Price Dispersion in Competitive Markets: A Real Options Explanation

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Abstract

This paper employs a real option model to analyze price dispersion in highly competitive markets. Explanations of price dispersion typically assume monopolistic competition, so these fail to explain price ranges in markets closely approximating the conditions of perfect competition. Here the price is a real option given by the producer to consumers to demonstrate how price dispersion is possible under minimal conditions: stochastic prices; price rigidity; and differential cost structures.

I. Introduction

As markets become more efficient, we expect price dispersion to decrease. Physical markets may be unlikely to attain this ideal, but with the advent of e-commerce and the consequent lessening of search and transaction costs, informational asymmetries, etc. economists anticipated price ranges to narrow in accord with the law of one price. This has not, however, occurred even in those markets[1] that approximate perfect competition. Producers[2] should either lower their price to match that minimum price or exit the market, and prices should converge to the market equilibrium price, i.e., the minimum price. Thus, the question of price dispersion resolves into the question of overpricing:[3] If a range of prices exists in perfect competition, the issue is not why there are *different* prices, but why *any* price is *greater than* the minimum price. Explanations of price dispersion typically assume some form of monopolistic competition: either products or producers or consumers can be distinguished along such dimensions as quality, reputation, or information. But if monopolistic competition does not occur and the market is even approximately perfectly competitive, it is difficult to understand how rational price dispersion is possible…yet there remains strong empirical evidence for price dispersion in such markets.[4]

This model of price dispersion that does not appeal to monopolistic competition; instead, it demonstrates how price dispersion may emerge when the products offered are identical and hence perfect substitutes and there exist no distinctions among either consumers or producers (other than the assumption that different producers have different costs of production). The result

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[1] Excluded are markets in financial products for which there is little evidence of price dispersion.

[2] I use the term 'producer' for any agent offering a product for sale whether or not they actually 'produce' it. I reserve 'seller' for the seller of an option, that is, an agent who takes a short position in an option contract. Analogously, I use 'consumer' for the agent buying a product and restrict 'buyer' to agent who takes a long position in an option contract

[3] In the following, the market equilibrium price is taken to be the minimum price on offer.

[4] This discussion is limited to intra-firm, or spatial, price dispersion, that is, different prices for the same product *at the same time*. The existence of temporal price dispersion, that is, price dispersion over time is a separate issue involving such price setting phenomenon as sales (Varian, 1980).

is to demonstrate that price dispersion only requires three conditions: 1) prices are stochastic; 2) there is some degree of price rigidity; and 3) producers face different cost structures.

The producer's price as a real option, i.e., an option on a real asset, specifically, a call option granted to consumers granting the right to buy the product at a fixed price for a specified period. The underlying 'security' is the (stochastic) equilibrium price for the product. If the equilibrium price remains below the producer's price, the consumer does not make the purchase (does not exercise the option), but, if the equilibrium price rises to the producer's price, the consumer makes the purchase (exercises the option). Thus, it can be rational to set a price above the equilibrium price if at any time during the 'life' of that price a new equilibrium price may exceed it.

Section 2 reviews previous theoretical work on price dispersion. Section 3 documents the existence of significant price dispersion both in markets in general and in internet markets. Section 4 delineates the assumptions of the model and reviews empirical evidence that these conditions obtain in the actual economy. Section 5 develops the real options model as an explanation of price dispersion/overpricing. Section 6 draws out the implications of the real option analysis for pricing-setting behavior. Section 7 concludes the paper.

II. A Brief Literature Review

It is worthwhile to review the range of explanations for intra-firm price dispersion[5] in markets approximating perfect competition[6] (discussion of the empirical evidence for price dispersion is deferred to the next section).[7] We may structure the typology along the four elements that interact in market transactions: product, consumer, producer, and the macroeconomic environment. Most obviously, differences in products motivate price dispersion, whether these are directly observable, or only signaled (Gabor & Granger, 1966; Milgrom & Roberts, 1986). More interesting are theories permitting price dispersion among homogenous products. Such dispersion can be motivated by differences among consumers: Informational asymmetries and differing search costs which divide consumers into informed and uninformed pools have an extensive literature (Stigler, 1961; Grossman & Stiglitz, 1976; Salop, 1977; Salop & Stiglitz, 1977; Pennerstorfer *et al*., 2015; Menzio & Trachter, 2017). Other consumer differences include reservation prices (Anderson & De Palma, 2005) and single versus multiple product purchases (Richards *et al*., 2016). Further, price dispersion can be motivated by differences among producers: advertising (Butters, 1977), service capacity (Dana, 1999; Arnold 2000; Chen & Kong, 2004), or profiling technologies (Belleflamme. Lam, & Vergote, 2017). Finally, there are macroeconomic explanations of price dispersion, e.g., inflation (Head &

[5] As mentioned in footnote 4 intra-firm (spatial) price dispersion is the existence of different prices for the same product *at the same time*.

