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Entry and Product Variety with Competing Supply Chains

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Abstract
We study a supply chain model where competing manufacturers located around a circle contract with privately informed and exclusive retailers. The number of brands in the market (determined by the manufacturers' zero profit condition) depends on the level of asymmetric information within supply chains and on the types of contracts between manufacturers and retailers. With two-part tariffs, wholesale prices fully reflect retailers' costs. With linear contracts, wholesale prices are constant and independent of retailers' costs. The number of brands is lower (resp. higher) with asymmetric information than with complete information when contracts are linear (resp. with two-part tariffs). Moreover, the number of brands is always higher with linear contracts than with two-part tari¤s. We also analyze the effects of endogenous entry on welfare.

Keywords: Product Variety, Entry, Competing Supply Chains, Vertical Contracting, Asymmetric Information.

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Table of contents

1. Introduction

The number and the characteristics of competing products supplied in a market is one of the most important aspects that firms take into account when making their entry and pricing decisions. This is because consumers' willingness to pay for a product depends on the availability of alternative products. The Marketing and Industrial Organization literatures have extensively studied the relationship between product differentiation, market competition and welfare (see, e.g., Lancaster, 1990). These models, however, usually neglect the interplay between the resolution of agency conflicts within supply chains and product diversity.

There is a large empirical literature showing that asymmetric information affects strategic decision in industries where firms are vertically separated (see, e.g., Lafontaine and Slade, 1997, and Lafontaine and Shaw, 1999). Only few theoretical models, however, analyze the relationship between entry, product differentiation and vertical contracting — see, e.g., Villas-Boas and Schmidt-Mohr (1999) for an application to credit markets. When uninformed upstream manufacturers deal with privately informed downstream retailers, the rents enjoyed by the latter (as a price for truthful information revelation) are likely to influence their pricing decisions, and hence the manufacturers' entry decision and ultimately social welfare.

The objective of this paper is to analyze how asymmetry of information between upstream manufacturers and downstream retailers affects the former's decision to enter a market, and therefore the equilibrium number of competing products. In order to address this issue, we consider a simple model where the number of competing supply chains, each composed by a manufacturer and an exclusive retailer,[1] is endogenous and show how it depends both on the type of wholesale contracts used by manufacturers and retailers, and on the presence of asymmetric information between them.

Following the classic Salop (1979) model, we assume that supply chains locate equidistantly on a circle where consumers are uniformly distributed. Consumers pay a transportation cost to reach a retailer and purchase its product. Each point on the circle may be interpreted as a possible variety of a product; a consumer's location represents its most preferred variety, while the supply chain's location represents the variety it produces.[2] This model captures the idea that different consumers prefer different varieties of a product, and the number of competing supply chains that enter the market affects the degree of differentiation among their products. Since each supply chain produces a different variety, the entry of more supply chains implies lower product differentiation.

Our model can be seen as a simplified representation of various industries, such as traditional

[1] Of course, our results apply more generally to any vertical contracting model where, for example, downstream firms may be manufacturers buying inputs from exclusive suppliers, and reselling the resulting products to downstream retailers. Exclusive dealings are widespread in many industries and have been analyzed in a large theoretical literature — see, e.g., Bonanno and Vickers, (1988), Caillaud *et al.* (1995), Gal-Or (1991, 1999) and Jullien and Rey (2007).

[2] Transportation costs can be interpreted as the loss of utility of a consumer that purchases a variety that is different from its most preferred one.

and business-format franchising (see, e.g., Lafontaine and Slade, 1997), where manufacturers choose to enter by selling differentiated products through exclusive retailers.[3] As an example, consider the "fast fashion" market where large manufacturers (like Promod, Benetton, H&M, etc.) sell to franchisee retailers with exclusive territories. In this market, manufacturers react to fast-changing fashion trends and consumers' volatile demand by delivering a multitude of up-to-the-minute fashion products to exclusive retailers that manage to quickly reach the targeted local costumers (Christopher and Towell, 2000).[4] Other examples of franchising industries where competing manufacturers produce differentiated products and sell to exclusive downstream firms include fast-food, ice cream and hotel chains.

What is the impact of asymmetric information between manufacturers and retailers on the number of products offered in a market? How does the contracting environment (e.g., the manufacturers' selling conditions) affect product differentiation? What is the contractual structure that maximizes social welfare for given intensity of information asymmetry?

To address these issues, we analyze manufacturers' entry decisions with two alternative contractual structures: one where they offer two-part tariffs (i.e., a fixed fee and a linear wholesale price); the other where they only offer a linear wholesale price. Both these types of contracts are standard in the vertical contracting literature. Two-part-tariffs are usually seen as pro-competitive relative to linear prices because they avoid double marginalization and guarantee a higher social welfare — see, e.g., Motta (2004, Ch. 6). However, linear prices are much simpler and do not require the payment of up-front fees that could refrain capital constrained retailers from accepting contractual offers. The empirical literature that tests whether retail prices are consistent with contracts that impose a uniform price or allow for quantity discounts shows that both types of contracts are used in real markets.[5]

We characterize market equilibria with two-part tariffs and linear prices under asymmetric information and compare these with the corresponding complete information benchmarks. Then, to analyze how alternative wholesale contracts affect the market structure, we also compare equilibrium outcomes across contractual regimes. Our main results are the followings.

When manufacturers offer two-part tariffs, the unique equilibrium with asymmetric information entails a separating outcome: retailers fully reveal their costs to manufacturers and wholesale prices fully reflect this information. Moreover, the equilibrium number of products is larger with asymmetric information than with complete information — i.e., asymmetric information enhances entry. This is because, when retailers are privately informed about their cost,

[3] Although in many franchising industries upstream suppliers deal with multiple exclusive downstream outlets, they often eliminate intra-brand competition (between outlets of the same supplier) by granting exclusive territories.

[4] See also "Building a Speedy Supply Chain for Fast Fashion," available at http://blogs.wsj.com/cfo/2013/08/02/building-a-speedy-supply-chain-for-fast-fashion.

[5] Liner prices are used in mainstream department stores or grocery retailing (Iyer and Villas-Boas, 2003) and in the U.K. grocery industry for milk, bakery and fresh products (Inderst and Valletti, 2009). On the other hand, non-linear prices are consistent with U.S. data on yogurt consumption (Berto Villas-Boas, 2007) and French data on bottled water consumption (Bonnet and Dubois, 2010).

manufacturers increase wholesale prices above the complete information benchmark in order to reduce retailers' information rents. Hence, retail prices are higher too and (ceteris paribus) sales revenues increase relative to their complete information level. This creates a positive strategic effect that always dominates the presence of information rents, thus inducing more manufacturers to enter the market. Therefore, with two-part tariffs, worse monitoring technologies (which amplify adverse selection between manufacturers and retailers) have a positive impact on product variety.

By contrast, when manufacturers offer linear contracts, in the unique equilibrium with asymmetric information manufacturers offer a constant wholesale price — a result that echoes Akerlof's lemon problem. Specifically, when wholesale contracts do not include a fixed component, manufactures cannot induce retailers to truthfully reveal their costs, because retailers always choose the lowest wholesale price. Hence, only pooling contracts are offered in equilibrium. But since wholesale price do not depend on retailers' costs, efficient retailers obtain a lower demand with asymmetric information. As a result, less manufacturers enter the market and the number of products is lower than with complete information. In contrast to the case of two-part tariffs, with linear contracts worse monitoring technologies have a negative impact on product variety.

Comparing equilibrium outcomes across contractual structures, we also show that the equilibrium number of products is higher with linear contracts than with two-part tariffs, both with complete and with asymmetric information. This result hinges on the double marginalization effect that emerges with linear wholesale pricing. Compared to two-part tariffs, linear prices induce manufacturers to increase wholesale prices to obtain a positive revenue. Ceteris paribus, this double marginalization leads to higher (average) retail prices and wholesale revenues, which makes entry more profitable.

On the normative side, we also study the impact of asymmetric information on welfare when entry is endogenous. When contracts between manufacturers and retailers are based on two-part tariffs, a social planner would like manufacturers to be fully informed about downstream costs, because social welfare is higher with complete information. Surprisingly though, when contracts between manufacturers and retailers are linear, a social planner prefers retailers to have private information, despite this leads to wholesale prices that do not depend on marginal costs — i.e., social welfare is higher with asymmetric information. Finally, social welfare is always higher with two-part tariffs than with linear prices (for a given information structure).

By endogenizing entry in a model with competing supply chains under asymmetric information, our analysis contributes both to the vertical contracting literature and to the literature on product differentiation and product diversity. First, with the exception of Raith (2003), existing models studying vertical contracting under asymmetric information usually assume an exogenous market structure — see, e.g., Blair and Lewis (1994), Gal-Or (1991, 1999), Kastl *et al.* (2011), and Martimort (1996) — while we show how information asymmetries between manufacturers and retailers affect entry. Second, our paper is the first to offer managerial insights about the link existing between entry incentives and the selling conditions offered by manufacturers to retailers.[6] Moreover, by showing that the number of supply chains that enter a market is larger with two-part tariffs relative to linear pricing, we also contribute to the empirical literature testing whether (actual) retail prices are consistent with linear contracts or two-part tariffs. The novel testable implication of our model is that, other things being equal, less market concentration signal that contracts are linear.

