FOB or Uniform Delivered Prices: Strategic Choice and Welfare Effects

by

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Abstract

In most spatial markets, firms use either FOB or uniform delivered pricing, so the competitive factors motivating this choice and its welfare implications are important research questions. Prior work on duopoly using inelastic demands leads to biased results and our model on duopsony with elastic supply eliminates the bias. (subject code: 3)

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FOB or mill pricing, where customers are responsible for shipping costs, is the best known and most widely studied spatial pricing policy. However, the incentives of firms in spatial markets to practice price discrimination based on customers' locations through absorption of some or all freight charges has long been recognized. Uniform delivered (UD) pricing, where sellers nominally bear the entire shipping cost, is almost as common in practice as FOB pricing, and the two policies jointly comprise the policies used by a majority of firms (Greenhut).

Both FOB and UD pricing policies are simple and easy to administer, and each is usually permissible under statutes regulating pricing behavior. Thus, in many contexts it makes sense to think of firms choosing between FOB and UD pricing policies, and the goals of this paper are to lend insight into the conditions when either pricing policy might emerge in practice and to evaluate the welfare implications of either policy. These questions have been analyzed extensively for the case of monopoly sellers. Beckmann and Beckman and Ingene showed that with a linear demand, FOB and UD prices yields equivalent profit to a monopolist, but FOB pricing generate higher welfare. Cheung and Wang showed that, with strictly convex (concave) demand and fixed market areas, UD prices result in lower (higher) profits and welfare than FOB prices. Lofgren and also Zhang derived a parallel set of results for the case of a spatial monopsonist. However, most real-world markets aren't monopolies or monopsonies, and the studies of these market structures fail to yield any insights into the role that competition might play in determining firms' choice of pricing policy.

Two prior studies, Espinosa and Kats and Thisse (KT), have focussed on firms' choice between UD and FOB pricing policies in spatial duopoly markets. KT study a two-stage game, where in stage 1 firms choose between UD and FOB pricing strategies and in stage 2 engage in production and price setting, given the stage 1 choice. This choice is made repeatedly within Espinosa’s infinite horizon framework. The key variable which indicates the degree of competitive interaction in these and similar models is the importance of the spatial dimension in the market relative to the economic dimension. The
former is measured as the product of per-unit shipping costs ($\gamma$) and distance ($d$) separating the firms. The latter is measured as the value ($\rho$) net of any production costs of the product being produced. Both Espinosa and KT assume that consumers' demands are perfectly inelastic (each consumes one unit subject to a reservation price, $r$), production costs are zero, and, thus, $\rho = r$. As the ratio $s = \gamma d / \rho$ increases, competition between the firms diminishes to the point where eventually they are spatially isolated monopolists.

The key consideration is how the underlying competitiveness of the duopoly or duopsony market influences firms' decisions to employ UD or FOB prices. KT find that UD pricing emerges as an equilibrium for all values of $s$. FOB pricing, however, is an equilibrium only for small values of $s$, i.e., only when the market is very competitive. Espinosa reaches similar conclusions as to the robustness of UD pricing. Mixed pricing, where one firm adopts UD pricing and the other FOB pricing, does not in general emerge as an equilibrium in either model.

These papers each suffer from a significant limitation due to their assumption of inelastic demands with a common reservation price. In the absence of competitive considerations, UD pricing is always preferred in this case because, by setting the UD price equal to the reservation price, the monopoly firm can capture all of the consumers' surplus. FOB pricing cannot accomplish the same result. Even when a second seller is introduced into the market, this "bias" in favor of UD pricing remains. Welfare analysis using models with inelastic demands is similarly problematic because deadweight costs are always zero for any price at or below the reservation price, and the transportation costs between a firm and a given customer are the same regardless of price level or price policy so long as the customer participates in the market.

