Trade in the Market of Biotechnological Livestock Products and the Theory of Intermediary Firms

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Abstract: Agricultural biotechnology, by changing the process of agricultural production in the agri-food sector, has posed a serious challenge for the industry. The fundamental problem is that the biotechnology industry, with tremendous vertical integration from the research sector through to farmgate, has still relied upon decentralized markets to commercialize their products. Their innovations have for the most part been left to find their own consumer markets. This paper examines the theory of market making and the role of intermediaries in creating new markets. The paper hypothesizes that without intermediation in the biotechnology market, the optimal market size will not be realized, reducing private research investment and depriving society of the potential social gains of this new technology.

Keywords:

Biotechnology; livestock; market-making; intermediation

1. Introduction

The adoption of modern biotechnological processes in the agri-food sector promises great benefits but poses serious challenges for the industry. So far biotechnological processes and products have had the greatest impact on plant-based agriculture but they are poised to begin to influence the livestock industry.

The fundamental problem is that the biotechnology industry has relied upon decentralized markets to commercialize their products. While there has been increasing vertical integration from the research sector through to the farm gate, most of the genetically modified products leaving the farmgate and entering the processing and food chain have been left to find their own markets. This approach to market-making can work when the quantities supplied and demanded, consumers' willingness to pay and sellers' opportunity costs are known. The biotechnology sector does not exhibit those traits. The credence-like attributes of biotechnology products result in uncertain demand and widely varying estimates of consumers' willingness to pay. Furthermore, high fixed costs (due to research and development expenses) and low variable costs yield increasing returns to scale to the industry, which complicates the discovery of quantities and the opportunity costs of supply.

This paper examines the theory of market making and the role of intermediaries in creating new markets. The paper hypothesizes that without intermediation in the biotechnology market, the optimal market size will not be realized, reducing private research investment and depriving society of the potential social gains of this new technology. Section 2 of this paper discusses the market situation in the biotechnology sector, comparing and contrasting the experiences in the crops industry with the potential in the livestock sector. Section 3 examines the market microstructure and the role for intermediation. Section 4 examines the theory more closely to determine the conditions that favor intermediation over decentralized trade. Section 5 discusses some of the implications and further research required to advance this analysis.

2. Background

Modern, molecular-based biotechnology burst into the global agri-food industry in 1994 with the introduction of Monanto's Flavr Savr^{TM} tomato. Since then 11 more crops have been modified to incorporate herbicide tolerance, insect resistance, viral resistance, abiotic stress resistance or output/quality traits. In 2000, those crops were grown on more than 44.2 million ha in 13 countries on all six continents (James 2000). From one perspective, the rate of adoption and commercialization of biotechnology in the crops sector is unprecedented. The problem is that the world market place has fragmented into at least two separate blocks: North America, Australia, South America and parts of Asia have aggressively adopted and used the new technology while since 1998 the EU and a handful of other countries have just as aggressively rejected it.

Phillips and Isaac (1998) have noted that one reason for the market disruption is that the current set of biotechnology products are credence goods, such that the ultimate benefits or risks of consuming the product is unknowable by the consumers either through search or experience. Credence goods require someone to mediate the market, providing quality assurance. Historically the food safety regulatory systems in domestic markets have provided the base upon which private firms could introduce new products. As long as consumers trusted the regulators and the industry, markets for new products could develop. Food safety scares in the EU virtually destroyed public confidence and trust in the regulators (specially the 1996 discovery of the causal link between bovine spongiform encephalopathy (BSE) and new variant Creutzfeld-Jakob disease (nvCJD) in the UK, which spread to France and Germany in 2000) (Gaskell, et. al., 1999). This posed a major problem for the biotechnology industry, as they needed the regulators to mediate the introduction of their new products. Where regulators maintain public confidence, markets remain open to new GM foods; where public confidence is absent, markets have been *de facto* closed to the new technology. In essence, there is no one mediating the market and providing the information and assurances necessary to calm consumer concerns.

As a result, adoption rates for GM crops slowed dramatically in 2000. As the two markets diverge, trade has been disrupted and marketing costs have begun to rise (Phillips and Smyth, forthcoming). This has translated into a number of the large, so-called 'life science companies' announcing plans to divest of their agricultural biotechnology operations: Upjohn Pharmacea reduced its stake in Monsanto in 2000 to 85% and has plans to go to a minority interest shortly; the newly merged Aventis (AgrEvo and Rhone Poulenc) has announced it will spin off its

merged agbio division as Agreva; and following the merger of Novartis and AstraZeneca, the new venture plans to spin off its agbio division under the name Syngeria. Given that none of the divested units would have internally generated funds large enough to continue their current rate of R&D, they will soon come under the scrutiny of the financial markets, which have indicated that they find some of the investments less than attractive. In short, the failure to gain access to the global market for these new genetically modified crops will lead to lower investment in coming years.

