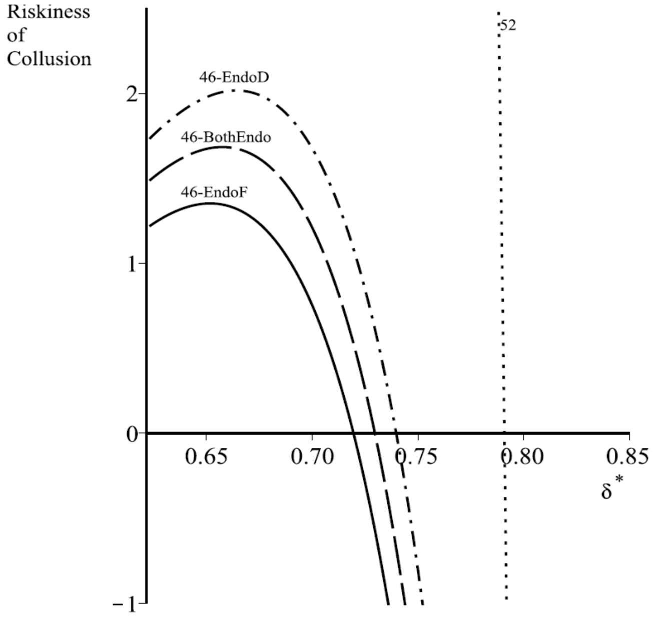


Figure 5.3 The riskiness of collusion

We therefore derive the following predictions with respect to subjects' cartel price choices in the presence of endogenous enforcement. First, when to collude, subjects would choose more often the low collusive price 46 attached with lower riskiness of collusion. This indicates the uncertainty-driven scope for composition deterrence. Second, collusion is more stable on price 46 than on price 52. Although we do not model frequency deterrence explicitly, the predicted increase in the stability of cartels on price 46 implies the trade-off between frequency and composition deterrence. This is evident from Figure 5.3 that the discount factors to sustain collusion are lower for price 46. Third, subjects' preference over cartel price 46, as well as the levels of cartel formation and stability on price 46, do not differ substantially across the treatments with endogenous enforcement.

5.3.4 Hypotheses

As we primarily seek to examine how endogenous enforcement may produce deterrence effects through affecting strategic uncertainty in infinitely-repeated non-cooperative games, the bulk of the hypotheses relate to the behaviour of subjects rather than to markets. This follows from the focus of the experimental design on identifying individuals' preferences, which might not translate to the same behaviour at a group level due to coordination difficulties. Nevertheless, market outcomes are important for the assessment of the overall effect of endogenous enforcement and are briefly addressed. Based on the existing literature and our theoretical predictions, we derive the following hypotheses.

First, given the prediction that collusion on price 46 is not a payoff-dominant collusive equilibrium in Baseline, we seek to verify that subjects do not choose to collude on 46 in Baseline. Baseline is the only treatment in which the expected profitability of collusion on the high and the low cartel prices are different. The potential failure of (stable) collusion on price 46 provides evidence that payoff dominance is an important equilibrium selection criterion and fundamentally affects subjects' decisions. As the only feasible collusive equilibrium is to collude on price 52, subjects who are willing to collude should do so on 52.

Hypothesis 5.1 In Baseline, the low cartel price is suggested less often than the high cartel price.

This in itself is not a new hypothesis to test, as the existing literature has already shown the importance of payoff dominance in equilibrium selection (see, e.g. Dal Bó and Frechette, 2011). However, providing evidence for Hypothesis 5.1 is necessary for confirming subjects' understanding of the game and for comparisons later on. We therefore explicitly test it before turning to the other hypotheses.

Next, we wish to examine the role of strategic uncertainty in the choice of cartel prices. In treatments EndoF, EndoD and BothEndo, endogenous enforcement equalises the expected payoff of colluding on both prices, whereas the expected punishment is imposed in a way such that collusion on 46 is the equilibrium with lower riskiness of collusion. If strategic uncertainty plays a role in collusive decisions, then as predicted in Section 5.3.3, the low price should be suggested more often. Furthermore, incidences of cheating by the others in the same group and detection by the antitrust authority should discourage collusion on price 52 in favour of 46, if subjects are to collude.

Hypothesis 5.2 In treatments EndoF, EndoD and BothEndo, the low cartel price is suggested more often than the high cartel price.

Limits to the substitutability between fines and detection probabilities have been a topic of interest in antitrust economics. These limits are important for the efficient and effective allocation of resources of antitrust authorities. The issue has been examined before experimentally with respect to frequency deterrence. Bigoni *et al*. (2015) and Chowdhury and Wandschneider (2015) study how variations of the fine and the detection probability given the same expected punishment influence cartel stability, without and with leniency programmes. Both studies find the two enforcement elements to be substitutes without leniency programmes, but fines to be more important with leniency programmes. Given that there is no leniency programme in this experiment and that the riskiness of collusion is identical for collusion on price 52 and similar for those on price 46 across the treatments with endogenous enforcement, subjects' price choices are not expected to differ significantly across these treatments.

Hypothesis 5.3 Subjects' suggested cartel prices do not differ significantly between EndoF, EndoD and BothEndo.

As cartels formed on prices 46 and 52 yield identical expected payoffs, but differ in the expected punishment, the choice between the two cartel prices is similar to a choice between two lotteries with different exogenous risks. Therefore, *ceteris paribus*, risk averse subjects might be more likely to choose the cartel price 46 or not to join a cartel at all, as opposed to choosing price 52 or being indifferent between the two prices. Studies on the relationship between risk aversion and cooperation do not provide conclusive findings. Sabater-Grande and Georgantzis (2002) suggest the relationship to be negative. Reuben and Suetens (2012) show that the majority of subjects behave strategically in infinitely-repeated non-cooperative games. Dreber, Fudenberg and Rand (2014) conclude that the primary determinant of subjects' behaviour in these games is payoff maximisation and find no conclusive pattern between cooperation and risk attitude.[8]

Recent studies that distinguish between subjects' risk attitudes towards exogenous uncertainty and their beliefs driven by strategic uncertainty measure the two elements separately (Heinemann *et al*., 2009; Berninghaus *et al*., 2013; Tan and Yim, 2014). Tan and Yim (2014) emphasize the role of strategic uncertainty over exogenous uncertainty and Berninghaus *et al*. (2013) find that beliefs rather than risk attitude explain subjects' choices. The importance of beliefs for cooperation in infinitely-repeated prisoner's dilemma games is also stressed by Dal Bó and Frechette (2011). Similarly, as we highlight the difference between exogenous and strategic uncertainty, and expect that subjects' price choices are not significantly different across treatments with endogenous enforcement (i.e., Hypothesis 5.3), we conjecture that strategic risk is the main driver of subjects' choices and that risk attitude only plays a minor role.

Hypothesis 5.4 Risk attitude does not determine subjects' suggested cartel prices.