While the assumption of inelastic demands simplifies modeling, it cannot be justified by an appeal to reality. When demand assumes the usual downward sloping form, we know from prior studies that a monopolist's choice between FOB or UD pricing depends upon the curvature of demand, and that the
preference for UD pricing that emerges with inelastic demands does not hold in general. We are able to surmount this key limitation of the prior studies more readily within an input market framework and, thus, we depart from our predecessors by focusing on a duopsony setting. The key consideration is that customers’ demand or supply characteristics do not bias the results in favor of one pricing policy or the other. In a duopoly model, this outcome is the property of a linear model, but the simplest linear demand model is characterized by two parameters and, hence, is undesirably complex. In contrast we can specify a farmer’s supply function in terms of a single slope parameter, which without further loss of generality can be set to 1, if we are willing to assume that the supply curve intercept is the origin. A monopsonist facing such a supply is indifferent between setting a UD or an FOB price (Lofgren, Zhang), and, in addition, deadweight costs from supracompetitive pricing exist. Thus, the stage is set to study the manner in which spatial competition affects the choice of pricing policy and to provide a more meaningful analysis of the welfare impacts of alternative pricing policies than has been possible previously.

THE MODEL

There are two processing firms, A and B, for the agricultural commodity, located at the end points of a line with unit length. Farmers are located continuously along the line with uniform density \( D = 1 \). A farmer ships production to whichever buyer offers the higher price net of any shipping costs the farmer bears. Each farmer has an identical supply function of the form \( q(w(r)) = w(r) \), where \( r \) is the farmer’s distance from the processor and \( w(r) \) is the net price the farmer receives at the farm gate. This supply curve passes through the origin, and the elasticity of supply is 1.0 for all \( q > 0 \). The cost of transporting a unit of raw product to a processing facility is \( \gamma \) per unit of distance.

A processor converts \( q \) into a finished product, \( g \), according to a fixed proportions production function, \( g = \min\{q/\lambda, h(Z)\} \), where \( Z \) is a vector of processing inputs, and \( \lambda = q/g \) is the fixed conversion factor between raw and processed product. \( \lambda \) can be set equal to 1.0 through choice of measurement units and, hence, \( q = g \). The processing cost function associated with the production function is \( C(q) = m(q)q + \)
$c(q)$, where $m(q)$ is the inverse supply function facing the processing firm, and $c(q)$ is the cost associated with the processing inputs $Z$. It will be convenient to assume constant marginal processing costs and, hence, $c(q) = cq$. The presence or absence of fixed costs has no effect on the model, so we ignore them. Further, we assume that processors are perfect competitors in the sale of the finished product and take output price, $p$, as given. We define $\rho = p - c$ as the finished product price net of per-unit processing costs. We further set $\rho = 1$ via a normalization, so all monetary units are measured in the units of $\rho$, and the relative importance of space in the market is measured by $s = \gamma/\rho$.

Firms play a two-stage game. In stage 1, they simultaneously choose between FOB and UD pricing, and in stage 2 they engage in production and price competition, given the choice of pricing policy from stage 1. We seek to find the subgame perfect equilibria for this game in terms of $s$. Such games are solved recursively. Thus, our first task is to characterize behavior in the three stage 2 price-setting games that may emerge from stage 1: (i) Both firms use FOB pricing, (ii) both use UD pricing, and (iii) one firm uses UD pricing and the other uses FOB pricing. Space limitations preclude us from discussing the stage two pricing games in any detail. Our working paper, Zhang and Sexton, provides this information.

Behavior When Both Firms Use FOB Pricing. Each firm offers a mill price, $m$, at the factory gate and farmers are responsible for the shipping cost. A farmer located at distance $r$ from a plant receives a net price $w(r) = m - sr$. When $s \geq 4/3$, each firm operates as an isolated monopsonist, and sets the monopsony price $m^* = 2/3$ and serves market radius $2/3s$ (Zhang). When $s < 4/3$, firms face competition from each other (Figure 1). Let $m_A$ and $m_B$ denote the FOB prices for A and B, respectively. The market boundary, $R_A$, between A and B is determined by the condition:

$$m_A - sR_A = m_B - s(1 - R_A).$$

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1. This assumption enables us to focus on analysis of the raw product market, but it is also very realistic in many settings where, due to perishability and bulkiness of the raw product, the farm product market is local or regional and served by few firms, but the market for the finished product is national or international and served by many firms.
Firm A’s profit function is $\Pi_A = (1 - m_A)Q_A(m_A, R_A)$, where $Q_A(m_A, R_A)$ is the aggregate supply to firm A, and

$$Q_A(m_A, R_A) = \int_0^{R_A} q(m_A, r)dr = R_A(m_A - \frac{sR_A}{2}).$$

Substituting for $R_A$ using (1), invoking Nash-Bertrand behavior, and (due to symmetry between firms) setting $m_A^* = m_B^* = m^*$, we obtain the optimal FOB price as follows:

$$m^*(s) = \frac{1 - 1.5s + \sqrt{1 - s + 3.25s^2}}{2}.$$

Behavior When Both Firms Use UD Pricing: Under UD pricing each processor offers a constant price $u$ to all producers at their respective farm gates and the processor pays nominally for all transportation costs. The firm's cost is $u + sr$ to purchase one unit from distance $r$. As in the FOB pricing case, each firm is a monopsonist for $s \geq 4/3$, and sets $u^m = 1/3$ and serves market area $R = 2/3s$ (Zhang). When $s < 4/3$, firms face competition from each other, and an equilibrium in pure strategies does not exist because the firms’ profit functions are discontinuous in $u$ (Schuler and Hobbs).

To see the problem, note that, given a price for firm B, $u_B$, firm A faces two choices. It can overbid B’s price by setting $u_A > u_B$ and obtain whatever supply it wants, or it can concede to B’s higher price and act as a monopsonist over any territory left unserved by B. Exactly matching B’s price can never be a best reply for A. Thus A’s profit is discontinuous in $u_A$ at the point where $u_A = u_B$. A Nash
equilibrium in mixed strategies does exist, however (Dasgupta and Maskin). In contrast to a pure price strategy which is expressed in terms of a rule for choosing price such as $m^*(s)$ in (2), a mixed price strategy equilibrium is expressed in terms of a cumulative probability distribution function $G(u)$, i.e., a probability rule for choosing $u$. Solving the mixed strategy equilibrium requires derivation of $G(u_A) = G(u_B) = G(u)$. We provide details in our expanded paper. Figure 2 illustrates $G(u)$ for the case where $s = 1$, and Figure 3 illustrates the lower and upper bounds, $u_1^*$ and $u_2^*$ respectively, of $G(u)$ for alternative values of $s$. Both $u_1^*$ and $u_2^*$ are decreasing in $s$ because higher values of $s$ imply diminishing competition between the duopsonists. When $s \geq 4/3$, A and B operate as monopsonists, and the equilibrium is in pure strategies.

![Figure 2: $G(u)$ For $s = 1$](image)

![Figure 3: Uniform Price Interval in Mixed Strategy Equilibrium](image)
Behavior When One Firm Uses FOB Pricing and One Uses UD Pricing: When the firms employ different price policies, competition is restricted to the market boundary as in the FOB pricing case. Two subcases are relevant. The first is where the boundary is determined by the UD pricing firm's monopsony market boundary. Let B be the UD pricing firm. The monopsony UD price is $u_B = 1/3$, and the market area is $R_B = 2/3s$. The FOB pricing firm A then acts as a monopsonist within the market area unserved by B. This subcase holds when the spatial dimension of the market is important, namely when $1.052 < s < 5/3$.

In the second subcase ($0 < s \leq 1.052$), the boundary, $R^*$, between the firms is determined by the equality between the firms’ net prices:

\begin{equation}
(m_A - sR^*) = u_B,
\end{equation}

and $R^* = (m_A - u_B)/s$. Equilibrium values for $m_A$ and $u_B$ are found by maximizing A’s and B’s profit functions with respect to $m_A$ and $u_B$ solving the resulting reaction functions simultaneously.

Figures 4 and 5 illustrate the outcomes for prices and profits, respectively. Both $m_A^*$ and $u_B^*$ are decreasing in $s$ over the range, $0 < s \leq 1.052$, of the second subcase. The UD pricing firm makes more profit than the FOB pricing firm over the entire range of $s$ ($s < 5/3$) where competition occurs. By discriminating against proximate customers, the UD pricing firm is able to compete more effectively for customers at the market boundary than is the FOB pricing firm.