Our paper is also related to the delegation literature that analyzes manufacturers' incentives to sell through independent retailers — see, e.g., McGuire and Staelin (1983), Coughlan (1985), Bonanno and Vickers (1988), and Cachon and Harker (2002). This literature shows that, when wholesale contracts are observable, vertical separation increases manufacturers' profits, because it allows them to soften downstream competition by charging wholesale prices higher than marginal costs. We obtain a similar result when we compare manufacturers' profits with and without asymmetric information when contracts are based on two-part tariffs, even though we assume that contracts are secret.[7] This is a crucial difference because, with secret contracts and two-part tariffs, the delegation literature shows that manufacturers do not obtain higher profit by selling through retailers when there is no asymmetric information (Coughlan and Wernerfelt, 1989; Katz, 1991). In our model the wedge between wholesale prices and marginal costs is exclusively driven by the retailers' private information, which leads manufacturers to offer higher wholesale prices to reduce retailers' information rent.

Finally, although we consider a simple model where each manufacturer only deals with one retailer (as in, e.g., Bonanno and Vickers, 1988, and Vickers, 1985), our insights apply more generally to any vertical contracting model where upstream firms deal with multiple downstream outlet. The reason is that upstream suppliers typically have an incentive to eliminate intra-brand competition through the imposition of exclusive territories (Rey and Stiglitz, 1995).

The rest of the paper is organized as follows. Section 2 presents the model. In Section 3 we analyze the equilibrium with two-part tariffs while in Section 4 we characterize the equilibrium with linear prices. Section 5 compares the equilibrium number of products under two-part tariffs with that obtained under linear pricing. Finally, in Section 6 we determine the impact on welfare of asymmetric information with linear prices and two-part tariffs, and compare welfare across these two contractual environments. Section 7 concludes. All proofs are in the Appendix.

2. The Model

Players and Environment. We consider a market described by the "circular city" model of Salop (1979). There is a unit mass of consumers uniformly distributed with density 1 around a circle of perimeter 1. Goods are distributed by N supply chains (firms) located equidistantly

[6] In a related paper, Reisinger and Schnitzer (2012) study a model with non-exclusive vertical relationships where entry is endogenous both in the upstream and in the downstream market. In contrast to our paper, the authors assume that there is perfect information and focus only on the case of two-part tariffs.

[7] Arguably, secret contracts are more realistic because, even if contracts are observable, they can be secretly renegotiated.

around the circle,[8] and each composed by one upstream supplier (or manufacturer) M_i and one downstream buyer (or retailer) R_i. There is a fixed entry cost $F > 0$ that a manufacturer has to pay to enter the market and distribute its product, and the number of firms N in the market is determined by a zero profit condition for manufacturers, that reflects the assumption of free entry and exit (see, e.g., Raith, 2003).[9]

A manufacturer supplies a fundamental input to his retailer, that is used to produce a final good. Each consumer has a valuation v for a single unit of the good, where for simplicity v is large enough so that each consumer always buys one unit, regardless of the price. Consumers pay a linear transportation cost to reach firms. Specifically, a consumer located at $x \in [0, \frac{1}{N}]$ between firm i and firm j pays a transportation cost equal to tx to buy from firm i and to $t\left(\frac{1}{N} - x\right)$ to buy from firm j. Hence, letting p_i be the retail price of firm i, the consumer is indifferent between the two firms if and only if

$$p_i + tx = p_j + t\left(\frac{1}{N} - x\right) \quad \Leftrightarrow \quad x\left(p_i, p_j\right) \equiv \frac{p_j - p_i + \frac{t}{N}}{2t}.$$

Letting p_{i-1} and p_{i+1} be the prices charged by the firms located to the left and to the right of firm i respectively, the total demand of firm i (in an interior solution)[10] is

$$D_i\left(p_i, p_{i-1}, p_{i+1}\right) = x\left(p_i, p_{i-1}\right) + x\left(p_i, p_{i+1}\right) = \frac{p_{i-1} + p_{i+1} - 2p_i}{2t} + \frac{1}{N}. \tag{2.1}$$

If all his rivals charge the same price p, firm i's demand is

$$D_i\left(p_i, p\right) = \frac{p - p_i}{t} + \frac{1}{N}. \tag{2.2}$$

Uncertainty and private information. Retailers are privately informed about their (constant) marginal costs of production.[11] R_i's marginal cost is θ_i, which is distributed uniformly on the compact support $\Theta \equiv [\mu - \sigma, \mu + \sigma]$, with mean μ and variance $\sigma^2/3 > 0$ — i.e., the distribution function is $G\left(\theta_i\right) = \frac{\theta_i - (\mu - \sigma)}{2\sigma}$. We interpret $\sigma > 0$ as a measure of the level of asymmetric information between manufacturers and retailers and we assume that $\sigma < \sqrt{3Ft/13} \equiv \bar{\sigma}$. This assumption ensures that the demand of each firm is always positive in a symmetric equilibrium (see the Appendix). We also assume that $\sigma < \mu$, so that marginal costs are always positive. For simplicity, manufacturers' marginal costs of production is normalized to zero.[12]

[8] The fact that supply chains locate equidistantly is a consequence of the principle of maximal differentiation in models of spatial competition.

[9] This can be interpreted as the result of a model in which a large number of manufacturers sequentially decide whether to enter the market.

[10] We are going to assume that all firms have positive demand (see below). This implies that each consumer buys from one of the two firms between which he is located, and that the demand of a firm only depends on the prices charged by its closest competitors.

[11] Our main results holds also when retailers are privately informed about demand (see Remark 2 beow).

[12] The assumption that only retailers are privately informed about their production costs is consistent with

Asymmetric information between manufacturers and retailers may arise because, when contracting with manufacturers, retailers are privately informed about the costs of other inputs such as labor, energy, and rental costs, that are not directly related to the provision of the manufacturers' essential input and are provided by other independent suppliers. Alternatively, asymmetric information may arise because retailers are privately informed about their production efficiency.

Vertical contracting. Contracts between manufacturers and retailers are secret and cannot be observed by competitors (e.g., because of the possibility of secret renegotiation). Following the vertical contracting literature, we consider the following two alternative types of contracts,[13] and we use the *Revelation Principle* to characterize the equilibrium — see, e.g., Myerson (1982) and Martimort (1996).

- *Two-part tariffs*: M_i offers a contract $\{w_i(m_i), T_i(m_i)\}_{m_i \in \Theta}$ to R_i, which is a direct revelation mechanism that specifies a (linear) wholesale price $w_i(m_i)$ and a (fixed) franchise fee $T_i(m_i)$ both contingent on R_i's report m_i about his cost θ_i.
- *Linear (wholesale) contracts:* M_i offers a contract $\{w_i(m_i)\}_{m_i \in \Theta}$ to R_i, which is a direct revelation mechanism that only specifies a (linear) wholesale price $w_i(m_i)$ contingent on R_i's report m_i about his cost θ_i.

The empirical literature shows that both types of contracts are used in practice. By comparing these contracts, we will provide new managerial insights that relate characteristics of the industry structure (i.e., the number of firms in the market) with the type of wholesale contracts signed by firms.

Timing. The timing of the game is as follows:

1. Manufacturers enter the market and located equidistantly around the circle.
2. Retailers privately observe their costs.
3. Manufacturers simultaneously offer contracts to retailers, who choose whether to accept them.
4. If a retailer accepts the offered contract, he makes a report about his cost.
5. Retailers choose prices, the market clears and contracts are executed.

the adverse selection literature, that focuses on the effects of the information rents obtained by a privately informed agent who contracts with a principal with full bargaining power. Introducing private information on manufacturers' marginal costs would not affect any of our qualitative results (Maskin and Tirole, 1990).

[13] See Remark 1 for a discussion of RPM contracts.

Equilibrium Concept. The solution concept is Perfect Bayesian Equilibrium (PBE). We restrict to symmetric equilibria where all manufacturers offer the same contract.

Since contracts are private, we have to make an assumption on retailers' beliefs about their competitors' behavior. Following most of the literature on private contracts (e.g., Caillaud *et al.*, 1995, and Martimort, 1996), we assume that agents have *passive beliefs* — i.e., that, regardless of the contract offered by his own manufacturer, a retailer always believes that rival manufacturers offer the equilibrium contract, and that each retailer expects that rival retailers truthfully report their types to manufacturers in a separating equilibrium (see Myerson, 1982, for a game-theoretic foundation of these beliefs). The assumption that retailers expect other manufacturers to offer the equilibrium contract captures the idea that, since manufacturers are independent and act simultaneously, a manufacturer cannot signal to his retailer information that he does not posses about the other manufacturers' contract: the *no signal what you do not know* requirement introduced by Fudenberg and Tirole (1991).[14] The assumption that retailers expect other retailers to truthfully report their types is consistent with the fact that communication within vertical structures is private, and hence retailers do not observe their competitors' reports.[15]

3. Two-Part Tariffs

In this section, we assume that manufacturers offer menus of two-part tariffs.