The four hypotheses above focus on individual subject's desired cartel prices. Yet, the overall welfare effects of endogenous enforcement, which we conjecture to be determined by a trade–off between frequency and composition deterrence, is important in assessing the efficiency of endogenous enforcement and for potential policy implications. We therefore

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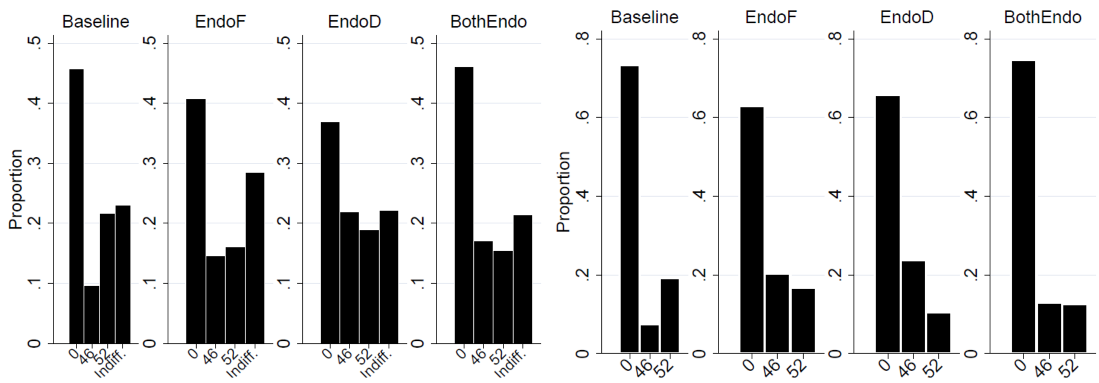
[8] There are two major differences between the experiment in Dreber *et al.* (2014) and in this paper, which might affect the results with respect to risk attitudes. First, the average cooperation period in our experiment (23.3 rounds) is significantly longer than that in theirs (10.7-11.5 rounds). Second, one feature in their experiment is that in all analysed treatments, an "execution error" occurs with 12.5% probability and alters subjects' chosen strategies. This makes it difficult for subjects to form beliefs about each other. Our experiment does not feature such a design. Thus, subjects in our experiment are relatively more likely to be able to form beliefs on their opponents and make informed decisions based on the history of cooperation and cheating.

analyse welfare effects as well. To do so, we compare market prices and cartel formation in Baseline with exogenous enforcement to those in treatments with endogenous enforcement. Whether endogenous enforcement is more efficient relative to exogenous enforcement, *ceteris paribus*, depends on which deterrence effect dominates in the trade-off, frequency or composition.

5.4 Results

As a preliminary to the regression analysis, we provide some descriptive statistics.[9] All reported results are based on the first 20 periods to avoid potential end–game effects and to consider all markets based on an even number of observations.



a) Subjects' suggested cartel prices **b)** Price agreements reached

Figure 5.4 Choice of agreements by treatment

Figure 5.4a shows the proportions of suggested cartel prices across all subjects separated by treatment, where *0* denotes subjects' preference of not to engage in price agreements, and *Indiff.* refers to instances in which subjects suggest both prices for an agreement. Figure 5.4b

[9] Figure 5.5 of the distribution of asking prices and market prices, as well as of the asking prices conditional on cheating in the previous period can be found in Appendix D2.

shows the proportions of actual price agreements reached across all markets, and *0* denotes when no agreement is reached.

At first glance, the observed patterns appear to be in line with our theoretical predictions. First, and relevant to Hypothesis 5.1, among all treatments, the collusive price 46 is suggested and agreed on the least often in Baseline. It suggests that the expected profitability plays an important role in cartel price choice. Second, and relevant to Hypothesis 5.3, the distributions of suggested cartel prices and price agreements reached do not seem to vary significantly across treatments with endogenous enforcement.

Variable	**Baseline**	**EndoF**	**EndoD**	**BothEndo**
$Asking\ prices$	43.801	44.133	43.856	43.543
$Market\ prices$	41.817	42.713	42.208	42.038
$Prop.agreement\ 46$	0.075	0.204	0.238	0.129
$Prop.agreement\ 52$	0.192	0.167	0.104	0.125
$Prop.new\ agreement$	0.117	0.167	0.096	0.108
$Prop.cheating\ 46$	1.000	0.429	0.750	0.818
$Prop.cheating\ 52$	0.818	0.684	0.818	0.533
$Prop.detection\ 46$	0.000	0.190	0.000	0.091
$Prop.detection\ 52$	0.227	0.316	0.273	0.200

Table 5.2 Descriptive statistics

Table 5.2 reports the means or proportions of selected market level outcomes. *Asking prices* represent the selling prices that subjects individually set in each market in each period. *Market prices* represent the prices at which goods are sold, i.e., the lowest asking prices in each market in each period. *Prop. agreement 46 (52)* measures the proportion of the markets and periods in which an active price agreement on 46 (52) is in place. An agreement is defined as active if it is either reached in the current period or reached in previous periods but has not yet been detected or cheated upon. *Prop. new agreement* denotes the proportion of markets with newly reached (instead of active) price agreements. *Prop. cheating 46 (52)* reports the proportion of the observed occurrence of cheating on an active agreement on 46 (52). Finally, *Prop. detection 46 (52)* is the observed proportion of markets in which agreements on 46 (52) are detected by the computer.

Several observations can be obtained from Table 5.2. First, asking and market prices do not differ substantially across treatments, and they both appear to be above the predominant non-cooperative equilibrium price of 41. This implies that prices rise with firms' attempts to collude. Second and in line with Figure 5.4, agreements on 46 are relatively rare (7.5%) in Baseline, compared to the treatments with endogenous enforcement (20.4%, 23.8%, and 12.9%, respectively). Strikingly, for the few agreements reached on 46 in Baseline, cheating occurred with 100%. This suggests that subjects appear to have a clear understanding of the fact that collusion on 46 is not an equilibrium in Baseline.

Furthermore, in all treatments, the proportions of cartel formation are low and the incidences of cheating are high. Overall collusion in our experiment is considerably less successful than in other experiments with similar design but a single collusive price.[10] In our experimental design, instead of facing two choices - to collude or not to collude, firms are offered four choices - to collude on the high price, the low price, either of them, or none of them. The descriptive statistics appear to suggest that the flexibility in choices does not induce collusion, instead, the availability of several collusive price choices turns out having a negative effect on collusion.

One reason for this might be that, in the presence of endogenous enforcement, more choices introduce significantly more uncertainty in group decision-making and coordination. Heinemann *et al*. (2009) show that the dispersion of subjective beliefs increases with the complexity of the coordination problem. With only limited communication, it becomes more difficult for firms to form beliefs about others' actions. Consequently, firms' heterogeneous response to strategic uncertainty triggers the failure of collusion and induces cheating as suggested by (Van Huyck *et al*., 1991).

[10] For example, in Chowdhury and Crede (2015) (with a critical discount factor for the ICC of 0.657), the proportion of cartel formation is around 20% and the incidence of cheating is around 10%, whereas in our baseline treatment, the proportion of cartel formation is 11.7% and the incidence of cheating is 85.7%. The main difference between their experimental design and ours is the number of collusive price choices. In their paper, cartels can only be formed on a single price whereas in ours cartelists can choose between two collusive prices.