Governments, research programs and livestock producers and processors are all beginning to wonder how biotechnology will affect their marketplace. This is probably a good time to ask the question, as none of the products in the market have yet sparked a response. There are three main GM products that could require greater market-making efforts.

The earliest biotechnology impact on the livestock sector involved GM vaccines and hormones. The first GM hormone, bovine somatotropin (rbST) was introduced in the US in 1994 and is now used in an estimated 30% of the US dairy herds (Fetrow 1999). The US industry mediated the introduction of this product domestically but they have not made any efforts to do so in other markets. While no other markets have yet to accept the use of the technology in their sectors, so far the US milk products produced with rbST are being accepted and consumed by all importing countries, more due to lack of knowledge of its presence rather than consumer acceptance. But there is a precedent for a problem. The EU has adopted an import ban on imports of US beef grown with bovine growth hormone (not a recombinant product) and, in spite of losing a dispute at the WTO, has sustained its ban in the face of US retaliation. Meanwhile, there are more than 94 genetically-modified veterinary biologics for cattle and hogs that have been developed and approved for use in Canada and the US (CFIA 2000). So far none of these has excited consumers or generated trade action by importers, but the potential exists.

There is also significant debate in some quarters about whether livestock fed on GM feeds should be treated differently than livestock fed on traditional feeds. While scientists assert that the genetic modifications of the feed do not cause any detectable impact on the meat (Western Producer 2000), some consumers groups have challenged the products and some food chains and governments have responded. In Belgium Aholt has announced that it will no longer sell meat fed on GM corn or soybeans while the UK, Netherlands and EU governments are examining the possibility of requiring special labels on meats fed on GM feeds. In absence of any intermediary for livestock fed on GM feeds, the market could fail.

Finally, there is some possibility that biotechnology techniques could be used to modify the genetics of cattle, hogs, sheep or poultry to display desirable consumer traits, such as marbling, tenderness, color and taste. There is significant effort underway to encode the genome of ruminants to enable this work. So far, however, all of the biotechnologically modified livestock have been developed for use in the pharmacological or industrial sectors. For example, transgenic pigs are designed for xenotransplantation, 'Dolly the sheep' is for use in pharmacological studies and Nexeria's goats will produce silk proteins for industrial applications. These applications are all well mediated. If this technology is expanded to the commodity food sector, intermediation will be necessary to develop the market.

In short, the global livestock sector has some breathing room, but it should learn from the mistakes in the crop sector. There are greater risks if market making is left to decentralized markets, especially given the recent decline in public confidence in regulators, who previously mediated some of the market-making.

3. Market microstructure and intermediation

Firms create and manage markets by acting as intermediaries between buyers and sellers. An *intermediary* is an economic agent who purchases from suppliers for resale to buyers or who helps buyers and sellers meet and transact. Intermediaries seek our suppliers, find and encourage buyers, select buy and sell prices, define the terms of transaction, manage the payments and record keeping for transactions, and hold inventories to provide liquidity or availability of goods and services.

In this paper, we examine the economic role of biotechnological firms in livestock products and the functioning of agro-biotech markets in general. Just as producing goods and services consumes resources, the establishment and operation of markets to allocate those goods and services also consumes scarce resources. Agricultural biotechnological companies incur costs in adjusting prices and communicating price information to buyers and sellers. However, the types of information they can obtain from the market are not perfect and, hence, they need intermediation activities from other firms.

The intermediaries play their roles in the market in different situations. When there is demand and supply randomness, intermediate firms provide liquidity or immediacy by standing ready to buy and sell. Moreover, even if there is no intention or willingness to pay or opportunity costs of trading between partners, intermediaries can coordinate transactions by matchmaking

and brokering activities. Sometimes the characteristics of buyers and sellers are unobservable, which requires the intermediate firms to generate market information and provide guaranties for product quality to address adverse selection. When the actions of buyers or sellers are costly to observe, intermediaries provide monitoring and contracting services.