3.1. Complete Information

As a benchmark, consider the case of complete information within firms — i.e., assume that M_i knows R_i's cost θ_i, but does not observe R_j's cost. Consider an equilibrium in which retailers choose the retail price $p_T^*(\theta_i)$.[16]

For any wholesale price w_i charged by M_i, R_i chooses the retail price that solves

$$\max_{p_i \geq 0} D_i\left(p_i, \overline{p}_T^*\right)\left(p_i - w_i - \theta_i\right), \tag{3.1}$$

where $\overline{p}_T^* = \frac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma} p_T^*(\theta_i)\, d\theta_i$ denotes the average equilibrium price. The solution of this problem identifies R_i's retail price function[17]

$$p_i^*(w_i, \theta_i) = \frac{\theta_i + w_i + \overline{p}_T^* + \frac{t}{N}}{2}, \tag{3.2}$$

[14] See Pagnozzi and Piccolo (2012) for an analysis of the role of beliefs when contracts between manufacturers and retailers are private.

[15] Since each retailer expects other manufacturers to offer their equilibrium contract, which must be incentive compatible in a separating equilibrium, passive beliefs are the most natural restriction to impose at the revelation stage.

[16] Of course, equilibrium prices also depends on the number of firms N. Throughout the paper, to save notation we suppress this dependence unless it is necessary to underline it.

[17] Details of the derivation of all expressions are in the Appendix.

which is increasing in R_i's total marginal cost of production $(\theta_i + w_i)$ and in the expected price $\overline{p}_T^*$ charged by his rivals.

Consider now manufacturers' choice of contracts. When M_i observes R_i's marginal cost, he fully extracts R_i's surplus by charging the franchise fee

$$T_i^*\left(w_i, \theta_i\right) = D_i\left(p_i^*\left(w_i, \theta_i\right), \overline{p}_T^*\right)\left(p_i^*(w_i, \theta_i) - w_i - \theta_i\right).$$

Hence, M_i's maximization program is

$$\max_{w_i} D_i\left(p_i^*\left(w_i, \theta_i\right), \overline{p}_T^*\right)\left(p_i^*(w_i, \theta_i) - \theta_i\right).$$

Notice that, since contracts are secret, strategic effects are absent — i.e., the choice of w_i does not affect the pricing decision of rival retailers.

Lemma 1. *With two-part tariffs and complete information, in a symmetric equilibrium M_i sets a wholesale price $w_T^*(\theta_i) = 0$ $\forall \theta_i$, and R_i sets a retail price*

$$p_T^*(\theta_i) \equiv p_i^*(0, \theta_i) = \frac{t}{N} + \frac{1}{2}\left(\mu + \theta_i\right) \quad \forall \theta_i. \tag{3.3}$$

With complete information, manufacturers act as if integrated with retailers and choose a wholesale price equal to marginal cost (which is normalized to zero). Since contracts are secret, a higher wholesale price would reduce R_i's ability to compete with his rivals by undercutting them, without creating any beneficial strategic effect. Hence, given the rivals' behavior, a positive wholesale price would only reduce the profit that M_i can extract from R_i.

Using the equilibrium retail price (3.3), when a manufacturer enters the market, his expected profits are

$$\tfrac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma} D_i\left(p_T^*\left(\theta_i\right), \overline{p}_T^*\right)\left(p_T^*(\theta_i) - \theta_i\right) d\theta_i = \frac{\sigma^2}{12t} + \frac{t}{N^2}.$$

Setting this equal to F yields the equilibrium number of products

$$N_T^* = \frac{2\sqrt{3}t}{\sqrt{12Ft - \sigma^2}}.$$

The equilibrium number of products is decreasing in the entry cost. Moreover, it is increasing in σ because (indirect) profit functions are convex in prices. Hence, more uncertainty (as reflected by a larger σ) increases profits and hence the number of products that are offered in the market. Finally, a higher t increases the number of products because higher transportation costs make products more differentiated from consumers' perspective, which increases prices and thus entry incentives.

3.2. Asymmetric Information

Assume now that retailers are privately informed about their marginal cost. In this case, retailers have an incentive to report a higher marginal cost in order to pay a lower fixed fee, yet producing at a lower cost. Therefore, manufacturers have to provide an information rent to retailers in order to induce truthful information revelation.

Consider a separating equilibrium in which retailers choose the retail price $p_T^e(\theta_i)$. Given a wholesale price $w_i(m_i)$, R_i chooses p_i to solve

$$\max_{p_i \geq 0} D_i(p_i, \overline{p}_T^e)(p_i - w_i(m_i) - \theta_i),$$

where $\overline{p}_T^e = \frac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma} p_T^e(\theta_i)\, d\theta_i$ denotes the average equilibrium price. The price that maximizes R_i's expected profits is

$$p_i^e(w_i(m_i), \theta_i) = \frac{\theta_i + w_i(m_i) + \overline{p}_T^e + \frac{t}{N}}{2}. \tag{3.4}$$

Following a standard convention in the screening literature, R_i's expected utility when his cost is θ_i and he reports m_i is

$$u_i(m_i, \theta_i) \equiv D_i(p_i^e(w_i(m_i), \theta_i), \overline{p}_T^e)(p_i^e(w_i(m_i), \theta_i) - w_i(m_i) - \theta_i) - T_i(m_i).$$

For a contract to be incentive compatible, truthfully reporting $m_i = \theta_i$ must maximize R_i's utility — i.e., the following local first- and second-order incentive constraints must hold[18]

$$\left.\frac{\partial u_i(m_i, \theta_i)}{\partial m_i}\right|_{m_i=\theta_i} = 0 \quad \Leftrightarrow \quad \dot{T}_i(\theta_i) = -D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e)\dot{w}_i(\theta_i) \quad \forall \theta_i. \tag{3.5}$$

$$\left.\frac{\partial^2 u_i(m_i, \theta_i)}{\partial m_i^2}\right|_{m_i=\theta_i} \leq 0 \quad \Leftrightarrow \quad \dot{w}_i(\theta_i) \geq 0. \tag{3.6}$$

Moreover, letting $u_i(\theta_i) \equiv u_i(\theta_i, \theta_i)$ denote R_i's utility when he reports his true type (i.e., his information rent), the participation constraint is

$$u_i(\theta_i) \geq 0, \quad \forall \theta_i. \tag{3.7}$$

Therefore, M_i solves the following maximization program

$$\max_{w_i(\cdot), T_i(\cdot)} \int_{\mu-\sigma}^{\mu+\sigma} \left[D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e)w_i(\theta_i) + T_i(\theta_i)\right] d\theta_i, \tag{3.8}$$

subject to conditions (3.5), (3.6) and (3.7).

Following Laffont and Martimort (2000, Ch. 3), we first ignore the constraint $\dot{w}_i(\theta_i) \geq 0$, and

[18] In the Appendix, we show that these conditions are also sufficient for global incentive compatibility — i.e., $u_i(\theta_i, \theta_i) \geq u_i(m_i, \theta_i)\ \forall (m_i, \theta_i) \in \Theta^2$.

then check that it is actually satisfied in the equilibrium that we characterize. In the Appendix, we show that $u_i(\theta_i)$ is decreasing and the participation constraint is binding when $\theta_i = \mu + \sigma$ — i.e., $u_i(\mu + \sigma) = 0$. Hence, R_i's rent is

$$u_i(\theta_i) = \int_{\theta_i}^{\mu+\sigma} D_i(p_i^e(w_i(x), x), \overline{p}_T^e)dx. \tag{3.9}$$

This rent is increasing in consumers' demand because a retailer obtains a higher utility by reporting a higher marginal costs when this allows him to sell a higher quantity on average — i.e., the information rent of a type is increasing in the quantity sold by less efficient types. Notice also that, since the demand for the good sold by R_i is decreasing in p_i, this provides an incentive for a manufacturer to increase the wholesale price to limit the retailer's rent (since by equation (3.4) retail prices are increasing in wholesale prices).

By a standard change of variables, the fixed fee is

$$T_i(\theta_i) = D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e)(p_i^e(w_i(\theta_i), \theta_i) - w_i(\theta_i) - \theta_i) - u_i(\theta_i).$$

Substituting this into (3.8) and integrating by parts, M_i's (relaxed) maximization program is

$$\max_{w_i(\cdot)} \int_{\mu-\sigma}^{\mu+\sigma} D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e) \left[p_i^e(w_i(\theta_i), \theta_i) - \theta_i - \frac{G(\theta_i)}{g(\theta_i)}\right] d\theta_i.$$

Lemma 2. *With two-part tariff and asymmetric information, in a symmetric equilibrium M_i sets a wholesale price*

$$w_T^e(\theta_i) = \theta_i - \mu + \sigma > 0 \quad \forall\theta_i \tag{3.10}$$

and R_i sets a retail price

$$p_T^e(\theta_i) \equiv p_i^e(w_T^e(\theta_i), \theta_i) = \theta_i + \sigma + \frac{t}{N} \quad \forall\theta_i. \tag{3.11}$$

Moreover, for a given number of firms, retail prices are higher with asymmetric information than with complete information — i.e., $p_T^e(\theta_i) > p_T^*(\theta_i)$.