5.4.1 Subjects’ suggested cartel prices

We now turn to the main analysis based on regression models. First, we examine individual subjects’ suggested cartel prices in a multi-level multinomial logit model with random effects at the subjects’ level and report results in Table 5.3.[11] Columns II to V present the estimated average marginal effects (with their cluster–robust standard errors in brackets) of the regressors on subjects’ choices of price agreements, with the choices being no agreement (0), an agreement on 46, an agreement on 52, and an agreement on either price (indifference between 46 and 52).

Lag asking price denotes the price that a subject set in the previous period. *Lag lowest seller* is an indicator variable showing whether the subject set the lowest price in the previous period (such that she made a positive profit). *Lag agreement 46 (52)* controls for the effects of previous periods’ active price agreement on 46 (52) on subjects’ suggested cartel prices in this period. *Lag choice 46, 52* and *46/52* are indicator variables of a subject’s suggested agreement price in the previous period, with no agreement (0) serving as the baseline. Given that a price agreement was in place in the previous period, *Lag cheating 46 (52)* and *Lag detection 46 (52)* indicate whether cheating or detection occurred on the respective agreement. *EndoF*, *EndoD* and *BothEndo* are treatment indicator variables that measure the treatment effects, and Baseline serves as the baseline. *Period* measures the period effects. *Automatic price 52* is an indicator variable for the markets in which a price of 52 is chosen automatically if all three subjects in the group are indifferent between the two cartel prices. Finally, *Risk attitude* measures subjects’ risk attitudes elicited in the risk elicitation task in the spirit of Eckel and Grossman (2008). This variable contains discrete values between 1 and 6 where value 1 represents the highest level of risk aversion and serves as the baseline.

[11] Here we use a multi-level model to estimate price choices of individual subjects because subjects are grouped and the parameters vary at both the market level and the subject level. In section 5.4.2 where we estimate price choices of cartels, a multinomial logit model is used.

	0	46	52	46/52
Lag asking price	0.003	0.001	0.006^{*}	-0.010^{**}
	(0.003)	(0.001)	(0.150)	(0.004)
Lag lowest seller	-0.046^{*}	0.010	0.016	0.020
	(0.026)	(0.016)	(0.019)	(0.022)
Lag agreement 46	−0.150	−0.033	0.097	0.085
	(0.151)	(0.059)	(0.102)	(0.124)
Lag agreement 52	−0.075	-0.086^{***}	0.087	0.074
	(0.087)	(0.023)	(0.062)	(0.074)
Lag choice 46	-0.231^{***}	0.143^{***}	−0.010	0.098^{***}
	(0.042)	(0.033)	(0.031)	(0.037)
Lag choice 52	-0.309^{***}	0.058^{**}	0.146^{***}	0.105^{***}
	(0.026)	(0.025)	(0.037)	(0.033)
Lag choice 46/52	-0.427^{***}	-0.053^{***}	-0.069^{**}	0.549^{***}
	(0.040)	(0.018)	(0.029)	(0.050)
Lag detection 46	0.169^{**}	−0.028	−0.024	-0.118^{***}
	(0.068)	(0.035)	(0.057)	(0.033)
Lag detection 52	0.150^{**}	−0.030	−0.056	−0.064
	(0.071)	(0.030)	(0.034)	(0.048)
Lag cheating 46	0.186	0.026	-0.115^{***}	−0.097
	(0.160)	(0.104)	(0.034)	(0.075)
Lag cheating 52	0.015	0.127^{*}	-0.091^{***}	−0.051
	(0.069)	(0.070)	(0.020)	(0.057)
EndoF	−0.068	0.091^{*}	−0.070	0.047
	(0.076)	(0.053)	(0.044)	(0.054)
EndoD	−0.099	0.154^{**}	−0.016	−0.040
	(0.072)	(0.063)	(0.046)	(0.055)
BothEndo	−0.005	0.098^{*}	−0.046	−0.047
	(0.065)	(0.058)	(0.048)	(0.047)
Period	0.014^{***}	−0.001	-0.008^{***}	-0.006^{***}
	(0.002)	(0.002)	(0.002)	(0.002)
Automatic price 52	−0.042	0.029	−0.035	0.049
	(0.048)	(0.025)	(0.038)	(0.039)
Risk attitude − 2	−0.084	0.011	0.080	−0.007
	(0.115)	(0.056)	(0.089)	(0.070)
Risk attitude − 3	0.007	−0.005	0.047	−0.049
	(0.104)	(0.068)	(0.089)	(0.072)
Risk attitude − 4	−0.202	0.073	0.164	−0.034
	(0.127)	(0.075)	(0.126)	(0.069)
Risk attitude − 5	−0.009	−0.015	0.030	−0.006
	(0.117)	(0.072)	(0.097)	(0.067)
Risk attitude − 6	−0.039	−0.003	0.034	0.008
	(0.110)	(0.061)	(0.080)	(0.075)
Pseudo-LL		−2135.055		
Observations		2736		

Table 5.3 Suggested cartel agreement – Multi-level multinomial logit
Notes: Values represent average marginal effects. Cluster-robust standard errors in parentheses.
***, **, and * denote 1%, 5%, and 10% significance levels.

We first address Hypothesis 5.1. The observations obtained from Table 5.2 suggest that relatively fewer price agreements are reached on 46 in Baseline and that all of them involve cheating. The regression analysis confirms this result. As shown in Table 5.3, the treatment dummies indicate that, *ceteris paribus*, subjects are between 9.1% to 15.4% more likely to suggest the low price 46 as the agreement price in the treatments with endogenous enforcement than in Baseline. Taken together, we have strong evidence for Hypothesis 5.1.

Result 5.1 In Baseline, the low cartel price is rarely chosen and results in unstable price agreements.

Result 5.1 confirms that subjects understand the game. The intuition behind is straightforward: colluding on the low cartel price is not a payoff–dominant collusive equilibrium in Baseline. It follows that, *ceteris paribus*, payoff dominance is an important condition for collusion to arise. However, being payoff-dominant may not be sufficient. The fact that the majority of subjects did not choose the payoff–dominant collusive price 52 indicates that subjects have other considerations and face additional constraints when agreeing on prices.

Unlike in Baseline, in EndoF, EndoD, and BothEndo, endogenous enforcement renders collusion on price 46 a payoff-dominant collusive equilibrium as well as the equilibrium with lower riskiness of collusion. If subjects care only about the expected payoff, 46 and 52 are equally likely to be chosen in these three treatments. However, as discussed above, issues of stability and sustainability are fundamental in cartel coordination, in which strategic uncertainty may hinder cooperative behaviour. If these considerations are taken into account, then given the theoretical predictions, subjects are more likely to choose 46 in these treatments.

As shown in Figure 5.4b, price agreements on 46 occur more often in the treatments with endogenous enforcement than those on 52. Regression results in Table 5.3 further allow us to study the dynamics of subjects' price choices. First, the *Lag cheating* variables suggest that cheating in the previous period strongly discourages subjects from choosing 52 as the agreement price in this period. However, cheating on an agreement on 52 in the previous period increases the probability of subjects choosing 46 in this period. Hence, subjects learn about the different levels of riskiness and their choices converge to the collusive equilibrium with lower level of riskiness.