![Figure 4: Prices Under Mixed FOB and UD Pricing](image-url)
EQUILIBRIUM IN THE STAGE 1 SUBGAME

Figures 6a and 6b summarize the equilibria to the various stage 2 pricing games. To consider equilibrium to the stage 1 game of choice of pricing strategy, let $\Phi = \{\text{FOB, UD}\}$ denote the set of feasible pricing policies. A firm's choice of pricing policy is denoted as $\phi_i \in \Phi$, $i = A, B$. Profits to the firms are determined by the pricing policy choices $\phi_A$ and $\phi_B$ and, given these choices, by the actual price or price distribution choices made in stage 2.

Solution to the stage 1 game is based simply upon the comparisons of profits from the various stage 2 outcomes as summarized in Figures 6. Table 1 lists the equilibria in terms of $s$, the measure of the relative importance of space in the market and, correspondingly, the competitiveness of the market. For $s \in (0, 0.413)$, space is relatively unimportant and the duopsony competition is correspondingly intense. FOB pricing is the dominant strategy equilibrium in this range of $s$. Because FOB pricing restricts competition to the market boundaries, it generates a greater total payoff to the firms than does UD pricing. If, for example, firm B adopted UD pricing, it would gain market area at the expense of A, and it would increase its share of the total profit above the half that it attains under FOB pricing. However, the switch to UD pricing diminishes the "mutual forbearance" in the market achieved by FOB pricing and increases competition at the market boundary. As a result total profit is sufficiently lower for $0 < s < 0.413$ under a
(FOB, UD) configuration than under (FOB, FOB) that it more than offsets the gain to B from capturing a greater share of the profits, and, hence, defection to UD pricing is not profitable.

Figure 6: Nash Equilibria to the Stage 2 Games

Table 1: Equilibrium in the Stage 1 Game

<table>
<thead>
<tr>
<th>Space range</th>
<th>Equilibrium strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>s ∈ (0, 0.413)</td>
<td>(FOB, FOB)**</td>
</tr>
<tr>
<td>s ∈ [0.413, 0.601]</td>
<td>(FOB, UD) or (UD, FOB)</td>
</tr>
<tr>
<td>s ∈ (0.601, 4/3)</td>
<td>(UD, UD)**</td>
</tr>
<tr>
<td>s ∈ [4/3, 5/3]</td>
<td>(FOB, FOB), (UD, UD)*</td>
</tr>
<tr>
<td>s ≥ 5/3</td>
<td>Any combination of pricing policy</td>
</tr>
</tbody>
</table>

** denotes a dominant strategy equilibrium, * denotes a weakly dominant strategy equilibrium
For moderate values of $s$ (0.413 $\leq$ $s$ $\leq$ 0.601), the equilibrium involves one firm using UD pricing and the other using FOB pricing. Neither KT nor Espinosa obtained similar mixed pricing equilibria. UD pricing's discriminatory property enables the UD pricing firm to compete effectively against the FOB pricing firm at the market boundary. The reduction in payoff caused by a unilateral defection from FOB pricing declines as a function of $s$. Higher values of $s$ imply less competition regardless of choice of pricing policy and, accordingly, the loss in joint profits from unilateral defection to UD pricing is less than when $s$ is small. Thus for $s \geq 0.413$ the benefit to, say, firm B of greater market and profit share from defecting to UD pricing exceeds its loss from diminishing the total profits in the market through enhanced competition. Firm A perseveres with its FOB strategy in the range 0.413 $\leq$ $s$ $\leq$ 0.601 because its use of FOB pricing in the presence of UD pricing by its rival restricts competition to the market boundary as opposed to the more general competition that would emerge if it also adopted UD pricing. A’s gain from recapturing its half of the market and the profits is dominated in this space range by its loss from diminishing the total profit pie.