In order to trade-off efficiency and rents, manufacturers increase wholesale prices above the complete information benchmark (i.e., a double marginalization effect), and this distortion is increasing in σ. As a result, retail prices are higher too. Notice that this double marginalization result is not due to contracts being public as in the delegation literature, but it arises as an equilibrium result due to asymmetric information between manufacturers and retailers, even if manufacturers offer secret contracts.

Using the equilibrium retail price (3.11) and letting $u^e(\theta_i)$ denote the equilibrium rent of the retailer, the expected profits of a manufacturer who enters the market are

$$\tfrac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\left\{D_i(p_T^e(\theta_i),\overline{p}_T^e)(p_T^e(\theta_i)-\theta_i)-u^e\left(\theta_i\right)\right\}d\theta_i=\underbrace{\frac{1}{N}\left[\frac{t}{N}+\sigma\right]}_{\text{sale revenues}}-\underbrace{\sigma\left[\frac{1}{N}-\frac{\sigma}{3t}\right]}_{\text{information rent}}.$$

These profits can be decomposed in two terms: sale revenues and information rents. This suggests a trade-off: a larger σ makes the retailers' mimicking opportunities more profitable, whereby making truthful information revelation more costly; but a larger σ also increases prices, and hence profit margins.

Setting this profit equal to F yields the equilibrium number of products

$$N_T^e=\frac{\sqrt{3}t}{\sqrt{3Ft-\sigma^2}}.$$

As with complete information, the number of products with asymmetric information is decreasing in F, and is increasing in t and σ. Hence, lower uncertainty (i.e., a low σ), as for instance implied by better monitoring technologies in the upstream market, lead to less entry and a lower product variety. The next proposition compares the complete information benchmark with the asymmetric information case.

Proposition 1. *With two-part tariffs: (i) more firms enter with asymmetric information than with complete information — i.e., $N_T^e > N_T^*$ — and (ii) average retail prices are higher with asymmetric information than with complete information — i.e., $\overline{p}_T^e\left(N_T^e\right) > \overline{p}_T^*\left(N_T^*\right)$.*

With asymmetric information, manufacturers charge higher wholesale prices in order to reduce retailers' information rents. Hence, as shown in Lemma 2, for a given number of firms retail prices and sales revenues are higher with asymmetric information than with complete information. This strategic effect dominates the effect of the presence of information rents and induces more manufacturers to enter the market with asymmetric information, in an attempt to make positive profits. Our result echoes the literature on strategic delegation: by increasing retailer's relevant costs through a higher wholesale price, manufacturers increase the profitability of the market, and thus induce more entry. However, in contrast to this literature, our result does not hinge on the observability of contracts, but on the presence of asymmetric information. Therefore, with two-part tariffs, worse monitoring technologies, which amplify the adverse selection problem between manufacturers and retailers, increase entry and hence product variety.

Even when taking into account the number of firms that enter the market, average equilibrium retail prices are higher with asymmetric information. This suggests that the effect of higher wholesale prices with asymmetric information dominates the (indirect) effect of the presence of more firms, which tends to reduce retail price because of more competition.

Remark 1. When manufacturers control retail prices (RPM), the equilibrium of the game is equivalent to the one in our model (both with and without asymmetric information). Specifically, this equivalence result holds when each manufacturer makes the retailer residual claimant of the sale revenues — i.e., M_i chooses a wholesale price equal to zero and imposes a retail price to R_i —[19] because there is a one-to-one relationship between retail and wholesale prices — see, e.g., Bassi *et al.* (2012). Hence, the (second-best) optimal price with two-part tariffs is also optimal when manufacturers directly choose retail prices, so that choosing retail prices is equivalent to choosing wholesale prices.

Remark 2. With linear demand and constant marginal costs, the main qualitative insights of our model hold even with asymmetric information about demand rather than costs. Specifically, if retailers are privately informed about demand (for instance, about the uncertain size of the circle) manufacturers still need to provide positive rents in order to induce truthful information revelation by retailers, and these rents are increasing in the quantity of final product sold by each retailer, so that wholesale prices are still upward distorted.[20]

4. Linear (Wholesale) Prices

The theoretical literature has often considered linear contracts in vertical relationships (e.g., Katz, 1986; Inderst and Valletti, 2009), because of mathematical simplicity and realism. As discussed in Section 1, there is also a growing empirical literature showing that, in many industries, manufacturers actually use linear contracts. Hence, to gain managerial insights that have direct implications for real-life practices, in this section we consider the impact on entry of linear prices, and then compare the resulting outcome with the case of two-part tariffs.

4.1. Complete Information

First assume that each manufacturer knows his retailer's marginal cost. Consider an equilibrium in which retailers choose the retail price $p_L^*(\theta_i)$. Since retailers solve the same program (3.1) as with two-part tariffs, for any wholesale price w_i, R_i's chooses the retail price

$$p_i^*(w_i, \theta_i) = \frac{\theta_i + w_i + \overline{p}_L^* + \frac{t}{N}}{2}, \tag{4.1}$$

where $\overline{p}_L^* = \frac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma} p_L^*(\theta_i)\, d\theta_i$ denotes the average equilibrium price.

Hence, M_i's maximization problem is

$$\max_{w_i} D_i\left(p_i^*\left(w_i, \theta_i\right), \overline{p}_L^*\right) w_i.$$

[19] Formally, M_i offers the contract $\{p_i(m_i), T_i(m_i)\}_{m_i\in\Theta}$, which specifies a retail price $p_i(\cdot)$ and a fixed fee $T_i(\cdot)$ as a function of R_i's report m_i.

[20] Suppose, for example, that retailers' costs are common knowledge while the total size of the circle, say α, is random and unknown to both manufacturers and retailers. It can be shown that, in this case, all our qualitative conclusions hold if retailers receive private i.i.d. signals (say s_i, $i = 1, 2$) about α and the conditional distribution function $F(\alpha|s_i)$ is linear. For correlated signals or the case where retailers are informed about α see, e.g., Gal-Or (1999) and Martimort and Piccolo (2010).

The first-order condition of this problem equalizes the marginal wholesale revenue to the manufacturer's cost (which is normalized to zero) — i.e.,

$$\frac{\partial D_i\left(p_i^*\left(w_i,\theta_i\right),\overline{p}_L^*\right)}{\partial p_i}\frac{\partial p_i^*\left(w_i,\theta_i\right)}{\partial w_i}w_i+D_i\left(p_i^*\left(w_i,\theta_i\right),\overline{p}_L^*\right)=0.$$

Lemma 3. *With linear wholesale prices and complete information, in a symmetric equilibrium M_i sets a wholesale price*

$$w_L^*\left(\theta_i\right)=\frac{2t}{N}+\frac{1}{2}\left(\mu-\theta_i\right)\quad\forall\theta_i, \tag{4.2}$$

and R_i sets a retail price

$$p_L^*\left(\theta_i\right)\equiv p_i^*(w_L^*(\theta_i),\theta_i)=\frac{3t}{N}+\frac{1}{4}\left(3\mu+\theta_i\right)\quad\forall\theta_i. \tag{4.3}$$

Since M_i cannot extract R_i's surplus through the franchise fee, to obtain a positive profit he chooses a positive wholesale price (rather than equal to zero as with two-part tariffs). This, however, also induces a higher retail price — a standard double marginalization result. The wholesale price is decreasing in θ_i: manufacturers want more inefficient retailers to pay a lower wholesale price in order to obtain a higher demand (since the retail price is increasing in θ_i). As expected, both wholesale and retail prices are increasing in t and μ, and decreasing in N.

Using (4.2) and (4.3), when a manufacturer enters the market, his expected profits are

$$\tfrac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\left[D_i\left(p_L^*\left(\theta_i\right),\overline{p}_L^*\right)\right]w_L^*(\theta_i)d\theta_i=\frac{\sigma^2}{24t}+\frac{2t}{N^2}.$$

Setting this equal to F yields the equilibrium number of products

$$N_L^*=\frac{4\sqrt{3}t}{\sqrt{24Ft-\sigma^2}}.$$

As with two-part tariffs, the equilibrium number of products with linear pricing and complete information is increasing in σ and in t.

4.2. Asymmetric Information

Assume now that retailers are privately informed about their marginal costs. Consider a separating equilibrium in which retailers choose the retail price $p_L^e\left(\theta_i\right)$. Given that M_i offers to R_i a menu of linear wholesale prices $w_i\left(m_i\right)$, since retailers solve the same program as with two-part tariffs, R_i chooses the retail price

$$p_i^e(w_i(m_i),\theta_i)=\frac{\theta_i+w_i(m_i)+\overline{p}_L^e+\frac{t}{N}}{2}, \tag{4.4}$$

where $\overline{p}_L^e=\frac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma}p_L^e\left(\theta_i\right)d\theta_i$ denotes average equilibrium price.