Second, the *Lag choice* variables suggest that, *ceteris paribus*, subjects show a 5.8% probability to switch from price 52 to 46, but no such substitution pattern can be observed for the opposite direction. This adds to the above finding that subjects' choices converge towards the equilibrium with the lower riskiness of collusion. Note that this finding is obtained given that we have controlled for the effects of events such as cheating, detection and previously reached price agreements. Thus, we find evidence in support of Hypothesis 5.2, which constitutes composition deterrence in line with the model predictions.

Result 5.2 Suggested cartel prices converge to the low cartel price in the treatments with endogenous enforcement.

As our analysis is limited to the first 20 periods of the game, the existence of this effect shows that it does not take long before subjects adjust choices towards the equilibrium with the lower riskiness of collusion.[12]

We next move on to the issue of substitutability between fines and detection probabilities in the treatments with endogenous enforcement. There are no significant treatment effects with respect to the probability of choosing cartel price 52. This is in line with the experimental design, in which the fines and detection probabilities for price 52 are identical across treatments. Furthermore, there are no significant differences between treatments regarding subjects' choices not to collude or to be indifferent between the two cartel prices. The only significant treatment effects remain to be compared are those on price choice 46.

As shown before, subjects choose cartel price 46 more often in treatments with endogenous enforcement than in Baseline. In order to assess whether the probabilities of subjects choosing cartel price 46 vary with the different combinations of fines and detection

[12] Yet, the effect might be more pronounced in longer games (see, Dal Bó and Fréchette, 2011).

probabilities across the treatments with endogenous enforcement, we compare across the associated treatment effects. Whereas the probabilities to choose price 46 in EndoF (9.1%) and BothEndo (9.8%) do not seem to differ from each other, the marginal effect is about 1/3 higher in EndoD (15.4%). To formally compare the treatment effects, we conduct pairwise Wald tests of the treatment indicator coefficients. The test results do not reject the Null hypothesis of equality of coefficients with p–values of 0.169 (EndoF/EndoD), 0.765 (EndoF/BothEndo), and 0.103 (EndoD/BothEndo). As such, different combinations of fines and detection probabilities given the same expected punishment offer the same deterrence effect.

As Baseline serves as the baseline in the regression analysis, concerns may arise from the unique collusive equilibrium in Baseline such that the coefficients for this treatment might differ from those in the other treatments. To ensure the robustness of the regression results, we re–estimate the multi–level multinomial logit model but exclude Baseline and use EndoF as the baseline. This potentially provides a more homogeneous sub–sample, increasing data precision whilst reducing the standard errors of the estimates.[13] We find that almost all qualitative findings shown in Table 5.3 are supported by the regression estimates based on the sub–sample, and that the quantitative results only change marginally. Hence Hypothesis 5.3 is supported by the data.[14]

Result 5.3 Subjects' suggested cartel prices are not sensitive to variations in the fine and the detection probability that feature the same expected punishment.

We then test Hypothesis 5.4 relating to the impact of risk attitude on subjects' suggested cartel prices. In order to rule out potential biases resulting from the specification of the functional form of the risk attitude measure, we include indicator variables for different degrees of risk aversion. Recall that we measure 6 different degrees of risk aversion using an

[13] The results of this robustness check can be found in Table 5.6 in Appendix D3.
[14] Note that we obtain the above result in a framework that is relevant to the field and features an overproportionate increase in punishment compared to an increase in cartel profit resulting from higher overcharge. The result may therefore not be generalized to enforcement regimes that have different punishment strategies, i.e. punishment that increases linearly or underproportionately to the increase in cartel profit, which have little relevance for the field.

Eckel and Grossman (2008) style risk elicitation task, and that the measure is negatively correlated with risk aversion (value 1 indicates the highest level of risk aversion). Strikingly, despite this very conservative approach of including the different levels as dummies, not a single effect is significant. Yet, it has to be tested whether the different coefficients are jointly significant. For this, we conduct joint F–tests of the coefficients for the risk attitude indicator variables for all outcome regressions. However, in each case the joint F–test reports that the variables are jointly insignificant with p–values of 0.252 for outcome regression 46, 0.327 for 52, and 0.790 for 46/52.[15] Therefore, Hypothesis 5.4 can be confirmed.

Result 5.4 Risk attitude does not determine subjects' cartel price choices.

The above result may possibly be due to the length of interaction of 20 periods, which enables subjects to repeatedly engage in learning about the strategies of the others in the same group. The effects of learning and belief-forming might dominate the effects of risk attitude on choices. We therefore re–run the same model but limit it to the first three periods of the game when information is limited and learning has not yet taken place, to see if risk attitude plays a role. The joint F–tests again indicate that the coefficients are jointly insignificant.[16]

5.4.2 Cartel prices reached and welfare effects

In this sub-section, we analyse the welfare effects of endogenous enforcement at both the subject level and the market level. First, we conduct a pairwise comparison of market prices and the overall proportions of cartel formation using MWU tests.[17] Although Table 5.2 reports

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[15] Similarly, the risk attitude coefficients are jointly insignificant in the specification that excludes Baseline, with p–values of 0.144 for 52 and 0.579 for 46/52. Only for the choice of 46, the risk indicator variables are jointly significant (p–value 0.038). This result is driven by a single significant coefficient of Risk attitude – 4. However, since most coefficients are individually insignificant, we do not consider this as sufficient evidence for the significance of risk attitude in affecting price choices.

[16] The results can be found in Table 5.7 in Appendix D4.

[17] Given the instability of agreements observed in Table 5.2, we regard the proportion of markets with newly reached price agreements as a more insightful measure of cartel formation for this purpose. Yet, the same results arise with the alternative measure of active cartel agreements.

that average market prices are slightly higher in the treatments with endogenous enforcement (in particular in EndoF), the p–values shown in Table 5.4 suggests no significant difference in market prices across all treatments.

Variable		EndoF	EndoD	BothEndo
$Market\ prices$	**Baseline**	0.386	0.312	0.751
	EndoF		0.840	0.214
	EndoD			0.452
$Prop.new\ agreement$	**Baseline**	1.000	0.702	0.768
	EndoF		0.836	0.883
	EndoD			0.977

Table 5.4 MWU test p-value matrices for pairwise treatment differences

Similarly, the p–values suggest that the proportions of cartel formation do not differ across the treatments. Recall that our experimental design imposes exogenous enforcement in Baseline and endogenous enforcement in the other treatments, our results seem to suggest that there is a lack of difference regarding welfare effects between the two enforcement regimes. Yet, this lack of difference might be due to the trade–off between frequency and composition deterrence.

To address the factors that might have contributed to the trade-off and the lack of overall welfare difference, we conduct regression analysis on cartel price agreements reached using a multinomial logit model with random effects. The estimated average marginal effects and cluster–robust standard errors are reported in Table 5.5. Unlike the multi–level multinomial logit model used to analyse subjects' cartel price choices, the regression table of cartels' price choices does not feature a column for indifference between the two prices, as price agreements can only be reached on a single price. Most of the regressors in Table 5.5 are introduced before in the discussion of Table 5.3. Nevertheless, as the new regression is based on market level observations, we use *Lag market price* to instead of *Lag asking price* included in Table 5.3.