[6] As an illustrative example of how closely some electronic market model perfect competition, we may consider the market for books, CDs, and DVDs in the Amazon.com Marketplace, which is a very close approximation to a perfectly competitive product market: 1) it is a large, liquid market in which individual sellers cannot influence the equilibrium price; 2) there are no significant entry, exit or participation costs; 3) all participants have equal market access and information; 4) the goods on offer are, except for condition, perfect substitutes; and, 5) transaction costs are equal across all sellers. Only price significantly distinguishes products, yet noteworthy price dispersion is typical for products offered in this market.

[7] This is only intended to illustrate the broad range of explanations. Papers such as Barron, Taylor, and Umbeck (2004) give a more extensive overview of these theories.

Kumar, 2005). There remains, however, the complication that near perfect markets lack the conditions required by these explanations.

III. Evidence for Price Dispersion

Price dispersion occurs between various aggregations of products, different countries and across time. Our concern is intra-firm price dispersion: differences among prices for the *same* product in the *same* market at the *same* time. This is well documented both in markets in general and in internet markets (where we would expect minimal price dispersion). While there are myriad studies of individual markets supporting intra-firm price dispersion, we shall only note some comprehensive studies of dispersion in general markets (Abbott, 1992; Lach, 2002; Silver, 1988).

Internet markets should be characterized by notably less intra-firm price dispersion if more competitive markets are expected to narrow dispersion. Pan, Ratchford, and Shankar (2004), however, reviewing twelve studies conclude 1) significant price dispersion exists in internet markets, 2) internet price dispersion is no less than in traditional markets, and 3) though internet price dispersion has slightly declined over time it remains persistent. Nelson, Cohen, and Rasmussen (2007) study online price dispersion for 542 homogeneous products in 13 different product categories and find an average coefficient of variation of 11.69%. Baye, Morgan, and Scholten (2006) consider 36 homogeneous products in online electronics sales and find no convergence after 18 months. Adjusting for product and producer differences they find 28% of price variation for homogeneous products is left unexplained. The results are similar in many other markets, e.g., digital cameras (Haynes & Thompson, 2008), textbooks (Arnold & Saliba, 2003), books and CD's (Clay *et al*., 2002) and (Brynjolfsson & Smith, 2000).

IV. Assumptions of the Model

Herein a 'minimalist' model is developed requiring three relatively uncontroversial economic conditions. But initially it is equally important to note the assumptions which are *not* required by this model. *First*, the model does not require any between exemplars of a given product distinctions. *Second*, there is no need for informational asymmetries either between or among producers and consumers. *Third*, no distinction is required among consumers–each may have the same taste preferences, budget constraints, etc. *Fourth*, no distinction is necessary between different producers, *except* that some face different costs of production[8] (Note that this does not introduce an informational asymmetry: these varying cost structures may be observable to both consumers and each producer's competitors). *Fifth*, no specific macroeconomic circumstances are required and, *sixth*, no differential transaction costs are needed.

[8] It is not even necessary that different producers face different costs *at the same time*, only that over time the costs of production may change.

The goal is to justify rational price dispersion under perfect competition relying on a minimum set of conditions. The model requires three assumptions: stochastic prices, price rigidity, and differing production costs.[9] *First*, product prices must be stochastic, so future prices are not fully predictable.[10] A stochastic price is a natural expectation since many of factors determining the equilibrium price are uncertain, e.g., factor costs, technology shocks, consumer preferences, etc. But the model does not depend on accepting any specific rationale for stochastic prices. Further, the degree of price volatility (as with price rigidity and differing production costs) is not crucial– so long as it is economically significant. Only the existence of stochastic prices is required, not any specific theoretical explanation.

Second, there must be some price rigidity. At least some producers cannot immediately adjust prices to respond to changes in the equilibrium price. For some producers setting a price is a commitment to maintain that price over a certain period, so that pricing behavior must be optimized, not instantaneously, but for the time horizon during which that price will be in force. Importantly, the rational for such rigidity is not relevant to the model. Only the existence of price rigidity for some producers need be assumed and empirical studies well justify this. While much controversy remains about both the reasons for the rigidity (e.g., adjustment costs, explicit, and implicit contracts, coordination failures, etc.) and the sensitivity of rigidity to other factors (e.g., product unit price, firm size, macroeconomic conditions, etc.), the existence of price rigidity is clear. In a survey of 170 Canadian firms (Amirault *et al*., 2004/2005), about 75% maintained a price for at least one month and 35% for one year or more. Using unpublished data from the U.S. Bureau of Labor Statistics for 350 categories of consumer goods and services, Bils and Klenow (2004) found more frequent price changes than other studies but still about 13% of firms maintained a price for one year or more. Aggregating the results of surveys conducted in 2003 and 2004 by nine central banks (Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Portugal, and Spain), Fabiani, *et al*. (2007) found that across all countries (except Germany and Luxembourg) about 70% of firms adjusted prices at most once yearly. Finally, Wolman (2007) summarizing over 50 studies concludes that this research "leaves no doubt that the prices of many goods change infrequently." While prices may change more quickly on the internet, they remain 'sticky' (Gorodnichenko, Sheremirov, & Oleksandr, 2016).