R_i's expected utility when his cost is θ_i and he reports m_i is

$$u_i\left(m_i, \theta_i\right) \equiv D_i(p_i^e(w_i(m_i), \theta_i), \overline{p}_L^e)\left(p_i^e(w_i(m_i), \theta_i) - \theta_i - w_i(m_i)\right).$$

For a contract to be incentive compatible, truthfully reporting $m_i = \theta_i$ must maximize R_i's utility — i.e., the following local first-order incentive constraint must hold[21]

$$\left.\frac{\partial u_i\left(m_i, \theta_i\right)}{\partial m_i}\right|_{m_i=\theta_i} = 0 \quad \Leftrightarrow \quad -D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_L^e)\dot{w}_i(\theta_i) = 0.$$

This constraint has a simple interpretation. Since with linear prices M_i cannot use the fixed fee to screen R_i's types, an incentive compatible contract either specifies a wholesale price that equalizes (expected) demand to zero — i.e., $D_i(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_L^e) = 0$ — which however would lead R_i to always lie so as to be offered the lowest possible wholesale price, or it entails a pooling allocation — i.e., such that $\dot{w}_i(\theta_i) = 0$ for any θ_i — which implies that there is no communication between M_i and R_i.[22] Hence, in an incentive feasible contract the wholesale price does not depend on θ_i — i.e., the upstream contracting game has only pooling equilibria.

Therefore, M_i chooses the same wholesale price regardless of R_i's cost. Letting this unique wholesale price be w_i, M_i solves

$$\max_{w_i} \int_{\mu-\sigma}^{\mu+\sigma} D_i(p_i^e(w_i, \theta_i), \overline{p}_L^e) w_i d\theta_i.$$

The first-order condition equalizes the expected marginal wholesale revenue to the marginal cost of the manufacturer

$$\int_{\mu-\sigma}^{\mu+\sigma} \left[\frac{D_i(p_i^e(w_i, \theta_i), \overline{p}_L^e)}{\partial p_i} \frac{\partial p_i^e(w_i, \theta_i)}{\partial w_i} w_i + D_i(p_i^e(w_i, \theta_i), \overline{p}_L^e)\right] d\theta_i = 0.$$

Lemma 4. *With linear wholesale prices and asymmetric information, in a symmetric equilibrium M_i sets a wholesale price*

$$w_L^e = \frac{2t}{N} \quad \forall \theta_i, \tag{4.5}$$

and R_i sets a retail price

$$p_L^e\left(\theta_i\right) \equiv p_i^e(w_L^e, \theta_i) = \frac{3t}{N} + \frac{1}{2}\left(\mu + \theta_i\right) \quad \forall \theta_i. \tag{4.6}$$

Moreover, retail and wholesale prices are higher with complete information than with asymmetric information, for a given number of products — i.e., $p_L^*\left(\theta_i\right) > p_L^e\left(\theta_i\right)$ and $w_L^*\left(\theta_i\right) > w_L^e$ — if and only if $\theta_i < \mu$.

Although asymmetric information leads to wholesale prices that are independent of retailers'

[21] See Martimort and Semenov (2006).

[22] Again, this result would still hold with uncertainty about demand instead of costs.

marginal costs, equilibrium retail prices do depend on retailers' costs because optimality requires to choose retail prices that equalize a retailer's marginal cost to marginal revenue.

In contrast to the case of two-part tariffs, with linear prices the comparison between wholesale and retail prices with and without asymmetric information is ambiguous and depends on the retailer's cost. Recall that, with complete information, the wholesale price is decreasing in θ_i. By contrast, with asymmetric information, retailers pay the same wholesale price regardless of their costs. This wholesale price is higher than the one with complete information when θ_i is higher than its expected value. In this case, since retailers choose retail prices according to the same rule both with and without asymmetric information, the retail price with asymmetric information is higher than with complete information.

Using (4.5) and (4.6), when a manufacturer enters the market, his expected profits are

$$\tfrac{1}{2\sigma}\int_{\mu-\sigma}^{\mu+\sigma} D_i(p_L^e(\theta_i), \overline{p}_L^e) w_L^e d\theta_i = \frac{2t}{N^2}.$$

Setting this equal to F yields the equilibrium number of products with linear wholesale prices and asymmetric information,

$$N_L^e = \sqrt{\frac{2t}{F}}.$$

In this case, neither M_i's profit nor the equilibrium number of products depend on the the degree of asymmetric information σ because wholesale prices are unresponsive to marginal costs and the demand function is linear in retail prices, which are also linear functions of costs.

Proposition 2. *With linear wholesale prices: (i) more firms enter with complete information — i.e., $N_L^* > N_L^e$ — and (ii) average retail prices are higher with asymmetric information — i.e., $\overline{p}_L^e\,(N_L^e) > \overline{p}_L^*\,(N_L^*)$.*

When retailers are privately informed about their marginal costs, manufacturers cannot induce them to truthfully reveal their type and the unique equilibrium entails a constant wholesale price. Hence, in contrast to the case of complete information, wholesale profits only depend on the expected marginal cost and not on its variance (although indirect profit functions are still convex in wholesale prices). Moreover, since manufacturers cannot adjust the wholesale price to retailers' costs with asymmetric information, they manage to sell a lower quantity on average. Therefore, entry is less profitable than under complete information (in contrast to the case of two-part tariffs). This also implies that, with linear contracts, worse monitoring technologies have a negative impact on product variety.

In the Appendix, we show that the comparison between average retail prices with and without asymmetric information only depend on N. Hence, entry by a larger number of firms with complete information implies lower average retail prices.

5. Linear Prices vs. Two-Part Tariffs

In this section, we compare the equilibrium number of products across contractual regimes for given information structure. This provides an empirical prediction on the different number of manufacturers entering a market, depending on the types of contracts with their retailers.

Proposition 3. *The equilibrium number of products is higher with linear contracts than with two-part tariffs, both with complete and with incomplete information: $N_L^* > N_T^*$ and $N_L^e > N_T^e$. The average retail price is higher with linear contracts than with two-part tariffs, both with complete and with incomplete information: $\overline{p}_L^* (N_L^*) > \overline{p}_T^* (N_T^*)$ and $\overline{p}_L^e (N_L^e) > \overline{p}_T^e (N_T^e)$.*

This result hinges on the double marginalization effect that emerges with linear wholesale pricing. In contrast to two-part tariffs, with linear pricing manufacturers increase wholesale prices above their marginal costs, in order to obtain a positive wholesale revenue. Ceteris paribus, this generates a double marginalization effect that leads to excessive retail prices and thus to higher wholesale revenues, which makes upstream entry more profitable. Interestingly, this result shows that, when the market structure is endogenous, the number of firms that enter with linear prices is unambiguously larger than with two-part tariffs.

This result offers a contribution to the empirical literature testing whether (actual) retail prices are consistent with linear contracts or two-part tariffs. The novel testable implication of our model is that, other things being equal, linear contracts are associated with lower market concentration.

Finally, by Propositions (1), (2) and (3): $N_L^* > N_L^e > N_T^e > N_T^*$: entry incentives are maximized with linear contracts and complete information, while they are minimized with complete information and two-part tariffs.

6. Welfare

In sections 3 and 4, we showed that the contractual structure between manufacturers and retailers and the presence of asymmetric information affect both the number of firms that enter the market and the retail price that they charge to consumers. In this section, we analyze the effects on ex-ante social welfare.

Since each consumer always purchases one unit of the good, total demand and production are fixed and social welfare is the difference between consumers' value for the good and total costs. These costs are the sum of consumers', firms' and entry costs, and depend both on the number of firms and on the demand for each product, given the realized retail prices. Hence, what matters for welfare is: (i) how far consumers travel to reach the firms from which they buy (depending on the distance between firms and on their relative prices), which affects transportation costs; (ii) how much each firm produces (depending on the firm's demand), which affects production costs; (iii) how many firms enter the market, which affects entry, production and transportation costs.

We first compare the actual number of products in the different contractual structures (derived in Sections 3 and 4) with the socially optimal number of products (derived in the Appendix).

Lemma 5. *Both with two-part tariffs and with linear prices, the actual number of products is higher than the socially optimal number of products, with and without asymmetric information.*

Therefore, in our model, there are always too many firms entering the market. This is consistent with the standard result of "excessive entry" in the Salop model and implies that social welfare is never maximized in any market equilibrium where entry is decided by manufacturers.

We then compare social welfare with different information structures.

Proposition 4. *With two-part tariffs, social welfare is higher under complete information than under asymmetric information. With linear prices, social welfare is higher under asymmetric information than under complete information.*

Hence, when contracts between manufacturers and retailers are based on two-part tariffs, a social planner prefers complete information, while he prefers asymmetric information when contracts are based on linear prices. To understand this result, notice that there are two differences between the regimes with and without asymmetric information: one depending on the sensitivity of prices to marginal costs and the other depending on the number of firms that enter the market.

First, in both contractual regimes, with asymmetric information retail prices are more sensitive to marginal costs and hence there are larger differences between firms' retail prices. When the number of firms in the market is the same with and without asymmetric information, this implies that: (i) transportation costs are higher since it is more likely that a firm has a much lower price than competitors and hence there are more consumers willing to travel larger distances; and (ii) production costs are lower since it is more likely that a firm with lower costs attracts a larger share of demand (recall that the total quantity produced is fixed, so a low cost for one firm implies a shift of demand from high-cost firms to the low-cost firm).