Furthermore, due to the market level observations, it cannot be controlled for individual subjects' suggested cartel prices in the previous period.[18]

	0	46	52
$Lag\ agreement\ 46$	-0.825^{***}	0.743^{***}	0.082
	(0.066)	(0.198)	(0.150)
$Lag\ agreement\ 52$	-0.828^{***}	0.318	0.511
	(0.057)	(0.318)	(0.321)
$Lag\ cheating$	0.138^{***}	-0.067^{***}	-0.071^{***}
	(0.013)	(0.019)	(0.016)
$Lag\ detection\ 46$	0.064^{***}	-0.007	-0.056^{***}
	(0.016)	(0.011)	(0.017)
$Lag\ detection\ 52$	0.093^{***}	-0.051^{***}	-0.042^{**}
	(0.019)	(0.014)	(0.019)
$Period$	0.007^{***}	-0.003^{**}	-0.004^{***}
	(0.002)	(0.001)	(0.002)
$Automatic\ price\ 52$	-0.005	-0.006	0.011
	(0.020)	(0.013)	(0.017)
$Lag\ market\ price$	0.009	-0.008	-0.001
	(0.006)	(0.006)	(0.003)
$EndoF$	-0.030	0.041	-0.011
	(0.041)	(0.036)	(0.017)
$EndoD$	0.002	0.032	-0.034^{**}
	(0.033)	(0.033)	(0.017)
$BothEndo$	0.001	0.026	-0.027^{*}
	(0.033)	(0.032)	(0.016)
Log pseudolikelihood		-290.758	
Observations		912	

Table 5.5 Choice of price agreements - Multinomial logit

Notes: Values represent average marginal effects. Cluster-robust standard errors in parentheses. ***, **, and * denote 1%, 5%, and 10% significance levels.

We start with the uncertainty–driven composition deterrence, as it is our primary focus. The treatment indicator marginal effects in Table 5.5 suggest that, compared to Baseline, fewer cartels are formed on the high cartel price 52 in EndoD and BothEndo. As the overall proportions of cartel formation do not differ across treatments, this indicates that more cartels are formed on the low cartel price 46 in these two treatments. We therefore find evidence that endogenous enforcement leads to composition deterrence which, on average, reduces the cartel

[18] Unlike in Table 5.3, we do not include separate effects of cheating on prices 46 and 52 in Table 5.5, as covariance matrices for the marginal effects cannot be calculated if the effects are determined separately.

overcharge. A similar treatment effect is missing in EndoF. Yet, the missing is *ceteris paribus*, i.e., it is possible that the treatment effect of EndoF is merely captured by the other coefficients.

Given the evidence of composition deterrence in EndoD and BothEndo, *ceteris paribus*, market prices should be lower in these treatments than in Baseline. The fact that market prices do not differ significantly, as shown in Table 5.4, implies that there must be an opposing effect driving market prices up. Recall Result 5.1 that subjects are significantly more likely to suggest cartel price 46 in the treatments with endogenous enforcement than in Baseline, it is possible that endogenous enforcement renders collusion on 46 so attractive that additional cartels are formed on 46, resulting in an adverse effect on frequency deterrence.

We now move on to discuss the dynamics of cartels prices reached. As shown in Table 5.5, the *Lag agreement* marginal effects indicate that price agreements on price 46 are persistent whereas those on price 52 are not. Furthermore, the *Lag detection* variables suggest that detection of an agreement on 46 in the previous period does not reduce the probability of reaching an agreement on 46 in this period, but significantly reduces the probability of reaching an agreement on 52. Hence, we find a second source of adverse effects on frequency deterrence: while endogenous enforcement induces composition deterrence towards the low cartel price 46, it increases the stability of collusion on this price.

Overall, we find evidence in support of the trade–off generated by endogenous enforcement on deterrence and welfare. First, it reduces cartel overcharges and leads to composition deterrence. Second, it increases the complexity of cartel coordination and renders reaching cartel agreements more difficult. Third, it leads to an adverse effect on frequency deterrence as it encourages additional collusion on the low cartel price. Finally, it leads to a second adverse effect on frequency deterrence as it stabilises collusion on the low cartel price. The first two effects are positive for cartel deterrence and welfare, whereas the latter two are negative. It is likely that due to these counteracting effects, the overall welfare effect of endogenous enforcement is unclear and that market prices and the proportions of cartel formation do not differ significantly between treatments with exogenous and endogenous enforcement.

Besides the trade-off, there are some additional factors that might account for the above result. First, this paper focuses on the indirect strategic uncertainty driven deterrence channel of endogenous enforcement, thus fines and detection probabilities are chosen to equalise the expected profitability of collusion on cartel prices 46 and 52. Yet, if the expected profitability differs between different cartel prices, then one might expect the overall effects of endogenous enforcement to change as well. For example, the composition deterrence effect would be stronger if the expected payoffs become higher for collusion on price 46 than on 52. Second, the communication protocol is designed to clearly capture individual subjects' preferences for cartel prices and to measure the effects of strategic uncertainty on decision–making. This comes at the cost of rendering coordination more difficult. Alternative communication protocols such as free–form chat may be more effective in establishing and sustaining collusion, as they allow bargaining to precede cartel price choices. This is in contrast to our experimental design, in which bargaining is only possible through signalling over the course of several periods of the game.

5.5 Conclusion

As it would be prohibitively costly for antitrust enforcement to deter cartels altogether, composition deterrence in the presence of endogenous enforcement may represent an important determinant of the overall welfare effects of antitrust laws as it may help to reduce the harm caused by cartels. To better understand the properties of endogenous antitrust enforcement, this paper seeks to establish its effect on composition deterrence that stems from its impact on strategic uncertainty on cartel prices.

For this purpose, we conduct a laboratory experiment on non–cooperative infinitely–repeated games in which subjects engage in price competition in homogeneous goods Bertrand triopoly markets. Subjects can coordinate on prices but face the risk of being detected and fined if they do. The experimental design and chosen parameters allow us to abstract from the profitability–driven incentives induced by endogenous enforcement and focus on the indirect effects of strategic uncertainty on subjects' decision–making. The implemented endogenous enforcement regime features an overproportionate increase in punishment compared to an increase in collusive payoffs resulting from higher overcharge, giving rise to payoff–equivalent collusive equilibria that bear different levels of riskiness of collusion.

Our results confirm that payoff dominance is a necessary but insufficient condition in determining cartel price choices in the presence of endogenous punishment. In line with the prisoner's other dilemma framework of Blonski *et al.* (2011) and Blonski and Spagnolo (2015), we find that subjects' choices converge to the collusive equilibrium with lower level of riskiness of collusion. This highlights the role of strategic uncertainty in cartel coordination problems. Furthermore, subjects' cartel price selection is insensitive to different combinations of fines and detection probabilities featuring the same expected punishment, and is not driven by their risk attitudes.

With regard to market outcomes, the results suggest a trade–off between increased composition deterrence and reduced frequency deterrence in the presence of endogenous enforcement. On the one hand, we find strong evidence of the strategic uncertainty–driven overcharge reducing composition deterrence. On the other hand, the frequency deterrence properties of the enforcement are reduced. This follows from the fact that cartels can self–select themselves into weaker expected punishment by colluding on low prices only. As a result of these opposing effects, the overall welfare effect of endogenous enforcement given our experimental design is unclear.