For $s \in (0.601, 4/3)$, (UD, UD) is the dominant strategy equilibrium. Although firms compete for customers in this range of space, the relative importance of space causes competition to be muted under any choice of pricing strategy. Thus, the benefit of restricting competition to the market border that results when at least one firm chooses FOB pricing is less important than when $s$ is small. Although the firms would earn more if they both agreed to abide by a mutual FOB pricing strategy, they each succumb in this range of space to the temptation to expand market share and relative profits by adopting UD pricing.

For $4/3 \leq s < 5/3$, (UD, UD) is a weakly dominant strategy equilibrium, but (FOB, FOB) is also an equilibrium. Recall that $R = 2/3s$ is the monopsony market radius under either FOB or UD pricing. Mixed FOB-UD pricing is not an equilibrium in this range because some customers within the FOB firm’s monopsony market area would defect to the UD pricing firm by incurring costs to ship their product to the
UD pricing firm's boundary. Finally, for \( s \geq 5/3 \), no competition emerges under any price strategy combination and, thus, any combination of UD and FOB pricing is an equilibrium.

**WELFARE ANALYSIS**

A common perception is that FOB pricing maximizes social welfare relative to other spatial pricing alternatives (e.g., Beckmann; Greenhut, Norman, and Hung; Anderson, de Palma, and Thisse). Our analysis in general does not affirm this perception. Welfare in our model consists of the sum of firm profits and farmer producer surplus, each net of any transportation costs incurred. Two primary effects are at work. First, UD pricing by discriminating against proximate customers always attracts relatively more business from distant customers than does FOB pricing when customer demands (or supplies) are elastic. Thus, shipping costs are always higher under UD pricing. However, UD pricing leads to more competitive market outcomes than does either FOB pricing or mixed FOB-UD pricing. When customer demands (or supplies) are elastic, deadweight losses are lower under UD pricing than the alternatives. Both effects are missing in models with inelastic demands or supplies.

In general, the welfare ranking among FOB, UD or mixed FOB-UD pricing depends upon the importance of the excessive transportation costs caused by UD pricing relative to UD pricing’s lower deadweight costs. Welfare under FOB, UD and mixed FOB-UD pricing is presented in Figure 7 as a percentage of the maximum welfare in the market (attained by an FOB pricing arrangement by both firms where \( m = 1 \)). For very low values of \( s \) (0 < \( s < 0.218 \)) UD-FOB pricing provides the highest welfare. For intermediate values of \( s \) (0.218 ≤ \( s < 1.082 \)), UD pricing yields the highest welfare. Only for markets with large \( s \) (\( s \geq 1.082 \)) does FOB pricing result in the highest welfare.

When \( s \) is small, the costs of the additional transportation engendered by UD pricing are unimportant. Conversely, the greater competition inspired by UD pricing is important and, accordingly, social welfare is higher under UD than FOB pricing. However, as \( s \) increases, the costs of inefficient transportation rise and the benefits of enhanced price competition under UD pricing diminish (because
high $s$ diminishes the potential for competition under any form of pricing. Thus, for sufficiently high values of $s$, FOB pricing provides greater welfare than either UD or mixed FOB-UD pricing.

![Figure 7: Welfare Comparison](image)

**CONCLUSIONS**

In results that differ considerably from our predecessors', we find that when the spatial dimension of the market is small relative to the net value of the product produced (i.e., small $s$), FOB pricing emerges as the dominant strategy equilibrium. FOB pricing restricts competition to the firms’ market boundaries and, thus, is a tacitly collusive pricing outcome. A mixed FOB-UD pricing equilibrium emerges for moderate values of $s$, with UD pricing emerging as the equilibrium only for relatively large values of $s$. Similarly our welfare analysis does not in general support the conclusion of prior research that FOB pricing generates higher welfare than UD pricing. FOB pricing yields higher welfare in our model only for values of $s \geq 1.082$, i.e., markets that were pure monopsonies or nearly pure monopsonies. Notably for significant ranges of $s$, the equilibrium pricing strategy is not the welfare maximizing strategy among the alternatives considered.
REFERENCES