Second, recall that the equilibrium number of firms is larger under asymmetric information with two-part tariffs but larger under complete information with linear prices: $N_T^e > N_T^*$ and $N_L^* > N_L^e$. A larger N increases entry costs but tends to reduce total production costs since it increases the variability of realized costs (so that a larger share of demand is allocated to more efficient firms). The effect of a larger N on transportation costs is ambiguous: a larger number of firms reduces the distance between them, which reduces transportation costs but it also makes it relatively more likely that a retailer has very low cost and hence a very low retail price, which induces consumers to travel further.

Therefore, with two-part tariffs, the effect of asymmetric information is to increase entry costs and reduce production costs; while in the Appendix we show that asymmetric information increases transportation costs. On balance, the effects of asymmetric information on entry and transportation costs are stronger than the effect on production costs and social welfare is higher under complete information.

By contrast, with linear prices, the effect of asymmetric information is to reduce entry costs and increase production costs; while in the Appendix we show that asymmetric information reduces transportation costs. On balance, the effects of asymmetric information on entry and production costs are stronger than the effect on transportation costs and social welfare is higher under asymmetric information.

Finally, we compare social welfare with different contractual structures.

Proposition 5. *Welfare is always lower with linear pricing than with two-part tariffs.*

Hence, welfare is higher with two-part tariffs regardless of the information structure, which is consistent with standard results that take as given the number of firms — see, e.g., Motta (2004). This depends on the following effects. With two-part tariffs, prices are more sensitive to marginal costs and hence are further away from each other (ceteris paribus), which increases transportation costs and reduces production costs. Moreover, less firms enter with two-part tariffs, which reduces entry costs but tends to increase production and transportation costs. In the appendix we show that overall costs are higher with linear prices.

7. Conclusions

Asymmetric information between manufacturers and retailers affects the variety of products offered in a market. To gain novel managerial insights on this topic, following Salop (1979) we have considered competing supply chains that enter a market and locate on a circle where consumers are uniformly distributed. When manufacturers offer two-part tariffs to their exclusive and privately informed retailers, the unique equilibrium entails a separating outcome: retailers fully reveal their costs and wholesale prices fully reflect this information. In this case the equilibrium number of products is higher with asymmetric information than with complete information. By contrast, when manufacturers offer linear contracts, the unique equilibrium entails a pooling outcome where manufacturers offer a constant wholesale price and the equilibrium number of products is lower with asymmetric information.

Our results contribute to the vertical contracting literature and to the literature on product differentiation and product diversity, which usually assume either an exogenous market structure or complete information. Moreover, comparing entry incentives across contractual structures, we have shown that (other things being equal) product diversity is higher when manufacturers use linear contracts, a prediction that can be used by the recent and growing empirical literature testing whether (actual) retail prices are consistent with linear contracts or two-part tariffs.

A. Appendix

Proof of Lemma 1. Substituting (2.2), R_i's maximization problem is

$$\max_{p_i \geq 0} \left(\overline{p}_T^* - p_i + \frac{t}{N} \right) (p_i - w_i - \theta_i).$$

The first-order necessary and sufficient condition,

$$w_i + \theta_i - 2p_i + \overline{p}_T^* + \frac{t}{N} = 0,$$

yields (3.2).

Substituting (2.2) and (3.2), M_i's maximization problem is

$$\max_{w_i} \left\{ (\theta_i - \overline{p}_T^* - \frac{t}{N})^2 - w_i^2 \right\}.$$

Since M_i's objective function is decreasing in w_i, it is optimal to set $w_T^*(\theta_i) = 0 \quad \forall \theta_i$. Replacing the equilibrium wholesale price into (3.2) and taking expectations with respect to θ_i yields the average equilibrium price, $\overline{p}_T^* = \mu + \frac{t}{N}$. Finally, $p_T^*(\theta_i)$ is obtained by substituting $\overline{p}_T^*$ and $w_T^*(\theta_i)$ into (3.2). ■

Proof of Lemma 2. The first-order condition associated for R_i's maximization problem is

$$\frac{\partial D_i(p_i, \overline{p}_T^e)}{\partial p_i}(p_i - w_i(m_i) - \theta_i) + D_i(p_i, \overline{p}_T^e) = 0, \tag{A.1}$$

$$\Leftrightarrow \quad w_i(m_i) + \theta_i + \overline{p}_T^e - 2p_i + \frac{T}{N} = 0,$$

where we have used (2.2) and $\frac{\partial D_i(p_i, \overline{p}_T^e)}{\partial p_i} = \frac{1}{t}$. Rearranging yields (3.4).

Consider now R_i's information disclosure problem. To characterize the set of incentive feasible contracts let

$$u_i(\theta_i, m_i) \equiv (p_i^e(w_i(m_i), \theta_i) - w_i(m_i) - \theta_i) D_i(p_i^e(w_i(m_i), \theta_i), \overline{p}_T^e) - T_i(m_i), \tag{A.2}$$

with $u_i(\theta_i) \equiv \max_{\theta_i \in \Theta} u_i(\theta_i, m_i)$. R_i truthfully reveals his cost only if the following first-order condition holds

$$\left. \frac{\partial u_i(\theta_i, m_i)}{\partial m_i} \right|_{m_i = \theta_i} = 0 \quad \Leftrightarrow \quad -\dot{w}_i(m_i) D_i(p_i^e(w_i(m_i), \theta_i), \overline{p}_T^e) - \dot{T}_i(m_i) \Big|_{m_i = \theta_i} = 0 \quad \forall \theta_i \in \Theta. \tag{A.3}$$

Differentiating $u_i(x)$ with respect to x and using (A.3) yields

$$\dot{u}_i(x) = -D_i(p_i^e(w_i(x), x), \overline{p}_T^e),$$

and integrating $\dot{u}_i(x)$ between θ_i and $\mu+\sigma$ yields

$$u_i(\theta_i) = u_i(\mu+\sigma) + \int_{\theta_i}^{\mu+\sigma} D_i(p_i^e(w_i(x),x), \overline{p}_T^e)dx.$$

This is equation (3.9) when the participation constraint binds at $\mu+\sigma$ — i.e., when $u_i(\mu+\sigma) = 0$.

However, $m_i = \theta_i$ is an optimum for R_i only if $u_i(\theta_i, m_i)$ is concave in m_i at $m_i = \theta_i$. Using standard techniques (see, e.g., Laffont and Martimort, 2000), this requires

$$\left.\frac{\partial^2 u_i(\theta_i, m_i)}{\partial m_i^2}\right|_{m_i=\theta_i} \leq 0, \quad \forall \theta_i \in \Theta. \tag{A.4}$$

Since (A.3) must be satisfied for every θ_i, differentiating with respect to θ_i yields

$$\left.\frac{\partial^2 u_i(\theta_i, m_i)}{\partial m_i^2} + \frac{\partial^2 u_i(\theta_i, m_i)}{\partial m_i \partial \theta_i}\right|_{m_i=\theta_i} = 0, \quad \forall \theta_i \in \Theta. \tag{A.5}$$

Condition (A.4) together with (A.5) yield

$$\left.\frac{\partial^2 u_i(\theta_i, m_i)}{\partial m_i \partial \theta_i}\right|_{m_i=\theta_i} \geq 0, \quad \forall \theta_i \in \Theta,$$

$$\Rightarrow \quad -\dot{w}_i(\theta_i) \left.\frac{\partial p_i^e(w_i(m_i), \theta_i)}{\partial \theta_i} \frac{\partial D_i(p_i^e(w_i(m_i), \theta_i), \overline{p}_T^e)}{\partial p_i}\right|_{m_i=\theta_i} \geq 0, \quad \forall \theta_i \in \Theta. \tag{A.6}$$

Since $\frac{\partial p_i^e(w_i(m_i),\theta_i)}{\partial \theta_i} \geq 0$ by (3.4) and $\frac{\partial D_i(.)}{\partial p_i} < 0$ by (2.2) equation (A.6) implies (3.6).

Next, we determine the equilibrium wholesale price. The first-order necessary and sufficient condition associated to M_i's relaxed maximization program is

$$\frac{\partial D_i\left(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e\right)}{\partial p_i} \frac{\partial p_i^e(w_i(\theta_i), \theta_i)}{\partial w_i} \left[p_i^e(w_i(\theta_i), \theta_i) - \theta_i - \frac{G(\theta_i)}{g(\theta_i)}\right] +$$
$$+ D_i\left(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e\right) \frac{\partial p_i^e(w_i(\theta_i), \theta_i)}{\partial w_i} = 0. \tag{A.7}$$

Notice that (A.1) implies

$$D_i\left(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e\right) = -\frac{\partial D_i\left(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e\right)}{\partial p_i} (p_i^e(w_i(\theta_i), \theta_i) - w_i(\theta_i) - \theta_i).$$

Replacing this into (A.7) yields

$$\frac{\partial D_i\left(p_i^e(w_i(\theta_i), \theta_i), \overline{p}_T^e\right)}{\partial p_i} \left[w_i(\theta_i) - \frac{G(\theta_i)}{g(\theta_i)}\right] = 0,$$

which yields the equilibrium wholesale price $w_T^e(\theta_i)$ in (3.10). Since $\dot{w}_T^e(\theta_i) > 0$, the local second-order incentive compatibility constraint (3.6) is satisfied. Inserting the equilibrium wholesale price into (3.4), and taking expectations with respect to θ_i, yields $\overline{p}_T^e = \mu + \sigma + \frac{t}{N}$. The equilibrium price (3.11) is obtained by substituting $\overline{p}_T^e$ and (3.10) into (3.4).