In contrast to the large body of literature exists for the two forms of deterrence, especially for frequency deterrence, little is known about how they interact under different enforcement regimes. While we highlight the trade-off between frequency and composition deterrence in this paper, we expect future research to investigate it further. For example, while we focus purely on uncertainty–driven effects, the trade–off may differ when profitability–driven effects are present as well. Several studies (e.g. Alm, McClelland and Schulze 1992; Alm, Sanchez and Juan, 1995) find that subjects do not react to punishment in accordance to its functional form. Therefore, the observed behaviour might differ from the best behaviour predicted by theory.

5.6 Appendices D

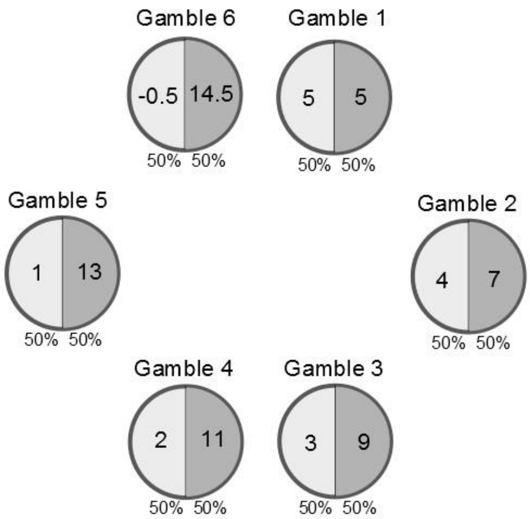
D1. Instructions of treatment BothEndo with automatic price 52

Welcome and thank you for taking part in this experiment. In this experiment you can earn money. How much money you will earn depends on your decision and on the decision made by other participants in this room. The experiment will proceed in two parts. The currency used in the experiment is experimental points. Each experimental point is worth 12 pence. All earnings will be paid to you in cash at the end of the experiment.

Every participant receives exactly the same instructions. All decisions will be anonymous, that is, your identity will not be revealed to other participants at any time during or after the experiment. It is very important that you remain silent. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you.

Instructions for Part 1

In the first part of the experiment you will be asked to choose from six different gambles (as shown below). Each circle represents a different gamble and you must **choose the one that you prefer**. Each circle is divided in half. The two numbers in each circle represent the amount of experimental points the gamble will give you.



An experimenter will toss a coin to determine which half of the circle is chosen. A volunteer will come to the front of the room and confirm the result of the coin toss. If the outcome is heads, you will receive the number of points in the light grey area of the circle you have chosen. If the outcome is tails, you will receive the number of points shown in the dark grey area of the circle you have chosen. Note that no matter which gamble you pick, each outcome will occur with a 50% chance.

Please select the gamble of your choice by **entering the number** of your gamble (1, 2, 3, 4, 5, or 6) in the field "I choose Gamble" and press OK.

Once everyone has made their decision, Part 1 will end and we will move on to Part 2 of the experiment.

Instructions for Part 2

In this part of the experiment you will form a group with two other randomly chosen participants in this room. Throughout the experiment you are matched with the same two participants. All groups of three participants act independently of each other. This part of the experiment will be repeated for at least 20 rounds. From the 20th round onwards, in each round there is **a 20 out of 100 (20%)** chance that the experiment will end.

Your job:

You are in the role of a firm that is in a market with two other firms. In each round, you will have to set a price for your product. This price must be one of the following prices:

40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52

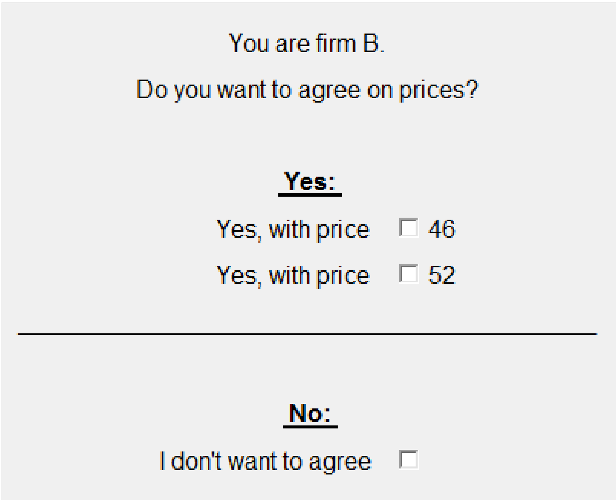
You will only sell the product if the other firms do not set a lower price than you in that round. If you sell the product, your earnings are equal to the difference between the price and the cost, which is 40:

Earnings = Price – 40.

Therefore, you will not make any profit if you set a price of 40. If you do not sell the product, you will not get any earnings but you will not incur costs either. If two or more firms set the same lowest price, the earnings will be shared equally between them.

Before you set your price, you may decide to agree with the other firms to set the same price and share the earnings. There are two prices you can agree on, **46** and **52**. If you agree with the other two firms to set the price of 46 and all firms set 46, each firm will get a profit of **2** experimental points. If you agree with the other two firms to set the price of 52 and all firms set 52, each firm will get a profit of **4** experimental points.

The picture below shows how this will look on the computer. All firms get asked whether they want to agree on prices.



If you want to agree on prices, you can indicate so by choosing the price you want to agree on. You can choose either 46 or 52, or you can choose both prices. The other two firms will do the same. If all three firms wish to agree on prices, and there exists a common price among the three firms' chosen prices, an agreement is reached on that common price.

If all three firms choose both prices, implying that they are fine agreeing on both prices, then a price agreement on 52 will be reached automatically. If there is no common price among firms' choices, no price agreement is reached. For example, no common price is reached if two firms suggest price 46 and one firm suggest price 52.

If you do not wish to agree on prices with the other two firms, you can indicate so by choosing the option No. If at least one firm chooses No, there will be no price agreement.

The following table summarises how price agreement can be reached:

Price agreement is reached, if	All three firms wish to agree on prices and they reach one common price	Agreed price is the common price (46 or 52)
	All three firms wish to agree on prices and they reach two common prices (when all firms choose both 46 and 52)	Agreed price is 52
Price agreement is not reached, if	All three firms wish to agree on prices and they reach no common price	
	At least one firm does not wish to agree on prices	

After deciding whether you would like to form a price agreement, you have to set a price by filling the “Choose a price” box shown below. If a price agreement is reached, a message will appear above the “Choose a price” box showing the price that you agreed on. If no price agreement is reached in that round, no message will appear and you have to set a price without being able to coordinate with the other firms.

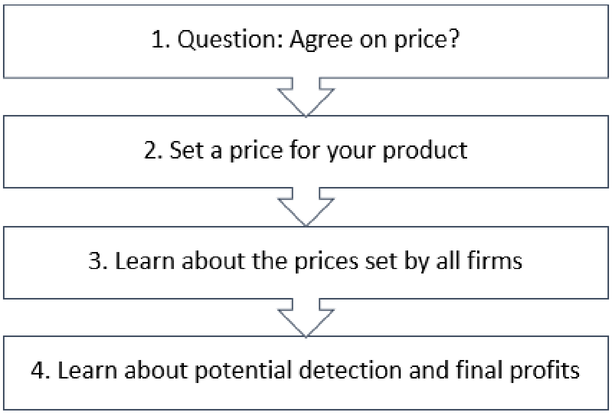
However, the agreement is not binding and you are not required to set the agreed price. After your price choice, you will be informed about the prices that you and the other firms set in that round. If you successfully reach a price agreement, the agreement may be discovered by the computer. The computer can discover the agreement on price 46 with **a 10 out of 100 (10%)** chance, and can discover the agreement on price 52 with **a 20 out of 100 (20%)** chance. If the agreement on price 46 is discovered, a fine of **4** experimental points has to be paid. If the agreement on price 52 is discovered, a fine of **12** experimental points has to be paid. If no price agreement is reached, you cannot be discovered or receive a fine.