The main function of market intermediaries is to figure out ways of clearing the market, that is, pricing to match purchases to sales. This important price-setting activity provides an explanation for a main question of neoclassical economics: how are market-equilibrium prices attained? Samuelson (1980) asserted that any society must find solutions for the three basic questions of the classical school: what goods to produce and in what quantities, how to produce them, and for whom particular goods are produced. Economic models answer these questions through markets that coordinate the actions of individual consumers and firms. For instance, in the neoclassical framework, the market is a description of an exogenous mechanism for selecting prices that equalize aggregate supply and demand. Individual consumers maximize their utilities by choosing their most preferred bundle of commodities subject to their budget constraints, taking prices as given, while firms, also taking prices as given, maximize profits corresponding to their production technology.

Stiglitz (1993) added a fourth question. He asserted that we must ask how these decisions are made, and who should make them? His concern was that economic analyses must address the incentives to acquire and process information. Spulber (1999) believed all four questions could be gathered into one—*who decides?*—which is answered by the presence of firms. He stated that by shifting the locus of economic decision making to the firm, it inevitably follows that managers act as decision makers and strategists.

Agricultural biotechnological companies, for instance, determine what goods and services to produce and, given the market circumstances, what quantity to produce. This, in turn, determines the scale of the companies. Some of the biotech companies may act as their own intermediaries so that they are able to answer the four questions by making decisions about the mix of products they will purchase from suppliers, the type of suppliers they will contract with, and the allocation of goods and services to be offered to their consumers. For them, it is not necessary to distinguish between merchants and manufacturers. In combination with managing transactions, intermediaries often transform products to add value by transporting, storing, repackaging, assembling, preparing for final use, and adding information and guaranties.

3.1 Intermediaries and the circular flow of economic activity

Figure 1 shows the role of intermediaries in the context of the circular flow of economic activity. It recognizes three types of agents in the economy: *consumers, market-taking firms,* and *market-making firms.* Market-taking firms take price signals and market institutions as givens. In contrast, market-making firms are intermediaries that create and operate markets. Some agricultural biotechnological companies can be accounted as market-making firms because they are price-making, going beyond other market institutions such as organized exchanges for securities, options, futures, and other financial assets. Such companies may coordinate transactions among consumers, market-taking firms and other intermediaries. The consumers send expenditures to market-taking firms in return for goods demanded and receive incomes from intermediaries in return for inputs supplied. Similarly, market-taking firms receive revenues from intermediaries in return for goods supplied and make factor payments to intermediaries in return for goods received.

Now the question is how do prices adjust to clear markets? In the perfectly competitive market model, firms simply react to prices. This is not the case in the biotech market, because many companies have at least some market power over prices because of a variety of factors such as they type of innovations, product differentiation, transportation costs, consumer switching costs, transaction costs, barriers to entry, intellectual property rights, and incomplete information about prices.

For a biotech company alone, setting prices can be a costly activity. It needs to gather information for demand and supply and monitor competitors' prices at the same time and also needs to perform computations to determine the profit-maximizing prices. It needs to communicate prices to its consumers and suppliers. It may incur menu costs in changing prices by printing new catalogs or issuing price lists. There is some evidence that price rigidities are observed in a wide range of biotechnological industries (Carlton 1986), which also suggests that changing price is costly (Barro 1972).

When companies act as intermediaries, they not only arbitrage between buyers and sellers, but they also coordinate their transactions through price signals. The traditional demand and supply model can be used to explain the market-clearing actions of intermediaries.