To satisfy the global incentive constraint (A.2), the equilibrium contract must satisfy

$$u_i(\theta_i) - u_i\left(\theta_i, \theta_i'\right) \geq 0 \quad \forall(\theta_i, \theta_i') \in \Theta^2$$

$$\Leftrightarrow \quad (p_i^e(w_T^e(\theta_i), \theta_i) - w_T^e(\theta_i) - \theta_i)D_i(p_i^e(w_T^e(\theta_i), \theta_i), \overline{p}_T^e) - T_T^e(\theta_i) \geq$$
$$(p_i^e(w_T^e(\theta_i'), \theta_i) - w_T^e(\theta_i') - \theta_i)D_i(p_i^e(w_T^e(\theta_i'), \theta_i), \overline{p}_T^e) - T_T^e(\theta_i')$$

$$\Leftrightarrow \quad \int_{\theta_i}^{\theta_i'} \left\{\dot{w}_T^e(x)D_i(p_i^e(w_T^e(x), \theta_i), \overline{p}_T^e) + \dot{T}_T^e(x)\right\} dx \geq 0.$$

where $T_T^e(x)$ is the equilibrium fixed fee. Substituting $\dot{T}_T^e(x) = -\dot{w}_T^e(x)D_i(p_i^e(w_T^e(x), x), \overline{p}_T^e)$,

$$\int_{\theta_i}^{\theta_i'} \{\dot{w}_T^e(x)D_i(p_i^e(w_T^e(x), \theta_i), \overline{p}_T^e) - \dot{w}_T^e(x)D_i(p_i^e(w_T^e(x), x), \overline{p}_T^e)\} dx =$$
$$-\int_{\theta_i}^{\theta_i'} \left\{\dot{w}_T^e(x) \int_{\theta_i}^{x} \frac{\partial D_i(p_i^e(w_T^e(x), y), \overline{p}_T^e)}{\partial p_i} \frac{\partial p_i^e(w_T^e(x), y)}{\partial y} dy\right\} dx \geq 0.$$

Suppose, without loss of generality, that $\theta_i' > \theta_i$ (so that $x > \theta_i$). Condition (3.6) — i.e., $\dot{w}_T^e(x) > 0$ — and the fact that $\frac{\partial p_i^e(.)}{\partial y} > 0$ $\frac{\partial D_i(.)}{\partial p_i} < 0$ guarantee that the global incentive constraint holds.

If the number of products is the same both with complete and with asymmetric information, the equilibrium retail price is higher with asymmetric information since

$$p_T^e(\theta_i) > p_T^*(\theta_i) \quad \Leftrightarrow \quad \theta_i > \mu - 2\sigma.$$

This concludes the proof. ■

Positive Demand. To ensure that, in equilibrium, all retailers' demand is (strictly) positive regardless of their costs, assume that R_i has the highest possible cost, $\mu + \sigma$, whereas his closest competitors, R_{i-1} and R_{i+1}, have the lowest possible cost, $\mu - \sigma$. In this case, by (2.1), R_i's equilibrium demand is

$$D_i(p_T^e(\mu + \sigma), p_T^e(\mu - \sigma)) = \frac{p_T^e(\mu - \sigma) - p_T^e(\mu + \sigma)}{t} + \frac{1}{N_T^e}$$
$$= \frac{\sqrt{3Ft - \sigma^2} - 2\sqrt{3}\sigma}{t},$$

where we have used (3.11) and the equilibrium number of firms N_T^e. This is strictly positive when $\sigma < \bar{\sigma} \equiv \sqrt{\frac{3Ft}{13}}$. Hence, in equilibrium, R_i's total demand is always positive regardless of his rivals' prices.

Furthermore, under this assumption, R_i's expected equilibrium rent is positive, since

$$\frac{1}{N_T^e} > \frac{\sigma}{3t} \quad \Leftrightarrow \quad \sqrt{9Ft - 3\sigma^2} > \sigma,$$

and this inequality is always satisfied when $\sigma < \bar{\sigma}$.

Proof of Proposition 1. The equilibrium number of firms is higher with asymmetric information since

$$N_T^e > N_T^* \quad \Leftrightarrow \quad \sqrt{12Ft - \sigma^2} > \sqrt{12Ft - 4\sigma^2}.$$

Average retail prices with complete information are

$$\overline{p}_T^* \left(N_T^*\right) = \mu + \frac{t}{N_T^*} = \mu + \sqrt{Ft - \frac{\sigma^2}{12}},$$

while average retail prices with asymmetric information are

$$\overline{p}_T^e \left(N_T^e\right) = \mu + \sigma + \frac{t}{N_T^e} = \mu + \sigma + \sqrt{Ft - \frac{\sigma^2}{3}}.$$

It is straightforward to show that $\overline{p}_T^e \left(N_T^e\right) > \overline{p}_T^* \left(N_T^*\right)$. ■

Proof of Lemma 3. Substituting (2.2) and (4.1), M_i's maximization problem is

$$\max_{w_i} \left(\overline{p}_L^* - \theta_i + w_i + \frac{t}{N}\right) w_i.$$

The necessary and sufficient first-order condition is

$$\overline{p}_L^* - \theta_i - 2w_i + \frac{t}{N} = 0 \quad \Leftrightarrow \quad w_i \left(\theta_i\right) = \frac{1}{2} \left(\overline{p}_L^* - \theta_i + \frac{t}{N}\right).$$

Taking expectations with respect to θ_i in (4.1), the average equilibrium price as a function of the expected wholesale price $\overline{w}_L^*$ is

$$\overline{p}_L^* = \mu + \overline{w}_L^* + \frac{t}{N}.$$

Replacing this into $w_i \left(\theta_i\right)$ and taking expectations with respect to θ_i yields $\overline{w}_L^* = \frac{2t}{N}$. Hence, the average equilibrium price is $\overline{p}_L^* = \mu + \frac{3t}{N}$. Replacing it into $w_i \left(\theta_i\right)$ yields the equilibrium wholesale price (4.2). Finally, inserting (4.2) and $\overline{p}_L^*$ into (4.1) yields the equilibrium retail price (4.3). ■

Proof of Lemma 4. Substituting (2.2) and (4.4), M_i's maximization problem is

$$\max_{w_i} \int_{\mu-\sigma}^{\mu+\sigma} \left(\overline{p}_L^e - \theta_i - w_i + \frac{t}{N}\right) w_i d\theta_i.$$

The necessary and sufficient first-order condition is

$$\overline{p}_L^e - \mu - 2w_i + \frac{t}{N} = 0 \quad \Leftrightarrow \quad w_i = \frac{1}{2}\left(\overline{p}_L^e - \mu + \frac{t}{N}\right). \tag{A.8}$$

Taking expectations with respect to θ_i in (4.4), the average equilibrium price as a function of the expected wholesale price $\overline{w}_L^e$ is

$$\overline{p}_L^e = \mu + \overline{w}_L^e + \frac{t}{N}.$$

Hence, (A.8) becomes

$$w_i = \frac{1}{2}\left(\overline{w}_L^e + \frac{2t}{N}\right).$$

Setting $w_i = w^e$ yields the equilibrium wholesale price (4.5). Moreover, $\overline{p}_L^e = \frac{3t}{N} + \mu$. Finally, inserting (4.5) and $\overline{p}_L^e$ into (4.4) yields (4.6).

If the number of products N is the same both with complete and with asymmetric information, the comparisons between $p_L^*(\theta_i)$ and $p_L^e(\theta_i)$ and between $w_L^*(\theta_i)$ and w_L^e are straightforward. ■

Proof of Proposition 2. The equilibrium number of firms is higher with complete information since

$$N_L^* > N_L^e \quad \Leftrightarrow \quad \sqrt{24Ft} > \sqrt{24Ft - \sigma^2}.$$

Comparing average equilibrium retail prices with complete and asymmetric information from Lemmas 3 and 4, $\overline{p}_L^e(N_L^e) > \overline{p}_L^*(N_L^*)$ since $N_L^* > N_L^e$. ■

Proof of Proposition 3. With complete information,

$$N_L^* > N_T^* \quad \Leftrightarrow \quad \sqrt{48Ft - 4\sigma^2} > \sqrt{24Ft - \sigma^2}.$$

With asymmetric information,

$$N_L^e > N_T^e \quad \Leftrightarrow \quad \sqrt{6Ft - 2\sigma^2} > \sqrt{3Ft}.$$

Both inequalities are satisfied for $\sigma < \bar{\sigma}$.

Comparing the average retail prices with asymmetric information (computed in Lemma 2 and 4),

$$\overline{p}_L^e(N_L^e) > \overline{p}_T^e(N_T^e) \quad \Leftrightarrow \quad 8\sigma^2 + 21Ft - 18\sigma\sqrt{2Ft} > 0.$$

The inequality is satisfied because the function on the left-hand-side is decreasing in σ and strictly positive when $\sigma = \bar{\sigma}$. Finally, it is straightforward to show that $\overline{p}_L^*(N_L^*) > \overline{p}_T^*(N_T^*)$. ■

Welfare Analysis. To highlight that actual demand depends on production costs through the realized retail prices, we define the (equilibrium) demand for firm i as $D_i(\theta_i, \theta_{i-1}, \theta_{i+1})$, where θ_{i-1} and θ_{i+1} are the marginal costs of the firms located to the left and to the right of firm i, respectively.