The chance of being discovered and the fine depend on the price agreement reached, but not on the prices you set afterwards. The table below summarizes the chance of being discovered by the computer and the associated fines:

	Chance of being discovered	Fine
No price agreement is reached	0%	0
Firms agree on price 46	10%	4
Firms agree on price 52	20%	12

A price agreement can be discovered as long as it has not been discovered in a previous round. Once this has happened, you will not be fined in the future, unless you make a price agreement again. If you and the other two firms had several price agreements and none of them has been discovered, the chance of being discovered and fine always depend on the latest price agreement.

The picture below summarizes the structure of Part 2 of the experiment.

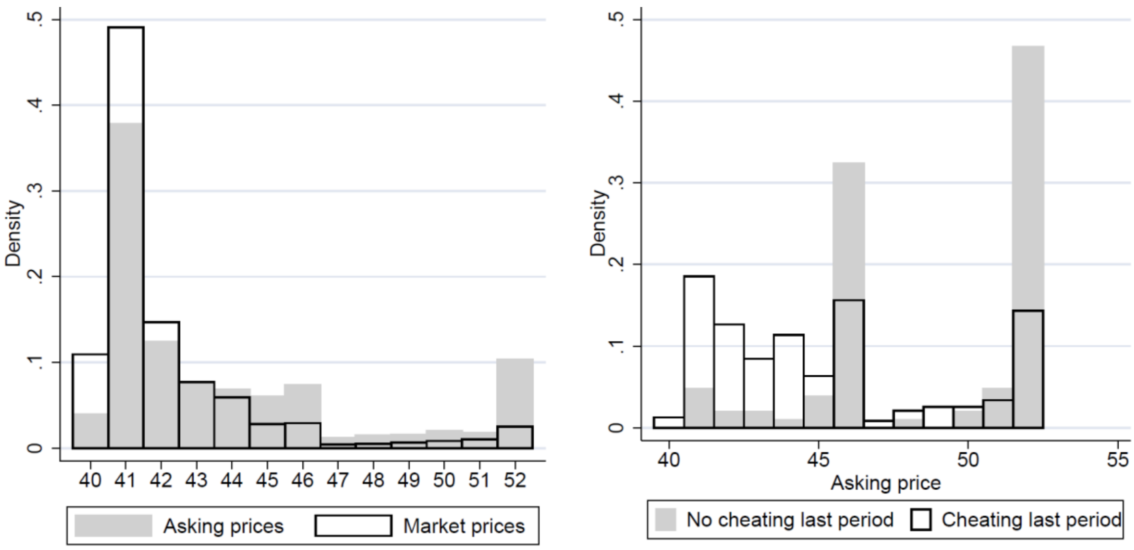


At the end of each round, you will be told the earnings you have made in this round. If you have reached a price agreement, you will also be told whether the agreement has been discovered by the computer.

Final payment:

At the beginning of the experiment you start with an initial endowment of 50 points = 6 GBP. The earnings you make in each round will be converted into cash. Each point is worth 12 pence, and we will round up the final payment to the next 10 pence. We guarantee a minimum earning of 2 GBP. □

D2. Figure 5.5



a) Asking and market prices **b)** Asking prices and previous cheating

Figure 5.5 Choice of prices

Figure 5.5a plots the distribution of both asking and market prices across treatments in the first 20 periods. As it illustrates, homogeneous goods price competition and incidences of cheating lead market prices to be below the asking prices. As previously stated, the predominant price set by subjects is 41, which is the only symmetric non-cooperative equilibrium and yields positive payoffs. Figure 5.5b plots the distribution of asking prices dependent on whether cheating occurred in the previous period on a price agreement reached in that period. Remarkably, although a number of agreements are reached on price 52, cheating primarily leads subjects to charge prices from range between 41 and 45. This can be observed from Figure 5.5a as well. In other words, subjects that deviate from agreements on price 52 tend to undercut by charging prices below the low cartel price of 46. □

D3. Table 5.6

	0	46	52	46/52
Lag asking price	0.004	0.002	0.004	-0.010^{**}
	(0.003)	(0.001)	(0.003)	(0.004)
Lag lowest seller	-0.045	0.018	0.000	0.027
	(0.033)	(0.020)	(0.022)	(0.023)
Lag agreement on 46	-0.126	-0.039	0.101	0.064
	(0.147)	(0.074)	(0.100)	(0.107)
Lag agreement on 52	0.039	-0.109^{***}	0.039	0.031
	(0.076)	(0.025)	(0.036)	(0.074)
Lag choice 46	-0.227^{***}	0.172^{***}	-0.028	0.082^{**}
	(0.046)	(0.032)	(0.034)	(0.036)
Lag choice 52	-0.321^{***}	0.063^{*}	0.120^{***}	0.138^{***}
	(0.030)	(0.027)	(0.037)	(0.056)
Lag choice 46/52	-0.443^{***}	-0.072^{***}	-0.058^{*}	0.573^{***}
	(0.052)	(0.023)	(0.035)	(0.068)
Lag detection 46	0.140^{**}	-0.029	-0.013	-0.098^{***}
	(0.068)	(0.044)	(0.059)	(0.033)
Lag detection 52	0.106	-0.035	-0.041	-0.066
	(0.084)	(0.035)	(0.029)	(0.060)
Lag cheating 46	0.181	0.033	-0.109^{***}	-0.104
	(0.166)	(0.121)	(0.037)	(0.069)
Lag cheating 52	-0.095^{*}	0.197^{**}	-0.066^{***}	-0.035
	(0.055)	(0.083)	(0.018)	(0.056)
EndoD	-0.029	0.055	0.055	-0.081^{*}
	(0.074)	(0.041)	(0.057)	(0.046)
BothEndo	0.070	-0.003	0.020	-0.086^{**}
	(0.070)	(0.041)	(0.056)	(0.040)
Period	0.015^{***}	-0.002	-0.008^{***}	-0.005
	(0.003)	(0.002)	(0.002)	(0.002)
Automatic price 52	-0.010	0.011	-0.041	0.040
	(0.054)	(0.033)	(0.042)	(0.045)
Risk attitude $-$ 2	-0.019	0.022	0.031	-0.034
	(0.112)	(0.052)	(0.079)	(0.068)
Risk attitude $-$ 3	0.037	0.026	0.027	-0.090
	(0.107)	(0.084)	(0.085)	(0.075)
Risk attitude $-$ 4	-0.278^{**}	0.213^{**}	0.121	-0.056
	(0.085)	(0.085)	(0.115)	(0.074)
Risk attitude $-$ 5	0.007	0.058	-0.009	-0.056
	(0.152)	(0.118)	(0.100)	(0.070)
Risk attitude $-$ 6	-0.004	0.048	-0.056	0.012
	(0.112)	(0.078)	(0.052)	(0.087)
Pseudo-LL		-1587.218		
Observations		2052		

Table 5.6 Suggested cartel agreement excluding Baseline – Multi-level multinomial logit
Notes: Values represent average marginal effects. Cluster-robust standard errors in parentheses. ***, **, and * denote 1%, 5%, and 10% significance levels.