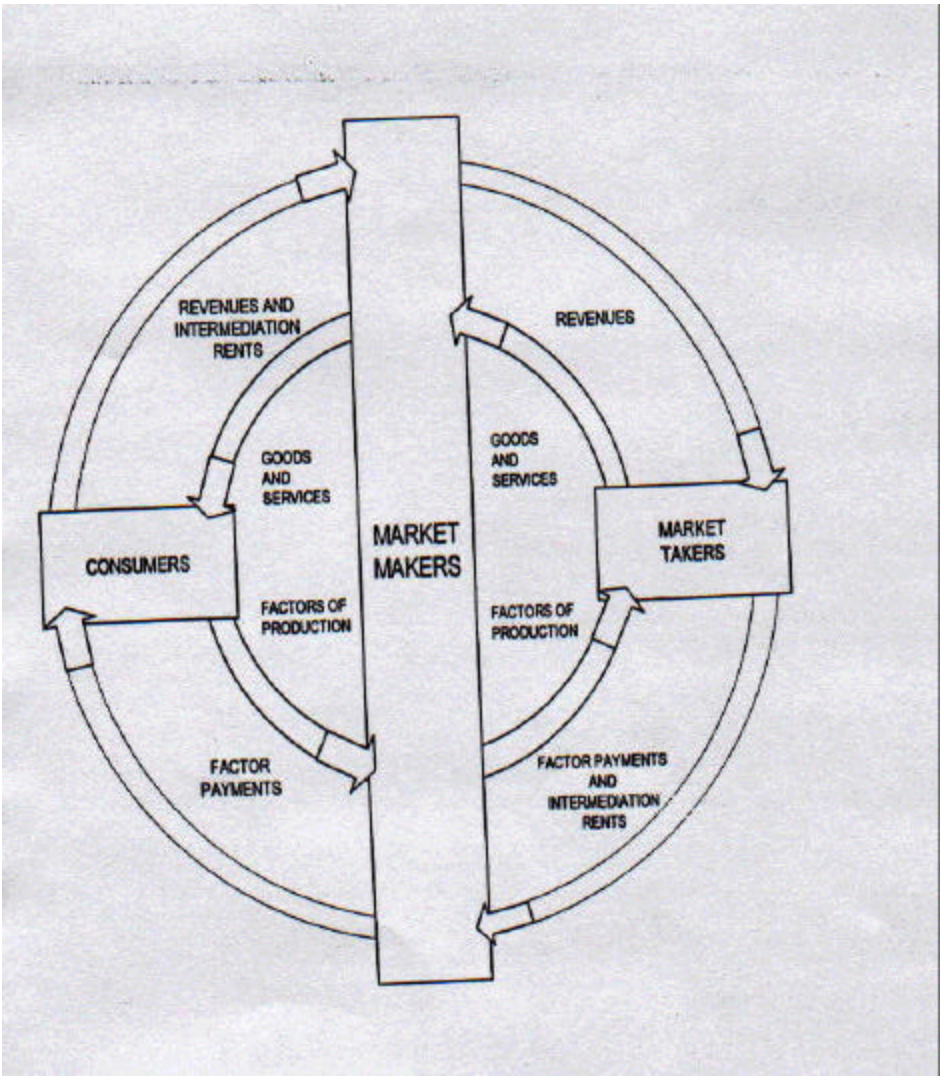

Figure 1: The circular flow of economic activity with market intermediaries. Source: Spulber (1999, p.11)

3.2 Intermediaries and the bid-ask price power

Now consider a biotech intermediary company that has market power in both its consumer and suppliers markets. This can happen when a firm is the primary purchaser and reseller of a differentiated product. Thus the intermediary firm has some power to set both *bid and ask prices* for its product and to make profits from the markup between the two. Figure 2 illustrates the situation of an intermediary firm when it has some power to determine both bid and ask prices.