Third, there must be a disparity between the production costs over time; that is, the total cost of producing (inclusive of all tangential costs associated with the sale of the product, such as shipping) must differ over time, though cost structure need not be different in every period. While explanations of these differences seem obvious, e.g., different production technologies, the actual reasons for the differences are not germane, as in the previous two conditions, only the

[9] While price rigidity contains an element of controversy (and hence we shall briefly examine the evidence for it), we shall take it as common knowledge that prices are stochastic and the production costs may vary between different producers.

[10] Note that this assumption does not beg the question and surreptitiously and exogenously introduce price dispersion, since there can be stochastic prices (price dispersion *across time*) without intra-firm price dispersion; that is, there could be only one price at any point in time but that price may randomly change over time. This is what we witness in the pricing of financial securities if arbitrage is not possible.

existence of differing cost structures is needed, not any specific theoretical explanation. In fact, one might even argue that this follows from the first assumption of stochastic prices for if the costs of the producer's input factors change over time it follows that their cost structures likewise change.

The model requires minimal assumptions: stochastic product equilibrium prices, price rigidity and differential production costs: it does not necessitate any specific explanation for these assumptions.

V. A Real Options Analysis

The model offered here involves a real option analysis of price setting behavior. The relevant characteristic is that, given some price rigidity, price setting involves a commitment to offer a product at an established price for some time interval during which the underlying market/equilibrium price (P) is stochastic. This is effectively to give a 'price option' to consumers to purchase the product at that price (S), i.e., the strike price, for that period of time. If it were practical for the producer to adjust prices to the equilibrium price instantaneously (or even with great frequency), then this real option approach would not apply. But price rigidity implies that price setting behavior must be a function of not just the spot price, but of the expected price path over the duration of the price. This gives a price the configuration of a call option; that is, setting a price (S) is analogous to selling a call option on the stochastic market equilibrium price (P). The option is given to the (generic) consumer, because the consumer receives the right but not the obligation to purchase the product at the specified price for some period,[11] and the consumer exercises the option if they do, in fact, purchase the product from that producer. The scale of price dispersion is the spread between the spot/equilibrium price (P) and the exercise price (S) of the price option, i.e., the price offered by the producer.

The one anomaly in this correspondence concerns the premium (or the price) typically paid by the buyer of the option to the seller[12]. Oddly, it would seem, the producer, as option seller, freely gives the call option to consumers without exacting a premium. There is even a (small) negative premium, since the transaction costs associated with offering a product for sale are paid by the seller. Thus the seller incurs a cost in freely giving the consumer the call option. This would be irrational in the case of a financial option, since the premium is the only possible cash flow to the seller. The key difference between a financial option and a price as option is that all sellers of financial options face the same 'production costs', e.g., an equity share has the same value to all sellers.[13] But in a price option, producers face different production costs. Producers can incorporate their normal required rate of return into the price and need not obtain a separate 'pre-paid' premium. The inclusion of the 'premium' in the price places the producer, *qua* seller of a call option, in a peculiar position: unlike the seller of a financial option, the producer *wants*

[11] Technically, this is an American option, since the owner has the right to exercise it at any time up to and including the maturity date.

[12] See n. 2.

[13] This suggests an explanation of why price dispersion does not exist in financial markets.

the market price to rise and the consumer to exercise the option, since only then does the producer receive a profit. [14]

Since different producers face different production costs, they will set different prices, so we should expect the range of prices typical of the empirical price dispersion literature. Should the equilibrium price rise, new producers (facing higher production costs) will enter the market as the value of setting higher prices increases, and these producers will offer products for sale above the new equilibrium price. Should the equilibrium price fall and after their current prices have expired, producers with outstanding price offers, depending on their production costs, may either leave the market or set a new price.[15] The decision to enter or exit the market will be the trade-off between the transaction (and possibly inventory) costs of offering the product for sale and the option value of the price.