D4. Table 5.7

	0	46	52	46/52
Lag asking price	0.017*	−0.016*	−0.007	0.006
	(0.010)	(0.009)	(0.013)	(0.009)
Lag lowest seller	0.061	−0.053	−0.095*	0.086
	(0.062)	(0.053)	(0.054)	(0.060)
Lag agreement on 46	0.059	−0.188***	0.297**	−0.168**
	(0.120)	(0.018)	(0.012)	(0.065)
Lag agreement on 52	−0.065	−0.222***	0.361***	−0.073
	(0.104)	(0.020)	(0.127)	(0.088)
Lag choice 46	−0.227***	0.067	0.011	0.149**
	(0.049)	(0.058)	(0.073)	(0.066)
Lag choice 52	−0.355***	0.030	0.279***	0.046
	(0.043)	(0.058)	(0.066)	(0.068)
Lag choice 46/52	−0.387***	−0.136***	−0.168***	0.691***
	(0.042)	(0.036)	(0.056)	(0.060)
Lag detection 46	0.169***	−0.028	−0.024	−0.118***
	(0.068)	(0.035)	(0.057)	(0.033)
Lag detection 52	0.406***	−0.107**	−0.149*	−0.150**
	(0.125)	(0.045)	(0.082)	(0.066)
Lag cheating 46	−0.194***	0.709***	−0.286***	−0.229***
	(0.028)	(0.020)	(0.031)	(0.075)
Lag cheating 52	−0.215***	0.658***	−0.239***	−0.204***
	(0.035)	(0.022)	(0.036)	(0.032)
EndoF	0.076	−0.020	−0.088	0.032
	(0.068)	(0.066)	(0.065)	(0.056)
EndoD	0.011	0.161**	−0.075	−0.098*
	(0.068)	(0.076)	(0.054)	(0.054)
BothEndo	0.001	0.203***	−0.117*	−0.086**
	(0.075)	(0.077)	(0.067)	(0.044)
Period	0.073	−0.082**	−0.015	0.025
	(0.048)	(0.037)	(0.057)	(0.044)
Automatic price 52	0.004	−0.003	−0.047	0.046
	(0.040)	(0.039)	(0.046)	(0.042)
Risk attitude − 2	0.009	0.059	0.019	−0.087
	(0.070)	(0.083)	(0.081)	(0.060)
Risk attitude − 3	0.068	−0.056	−0.038	0.026
	(0.087)	(0.072)	(0.076)	(0.080)
Risk attitude − 4	−0.196***	0.146	0.101	−0.052
	(0.066)	(0.102)	(0.090)	(0.059)
Risk attitude − 5	−0.020	0.063	0.008	−0.051
	(0.076)	(0.095)	(0.104)	(0.061)
Risk attitude − 6	0.019	0.086	−0.022	−0.083
	(0.084)	(0.094)	(0.077)	(0.058)
Pseudo-LL		−296.673		
Observations		288		

Table 5.7 Suggested cartel agreements – Multi-level multinomial logit

Notes: Values represent average marginal effects. Cluster-robust standard errors in parentheses. ***, **, and * denote 1%, 5%, and 10% significance levels. Includes only the first three periods.

Chapter 6

Conclusion

This thesis consists of four independent essays, each addressing a specific issue regarding firms' strategic incentives and inter-firm agreements. These essays are meant to contribute to our understanding of some new issues emerged along the progress of economy and information technology that, in general, have not yet received much investigation by the economic literature. In the first three essays, we apply IO theory to examine the nature of the selected new phenomenon observed in the real world, assessing their underlying motives, as well as the effects on competition and welfare. In the final essay, we seek to blend some behavioral insights into IO theory in a laboratory experiment.

To briefly sum up, Chapter 2 evaluates the profitability, entry deterrence and welfare effects of quality proliferation in a market of vertical maximal differentiation. Chapter 3 examines the agency model characterizing a vertical relation through comparing it to the wholesale model and linking it to the antitrust treatment of vertical restraints. Based on a broader framework, Chapter 4 formally distinguishes between classic RPM and agency RPM, with the agency model as an example of the latter, and clarifies the *ceteris paribus* effects of reversing decision roles and changing forms of the transfer payment in vertical contracts. Finally, Chapter 5 establishes the strategic uncertainty driven channel of cartel deterrence in the presence of endogenous enforcement, and highlights the trade-off between frequency and composition deterrence.

We discuss future research relating to each essay in turn. While Chapter 2 is inspired by the popular high-street and luxury brands collaboration, it aims at examining the effects of proliferation when it is adopted by a single high quality firm. Nonetheless, we repeatedly observe in the fashion apparel industry that brands collaborations are conducted by two vertically differentiated brands, and sometimes high-street brands, rather than designer brands, seem to take the initiative.[1] Hence we consider it relevant to include the low quality firm in the analysis. Joint proliferation has been examined in the marketing literature as a type of strategic alliance, joint venture or co-branding (e.g., Chun and Niehm, 2010), with the focus being whether such proliferation strategies can benefit both collaborating parties. Meanwhile, there is a lack of economic analysis on the respective incentive of vertically differentiated firms to engage in joint proliferation.

Furthermore, although vertical joint proliferation is usually conducted by two vertically differentiated branded manufacturers, e.g., Lavin for H&M (2010) and Vivienne Westwood for Lee (2010), it can also be between a designer brand and a high-street retailer, e.g., the US Target Corporation has teamed up with a number of designer brands. Hence future research can examine proliferation strategy from the perspective of vertical relation. Moreover, as consumers care increasingly more about the non-physical utility offered by physical goods, distinguishing between true quality and perceived quality while having bounded-rational consumers in the model would be an alternative approach to enrich the analysis and increase policy relevance.

While Chapter 4 in many ways extends Chapter 3, there are several interesting avenues for future research based on itself. First, given the analysis of each pure form two-level vertical

[1] H&M collaborations are a typical example of such. It has been actively engaging in collaborations with various designers for decades. In May 2016, it announced its next collaboration with French designer brand Kenzo, to be launched in November 2016.

contract, future research can assess more complex contracts that involve both unit-fee and revenue-sharing transfer payments, as well as multi-level vertical markets in which different vertical contracts are written between different levels of the market. This kind of analysis would allow us to better evaluate RPM used in a particular industry. Second, it is important for future research to study the equilibrium contract selection problem, assuming fully noncooperative behavior of firms; and to examine the effects of any additional vertical restraint used when there is room for joint profit maximisation.

Regarding the final chapter, future research should continue the study on the strategic uncertainty driven channel of deterrence and the trade-off between frequency and composition deterrence. In particular, future experimental studies may wish to consider alternative designs to examine the effects of endogenous enforcement. The trade-off between the two forms of deterrence may differ when the profitability-driven incentives are present as well.

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