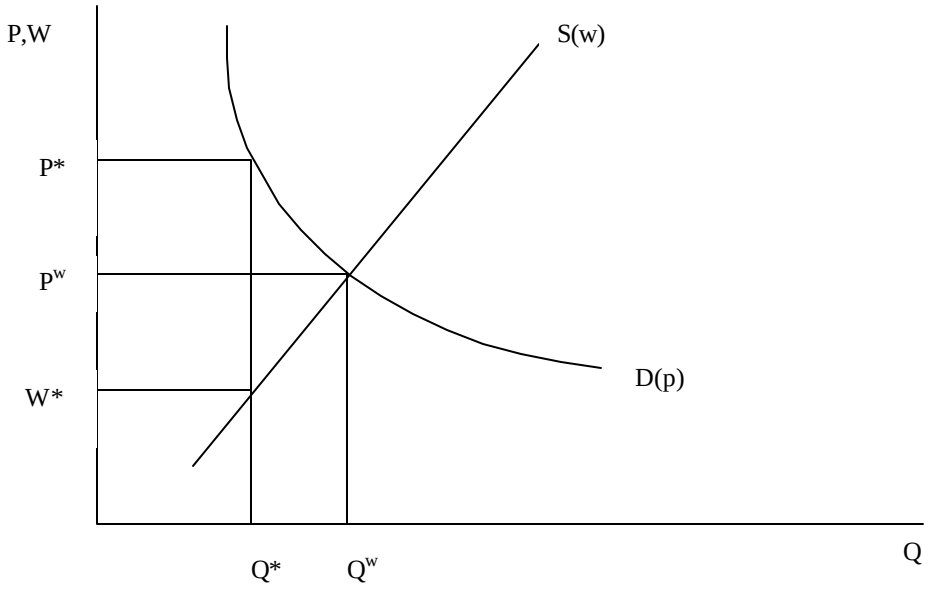

Figure 2: The bid-ask spread and the supply-and-demand model

The demand curve represents the residual demand of the firm's customers. The supply curve represents the residual amount that the company's suppliers are willing to provide at various factor prices. The firm chooses its profit-maximizing buy and sell prices given its best estimate of these supply and demand functions. There is a bid price W that is offered to sellers, and an ask price P that is proposed to buyers. The seller's supply function is $S(w)$ and the buyer's demand is $D(p)$.

The profit-maximizing firm sets prices to equate its marginal revenue to its marginal factor cost. The profit-maximizing bid and ask prices are W^* and P^*, and Q^* is the amount traded. In Figure (2), the intermediary's profit is the rectangle whose area equals $(P^*-W^*)\ Q^*$. In equilibrium the firm chooses the buy and sell prices to clear the market: $Q^* = D(P^*) = S(W^*)$. The sell and buy prices straddle the Walrasian price P^w, and output is also below the Walrasian output Q^w. There are many factors involved in determining the bid-ask spread prices. Some of them are elasticity of supply and demand, the company's transaction costs, and the alternatives available to buyers and sellers.

The question is how do prices adjust to clear markets? In markets in which there are intermediaries with market power, we can use the simple model in Figure 2 to answer this question. The firm will adjust both its buy and sell prices in response to changes in supply or demand. For instance, firms may observe a rise in demand that shifts the demand curve to the

right. What firms generally do in this situation is to increase the sell price to ration demand and increase the buy price to encourage supply. Thus the intermediary adjusts prices so that the market clears at a higher output.

Intermediaries will also provide immediacy by holding inventories and cash. Price-setting intermediaries will adjust prices to maintain inventories. For example, the intermediary might choose to reduce inventories either by decreasing the ask price P below the level shown in Figure (2), thus increasing consumer demand, or by raising the bid price W shown in the Figure, which leads to additional supplies. With this policy, the bid and ask prices will vary depending on inventory levels observed after demand and supply are realized.

3.3 Intermediaries compared with other theories of the firm

Economics offers a vast selection of approaches to the firm that provide both rigorous analytical modeling and penetrating insights. However, one thing they all have struggled with is how to address both decision making by firms and market allocation within the same framework. Spulber (1999) categorized the array of theories of the firm into four main categories based on the level of aggregation: (a) neoclassical, (b) industrial organization, (c) contractual (or transaction cost), and (d) organizational-incentive (or principal-agent).

Neoclassical market models aggregate across the entire economy. By assuming price-taking behavior, neoclassical analysis effectively considers that the firm is small in size relative to the economy as a whole, which implicitly assumes an extremely large number of firms. The industrial-organization theory of the firm focuses on the industry and recognizes the market power of individual firms. Contractual theories of the firm examine the firm's relationships with individual trading partners, taking transactions as the unit of analysis. The organizational-incentive theories of the firm examine hierarchical relationships within an individual firm.

As we may notice none of the four theories constitute a unified view of the firm. Neoclassical economics stresses the role of the firm as operator of technology. Industrial-organization models emphasize market power and strategic interaction. Contractual theories of the firm focus on choosing the boundaries of the firm where market transaction costs exceed the costs of organization. Organizational-incentive theories of the firm stress delegation within hierarchies.

The intermediation theory of the firm draws on elements of all four theories. The theory retains the input-output approach of neoclassical theory. It presumes competitive price setting by

firms as in industrial organization. The intermediation approach addresses transaction costs and opportunism as in contractual theories of the firm. It also incorporates principal-agent relationships both within the firm and between the firm and its suppliers and customers.

In summary, intermediation models posit that the firm is a market maker, coordinating the actions of its customers and suppliers. The level of aggregation in intermediation models is narrower than that of neoclassical models, which looks across markets, but is broader than that of industrial organization because it incorporates both the firm's input and output markets. The focus is considerably broader than contractual theories of the firm since intermediation theory attempts to examine the full set of the transactions carried out by the organization. Intermediation theory addresses organizational issues by noting that the firm delegates intermediation to managers, employees, and suppliers.