Let

$$x(\theta_i, \theta_{i+1}) \equiv \frac{p_{i+1}(\theta_{i+1}) - p_i(\theta_i) + \frac{t}{N}}{2t}.$$

The transportation costs of firm i's consumers are the sum of the transportation costs of the consumers that are located to the left of firm i and buy from firm i — i.e., $\int_0^{x(\theta_i,\theta_{i-1})} zdz$ — and the transportation costs of the consumers that are located to the right of firm i and buy from firm i — i.e., $\int_0^{x(\theta_i,\theta_{i+1})} zdz$.

Consumers' total expected transportation costs are the sum of the transportation costs paid by consumers of all firms — i.e.,

$$TC = \frac{t}{4\sigma^2}\sum_{i=1}^{N}\left[\int_{\mu-\sigma}^{\mu+\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\int_0^{x(\theta_i,\theta_{i+1})} zdzd\theta_i d\theta_{i+1} + \int_{\mu-\sigma}^{\mu+\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\int_0^{x(\theta_i,\theta_{i-1})} zdzd\theta_i d\theta_{i-1}\right].$$

Firm i's production costs are $\theta_i D_i(\theta_i, \theta_{i-1}, \theta_{i+1})$. Hence, firms' total expected production costs are

$$PC = \frac{1}{8\sigma^3}\sum_{i=1}^{N}\int_{\mu-\sigma}^{\mu+\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\int_{\mu-\sigma}^{\mu+\sigma}\theta_i D_i(\theta_i, \theta_{i-1}, \theta_{i+1})\, d\theta_{i+1}d\theta_{i-1}d\theta_i.$$

Total entry costs are $EC = N \times F$.

Hence, social welfare with complete information is

$$W_k^*(N) \equiv v - TC_k^*(N) - PC_k^*(N) - EC_k^*(N),$$

while social welfare with asymmetric information is

$$W_k^e(N) \equiv v - TC_k^e(N) - PC_k^e(N) - EC_k^e(N).$$

where $k = T, L$ denotes the contractual structure.

Proof of Lemma 5. First, consider two-part tariffs. With complete information, using (3.3) firm i's demand is

$$\frac{\theta_{i-1} + \theta_{i+1} - 2\theta_i}{4t} + \frac{1}{N}.$$

Hence, maximizing

$$W_T^*(N) \equiv v - \frac{8FN^2t - N^2\sigma^2 + 2t^2 + 8Nt\mu}{8Nt}$$

yields the socially optimal number of firms $N_T^{opt,*} = \frac{\sqrt{2}t}{\sqrt{8Ft-\sigma^2}}$. Recalling that $\sigma < \bar{\sigma}$, there is excessive entry since

$$N_T^* > N_T^{opt,*} \quad \Leftrightarrow \quad 36Ft > 5\sigma^2.$$

With asymmetric information, using (3.11) firm i's demand is

$$\frac{\theta_{i-1} + \theta_{i+1} - 2\theta_i}{2t} + \frac{1}{N}.$$

Hence, maximizing

$$W_T^e(N) \equiv v - \frac{12FN^2t - 2N^2\sigma^2 + 3t^2 + 12Nt\mu}{12Nt},$$

yields the socially optimal number of firms $N_T^{opt,e} = \frac{\sqrt{6}t}{2\sqrt{6Ft-\sigma^2}}$. Recalling that $\sigma < \bar{\sigma}$, there is excessive entry since

$$N_T^e > N_T^{opt,e} \quad \Leftrightarrow \quad 9Ft > \sigma^2.$$

Second, consider linear prices. With complete information, using (4.3) firm i's demand is

$$\frac{\theta_{i-1} + \theta_{i+1} - 2\theta_i}{8t} + \frac{1}{N}.$$

Hence, maximizing

$$W_L^*(N) \equiv v - \frac{96FN^2t - 7N^2\sigma^2 + 24t^2 + 96Nt\mu}{96Nt},$$

yields the socially optimal number of firms $N_L^{opt,*} = \frac{2t\sqrt{6}}{\sqrt{96Ft-7\sigma^2}}$. Recalling that $\sigma < \bar{\sigma}$, there is excessive entry since

$$N_L^* > N_L^{opt,*} \quad \Leftrightarrow \quad 168Ft > 13\sigma^2.$$

With asymmetric information, using (4.6) firm i's demand is

$$\frac{\theta_{i-1} + \theta_{i+1} - 2\theta_i}{4t} + \frac{1}{N}.$$

Hence, maximizing

$$W_L^e(N) \equiv v - \frac{8FN^2t - N^2\sigma^2 + 2t^2 + 8Nt\mu}{8Nt},$$

yields the socially optimal number of firms maximizes $N_L^{opt,e} = \frac{\sqrt{2}t}{\sqrt{8Ft-\sigma^2}}$. Recalling that $\sigma < \bar{\sigma}$, there is excessive entry since

$$N_L^e > N_L^{opt,e} \quad \Leftrightarrow \quad 7Ft > \sigma^2.$$

This concludes the proof. ■

Proof of Proposition 4. Recall that $\sigma < \bar{\sigma}$. First, with two-part tariffs,

$$W_T^*(N_T^*) > W_T^e(N_T^e) \quad \Leftrightarrow \quad \left(3Ft - \sigma^2\right)\left(12Ft - \sigma^2\right)\left(13\sigma^4 + \left(900Ft - 195\sigma^2\right)Ft\right) > 0.$$

Moreover, in equilibrium transportation and production costs are

$$\begin{aligned} TC_T^* &= \sqrt{3}\tfrac{\sigma^2+12Ft}{24\sqrt{12Ft-\sigma^2}}, \qquad & TC_T^e &= \sqrt{3}\tfrac{\sigma^2+3Ft}{12\sqrt{3Ft-\sigma^2}}, \\ PC_T^* &= \mu - \tfrac{\sigma^2}{\sqrt{3}\sqrt{12Ft-\sigma^2}}, \qquad & PC_T^e &= \mu - \tfrac{\sigma^2}{\sqrt{3}\sqrt{3Ft-\sigma^2}}. \end{aligned}$$

It is straightforward to show that $PC_T^* > PC_T^e$ and that

$$TC_T^e > TC_T^* \quad \Leftrightarrow \quad 108F^2t^2 + \sigma^2\left(15Ft - \sigma^2\right) > 0.$$

Finally, $EC_T^e > EC_T^*$ since $N_T^e > N_T^*$.

Second, with linear prices,

$$W_L^e(N_L^e) > W_L^*(N_L^*) \quad \Leftrightarrow \quad \left(24Ft - \sigma^2\right)\left(8\sigma^4 + 1944F^2t^2 - 261Ft\sigma^2\right) > 0.$$

Moreover, in equilibrium transportation and production costs are

$$\begin{array}{ll} TC_L^* = \sqrt{3}\frac{24Ft+\sigma^2}{48\sqrt{24Ft-\sigma^2}}, & TC_L^e = \frac{\sigma^2+3Ft}{12\sqrt{2Ft}}, \\ PC_L^* = \mu - \frac{\sigma^2}{\sqrt{3}\sqrt{24Ft-\sigma^2}}, & PC_L^e = \mu - \frac{\sigma^2}{3\sqrt{2Ft}}. \end{array}$$

It is straightforward to show that

$$\begin{array}{lllll} TC_L^e & > & TC_L^* & \Leftrightarrow & 141Ft > 8\sigma^2, \\ PC_L^* & > & PC_L^e & \Leftrightarrow & 18Ft > \sigma^2. \end{array}$$

Finally, $EC_L^* > EC_L^e$ since $N_L^* > N_L^e$. ■

Proof of Proposition 5. Recall that $\sigma < \bar{\sigma}$. With complete information,

$$\begin{aligned} & W_T^*(N_T^*) > W_L^*(N_L^*) \\ & \quad \Leftrightarrow \quad \left(24Ft - \sigma^2\right)\left(12Ft - \sigma^2\right)\left(F^2t^2(214\,272Ft - 29376\sigma^2) + \sigma^4(1116Ft - 29\sigma^2)\right) > 0. \end{aligned}$$

It is straightforward to show that $TC_T^* > TC_L^*$, $PC_L^* > PC_T^*$, and $EC_L^* > EC_T^*$.

With asymmetric information,

$$W_T^e(N_T^e) > W_L^e(N_L^e) \quad \Leftrightarrow \quad \left(3Ft - \sigma^2\right)\left(\sigma^4(15Ft - \sigma^2) + F^2t^2\left(93Ft - 75\sigma^2\right)\right) > 0.$$

It is straightforward to show that $TC_T^e > TC_L^e$, $PC_L^e > PC_T^e$, and $EC_L^e > EC_T^e$. Hence, using the results of Proposition 4,

$$W_T^*(N_T^*) > W_T^e(N_T^e) > W_L^e(N_L^e) > W_L^*(N_L^*).$$

This concludes the proof. ■

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