Finally, we have used a call option as a preliminary archetype, but the structure of price setting is rather more complex.[16] Its characteristics are more closely approximated by an 'up and in' barrier option, i.e., an option whose payoff (V) depends upon reaching or exceeding a specified price barrier (S) at any time during the life of the option. We may broadly describe the real option characteristics of price setting as the producer offering consumers an up and in barrier option in which the underlying security is the market equilibrium price (P), the barrier (S) is the price set by the producer, the maturity is the time horizon (T) over which the price is in effect, and premium, i.e., the transaction costs (of offering the product for sale), is paid by the seller, not the buyer.[17]

[14] There are other transactions, which also follow a real options paradigm in which the seller may receive a positive premium. If, for example, the seller requires a deposit to hold a product and the deposit is forfeit if the consumer does not complete the sale, the deposit functions like a premium paid for the option to hold the product for a particular consumer. Transactions with a real options structure and positive premium are, in fact, common: purchases stipulating a termination or cancellation fee, a re-shelving or restocking fees, etc. (cf. Scott & Triantis, 2004; Bodily, 2006). For low-price guarantees as real options, cf. Marcus and Anderson (2006).

[15] Note that this analysis even allows dispersion among the prices on offer by the *same* producer. If price offers were made asynchronously, a new (and different) price could be set prior to the expiration of a previous offer.

[16] There is no gain to specifying the exact structure of this price option beyond the following general analysis. First, making the structure more specific would remove the general applicability and introduce arbitrary factors; for example, the price option of a producer holding one product in inventory has different characteristics that that of one holding multiple products. Second, it would be infeasible to calibrate the model to the characteristics of individual sellers. Thus a more detailed specification of the option structure or a precise price algorithm would yield no significant gain.

[17] It is important to note that this is only an approximation and that no standard option captures all the nuances of a price option. For example, the value of the up and in barrier option described above is not a function of *when* that barrier is breached, but an early sale is, to the seller, more valuable than a later sale simply because of the time value of money.

VI. Price Behavior Implications

The analysis of price setting as a real option has, as we have seen, offered an explanation of price dispersion, but this approach has the further advantage of yielding predictions about the scale of price dispersion and the parameters determining that scale. The greater the value of the price option, the more price dispersion should be expected in a market. If the price option were valueless, then producers would only offer products at the market equilibrium price. As the value of the price option rises, producers with higher production costs will enter and set prices farther above the market equilibrium. Price dispersion is a function of the value of the price option. Here we can apply the standard[18] comparative statics of financial call options:[19] *First*, the value of the price option is increasing in the volatility of the market equilibrium price, since volatility increases the probability of exercise. There should be more price dispersion in markets whose equilibrium price has greater volatility. *Second*, the price option increases in value with longer maturity, so greater price rigidity, i.e., the longer horizon over which the firm must maintain the same price, increases the value of the price option. The longer the horizon, the more likely a higher equilibrium price will be attained, so there should be more price dispersion in markets with greater price rigidity.

VII. Conclusion

Given standard economic principles, we expect price dispersion to decrease and prices to converge to an equilibrium price as markets become more efficient. Unfortunately, the empirical evidence strongly contradicts this conclusion–while prices may narrow they certainly do not converge. Economists have offered a range of explanations for intra-firm price dispersion, but these rarely apply to markets whose characteristics approximate perfect competition. This model offers an explanation of price dispersion in such markets by relying on only three assumptions: stochastic prices, price rigidity, and differing production costs. It analyzes price setting as a real option: if prices are rigid, setting a price is giving consumers a real option to purchase the product at that price for some period of time. This Implies That producers set prices as a function of the price path of the expected market equilibrium over the 'life' of the price–not just the initial ('spot') price of the product. If prices are stochastic, it is then rational to set prices above the market price, i.e., to initiate price dispersion, because the equilibrium price has some possibility of rising to the producer's price. If different producers have different production costs, then we would expect prices to be set at different levels above the current market price. Finally, the real option analysis of price setting projects when price dispersion will occur: price dispersion should increase when the equilibrium price has greater volatility, and there is greater price rigidity.

Most economists see price dispersion as a 'problem' or market failure to be explained by product differences, informational asymmetries, macroeconomic conditions, etc., so it is especially thorny to explain why price dispersion occurs in perfectly competitive markets. This

[18] In the case of financial options, it is standard to consider the sensitivity of the option price to a change in the risk free rate of interest, but this factor is likely to be a little significance in understanding price dispersion.

[19] The following comparative statics may seem unusual until one recalls that the producer only gains value if the option is exercised by the consumer.

model suggests, rather, that price dispersion is a natural phenomenon associated with market uncertainty requiring only a minimal and generally accepted set of assumptions that apply to approximately competitive markets.

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