The intermediation theory of firms and markets provides an answer to the question of who decides. In this theory, the firm's managers engage in a wide range of decision-making activities, which means searching for trading partners, selecting prices, managing customer and supplier relationships, and identifying new opportunities for establishing and operating markets. The intermediation model of the firm draws on important insights from the four principal economic models of the firm. It combines many of the significant elements of those models in a consistent manner. Following the fundamental neoclassical framework, firms acting as intermediaries coordinate input purchasing, production and supply decisions, recognizing the connections between prices in input and output markets. As in industrial-organization models, intermediaries act as competing price makers. Following transaction-cost models, firms acting as intermediaries earn returns from the reduction of transaction costs, thus lowering the costs of using markets for their customers and suppliers by carrying out market-making activities. Furthermore, based on organizational-incentive models, firms acting as intermediaries reduce contracting costs by carrying out delegated bargaining and monitoring activities.

3.4 An intermediation example from the U.S. economy

Spulber (1999) reported that intermediaries, or market-making firms have made a substantial contribution to the U.S. economy. The exact amount is difficult to assess as it requires estimating the contribution of market-making activities to value added in sectors such as manufacturing, agriculture, mining, construction, transportation, or public utilities, but as a rough estimate of shares of the gross domestic product, one might begin with the idea that

intermediation includes retail trade (8.7%), wholesale trade (6.8%), finance and insurance (7.4%), and some business services and other services (2.1%). Whle this is a conservative estimate because it assumes that market-making activities in all other sectors are zero, intermediation activities would still account for approximately one-quarter of the U.S. gross domestic product.

4. Intermediation as opposed to decentralized trade

Biotechnology companies engage in market making by setting prices, allocating goods and services, and holding inventories to coordinate transactions. Intermediation provides an endogenous mechanism for price setting that coordinates the activities of buyers and sellers. Livestock biotech intermediary companies will need to choose two sets of prices: ask prices for consumers and bid prices for suppliers. The bid-ask spread, familiar from financial markets, provides an alternative perspective on the economic profit of firms. Economic profit reflects the returns to the market-making activities of firms. Now, one might may ask if livestock biotech companies are able to find customers to buy their products, why do we need intermediary firms to avoid decentralizing trade?

The answer is not difficult and can be found by examining the role of intermediary firms. Intermediaries compete with direct exchange to absorb buyers and sellers. Consumers and suppliers choose between seeking each other out and bargaining over the terms of trade and exchange with the intermediary. In this situation, consumers and suppliers will definitely incur costs of search and bargaining under decentralized trade, so that the existence of intermediary firms will be economically viable provided that they can somehow manage to have lower transaction costs.

There are many models which present a picture of markets as decentralized mechanisms with pairwise meetings of agents. Detailed models are discussed in Diamond and Maskin (1979), Mortensen (1976, 1982), and Rubinstein and Wolinsky (1985, 1990). The last study showed that such models contribute an understanding of the micro-mechanisms of price formation and their role in shaping market outcomes. In contrast, intermediated markets are more centralized because the intermediary deals with multiple buyers and sellers. Price-setting intermediaries provide an explicit mechanism of price adjustment that differs from pairwise bargaining.

Out of the several models available we extend the one proposed by Gehrig (1993) which is a model of competition between an intermediary and a decentralized matching market.

Naturally, buyers and sellers in the decentralized market engage in first-and-final-offer bargaining. The intermediary chooses a price spread in competition with the decentralized market. In equilibrium, the price spread offered by the intermediary depends on the efficiency of search and bargaining in the matching market. At the equilibrium price spread, high-willingness-to-pay buyers and low-opportunity-cost sellers trade with the intermediary (in short the early adopters). In this situation, buyers who have a moderate willingness to pay and sellers who have moderate opportunity costs enter the matching market.

4.1 Gehrig's model of intermediation compared with matching markets

In Gehrig's model consumers and suppliers have two choices. They can enter into a decentralized matching market where they meet randomly and bargain over the price of the good or they can transact with an intermediary. One could extend the model a little bit by altering the bargaining conditions and consider additional types of transaction costs, but this paper concentrates on the simple case (readers interested in the more complex model can refer to Spulber, 1999).

A buyer and a seller who meet in the matching market may fail to transact even if there are potential gains from trade. The asymmetric information about buyer willingness-to-pay levels and seller opportunity costs may impede trade. One scenario for interpretation of the event can be as follows. Intermediaries select prices and announce those prices to the buyers and sellers. After observing those prices, buyers and sellers will decide whether they will deal with the intermediary or go to the matching market process. Meanwhile some buyers and/or sellers may be quantity rationed by the intermediary and sent to the matching market.

If there is a monopoly intermediary situation at market equilibrium, then both the intermediated market and the decentralized market would be active. In contrast, if there are competing intermediary situations at market equilibrium, then the bid-ask spread collapses to the Walrasian price which means all consumers and suppliers transact through intermediaries, and the decentralized market does not operate.

4.2 Model description

Suppose a buyer's willingness-to-pay levels are represented by v, and his utility function for a willingness-to-pay level v at price p is

$$U(v) = v - p \qquad (4.1)$$

If we assume various buyers whose willingness-to-pay levels are uniformly distributed on the unit interval, then the aggregate demand is linear and equals $D(p) = 1 - p$.

We may also suppose a seller's opportunity costs are represented by τ so that his net benefit at price ω is

$$R(\tau) = \omega - \tau \qquad (4.2)$$

If we assume various sellers whose opportunity costs are uniformly distributed on the unit interval, then the aggregate supply is linear and equals $S(\omega) = \omega$.

Although the aggregate demand and supply are common knowledge to the market, the buyers willingness-to-pay and the sellers opportunity costs are known but are private information, which is differentially known by different buyers and sellers. This is a fundamental distinction between decentralized and intermediated markets. In the decentralized markets, buyers' willingness-to-pay and sellers' opportunity costs are not known, and both search and bargaining are restricted by uncertainty about the characteristics of potential trading partners and the way that trade is done. Even if trade is done, the uncertainty still exists and continues because of the type of traders they are dealing with. The uncertainty in the bargaining process affects the search process by making the returns to search uncertain.

This is not the case in the intermediated markets. Intermediaries can post prices and also are able to select prices to mobilize aggregate demand and supply. Even though individual buyers and sellers also know aggregate demand and supply, they are not able to make full use of this information because of the search and bargaining costs involved.

Now consider the decentralized matching process. It is clear that the number of agents on the buyer and seller sides of the market may differ. The matching technology acts as if an agent from the long side of the market is matched somehow with an agent from the short side of the market with the probability of λ (the so-called *efficiency of the matching process),* where λ is between zero and 1 and is determined by the relative number of agents on each side. The more λ approaches 1 the more efficient is the matching market, leading to lower transaction costs for buyers and sellers. The bargaining process reflects asymmetric information of buyers and sellers in the matching markets. Once a match is formed, one of the two partners *makes a take-it-or-*

leave-it offer. The other one can either choose to accept the bid-price and the trade happens, or can decline the bid-price, forgoing the trade.

If we want to be specific about the trade, we may think of only buyers and sellers who expect gains from trade entering the matching market. In this case, assume $\delta(v)$ and $\eta(t)$, respectively, representing the conditional distribution of trader types active in the matching market. If the buyer and seller bidding strategies equal $s(v)$ and $g(\tau)$, respectively, then their expected utilities in the matching market are

$$U(v) = \frac{\lambda}{2} \int_{t \le s(v)} (v - s(v)) \, d\eta(t) + \frac{\lambda}{2} \int_{g(t) \le v} (v - g(t)) \, d\eta(t), \tag{4.3}$$

$$R(t) = \frac{\lambda}{2} \int_{v \ge g(t)} (g(t) - t) \, d\delta(v) + \frac{\lambda}{2} \int_{s(v) \ge t} (s(v) - t) \, d\delta(v). \tag{4.4}$$

What an intermediary firm does is to set an ask-price p and a bid-price w, in competition with the matching market. It usually randomly rations the long side of the market provided that the number of buyers (q) and sellers (x) that go to the market are not equal. Then, it maximizes its profit

$$\Pi = (p - w) \min(q, x) \tag{4.5}$$

Spulber (1999) stated that in this circumstances, the value to buyers of trading with the intermediary, $v - p$, and the value to sellers, $w - t$, are contingent on not being quantity rationed by the intermediary. How market equilibrium is obtained will depend on three things: a bid and ask price for the intermediary; buyer and seller expectations about whether or not they will be rationed by the intermediary; and buyer and seller choices of which of those markets to enter. No matter which market is chosen there are three stages to the market-clearing process. In the first stage, intermediaries select prices to maximize profit. Second, buyers and sellers choose between the matching market and the intermediary. Those rationed by the intermediary will move to the matching market. Finally, the matching market clears.

For any positive bid-ask spread, there will be an active matching market because buyers with willingness-to-pay such that $w < v < p$ and sellers with opportunity costs such that $w < t < p$ will expect gains from trade entering the matching market. Traders in the matching market have positive expected gains from trade since they anticipate benefits from making a match and

carrying out first-and-final-offer bargaining with no explicit costs of matching. The distributions of agents in the matching market $\delta(v)$ and $\eta(t)$ are equal to the uniform distribution on $[\underline{t}, \bar{v}]$, which defines the set of buyers and the set of sellers in the matching market. The buyer's optimal bid strategy is the standard take-it-or-leave-it offer that maximizes

$$\int_{\underline{t}}^{s} (v - s) \frac{dt}{\bar{v} - \underline{t}} \tag{4.6}$$

Thus the buyer's offer strategy is $s(v) = (v + \underline{t})/2$. The seller's offer maximizes

$$\int_{g}^{\bar{v}} (g - t) \frac{dv}{\bar{v} - \underline{t}} \tag{4.7}$$

So that the seller's offer strategy is $g(t) = (\bar{v} + t)/2$.

By substituting the bid functions into (4.3) and (4.4), we have

$$U(v) = \frac{\lambda}{8} \frac{1}{\bar{v} - \underline{t}} \left[(v - \underline{t})^2 + (2v - \bar{v} - \underline{t})^2 \right], \tag{4.8}$$

$$R(t) = \frac{\lambda}{8} \frac{1}{\bar{v} - \underline{t}} \left[(t - \bar{v})^2 + (2t - \bar{v} - \underline{t})^2 \right]. \tag{4.9}$$

Therefore the critical pay-off levels $U(\bar{v})$ and $R(\underline{t})$ are equal to

$$U(\bar{v}) = R(\underline{t}) = (\lambda/4)(\bar{v} - \underline{t}).$$

Gehrig (1993) showed that the intermediary's prices are market clearing. This means that the prices equate the demand and supply faced by the intermediary, $D(p^*) = S(\omega^*)$, which in this case is

$$1 - p^* = \omega^*$$

Thus neither side of the market is rationed, and the value of visiting the intermediary is $v - p^*$ for buyers and $\omega - t$ for sellers.

For the critical traders $\bar{v}$ and $\underline{t}$,

$$U(\bar{v}) = \bar{v} - p^* \tag{4.10}$$

$$R(\bar{t}) = w^* - \bar{t}. \tag{4.11}$$

By solving for $\bar{v}$ and $\bar{t}$, the value of trading volume is obtained

$$1 - \bar{v}^* = \bar{t}^* = \left[4(1 - p^*) - l\right] / 2(2 - l) \tag{4.12}$$

The intermediary's profit function is $\Pi = (p^* - w^*)\bar{t}^*$, or

$$\Pi = (2p^* - 1)\bar{t}^* \tag{4.13}$$

The profit-maximizing prices that solve the intermediary's problem depend on the search-efficiency parameter:

$$p^* = 3/4 - l/8, \qquad w^* = 1/4 + l/8 \tag{4.14}$$

Trading volume equals

$$1 - \bar{v}^* = \bar{t}^* = 1/4 \tag{4.15}$$

As a conclusion of the model, from (4.14) we can say that the intermediary firm trades with buyers in the interval [0.75,1] and sellers in the interval [0, 0.25]. Buyers and sellers in the interval [0.25, 0.75] enter the matching market. Ultimately, we may also conclude that at the equilibrium, buyers and sellers are those that believe they will not be quantity rationed by the intermediary (see Spulber 1999).

5. Implications and further research

The livestock industry faces a significant challenge from the introduction of biotechnologically modified inputs and outputs. If the biotechnology industry or the livestock sector does not find someone to intermediate the market, it faces the same fate as the crop sector. Wherever public regulators are weak, markets for these new credence-like products may not be forthcoming, leading to fragmentation.

The theory of intermediation suggests that without intermediation there is the possibility that up to 50% of any market might not be realized, which would seriously impede adoption of the new technologies. As a result, innovators would face lower rates of return and would respond with lower R&D, which would translate over time into lost consumer and producer benefits. Furthermore, given the difficulty in segregating GM from non-GM production, existing

livestock producers could face higher marketing costs from the unmediated introduction of new GM livestock products.

This is obviously a preliminary application of the theory. This will need to be applied more concretely to a variety of markets involving both GM and non-GM products to determine its general applicability. On the face of it, however, it offers a refreshingly new and potentially useful framework for analyzing markets in the making.

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