Transportation Cost and Market Power of Middlemen: A Spatial Analysis of Agricultural Commodity Markets in Developing Countries

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High transportation cost and market power are long-recognized sources of market inefficiency. This is especially true in the context of agricultural commodity marketing in developing countries, where traders have been found to have market power over farmers even after market liberalization in the 1980s and 1990s (Barrett, 1997; Fafchamps, 2004). Not only do high transportation costs decrease the profit of farmers selling commodities to traders, but they also often cause nonexistence of markets in rural areas (Taylor and Adelman, 2003).

The importance of transportation costs in economic development has long been recognized in the literature. Recent studies have presented focused discussions on transportation cost at both the micro-agent and economy-wide levels. The former group includes studies on the relation between transportation cost and farmers' crop choice (Omamo, 1998) and existence of "missing markets" due to high transportation cost (de Janvry, Sadoulet, and Fafchamps, 1991; Taylor and Adelman, 2003). The latter group includes studies on the significance of transportation costs in planning trade liberalization (Bivings, 1997), the linkage between transportation costs, entry of traders, and market power (Barrett, 1997), and the role of high transportation costs in restricting the growth of key industries and sustaining low producer prices (Staal, Delgado, and Nicholson, 1997).

Although transportation costs have been discussed widely, the development literature has focused on confirming the positive impacts of lowering transportation cost on market efficiency by using regression models or numerical optimization and has not established an analytical framework to determine how lower transportation cost can contribute to reducing marketing costs, and also to limiting buyers' market power, thereby increasing producer welfare in two dimensions. On the other hand, the industrial organization literature provides the basis to analyze the interface of transportation cost and market power, as reflected for example in the work of Faminow and Benson (1990) and Zhang and Sexton (2000 and 2001). In order to understand fully this classical impediment to market efficiency in developing countries, it is important to study analytically the mechanism of how transportation costs interact with market power and how farmers or policy makers might be able to overcome this market impediment.

The research question we address in this paper is the mechanism by which lower transportation costs increase farm prices and profits, and how funds to improve transportation infrastructure can be raised through an endogenous financing mechanism. We study the linkage between transportation cost, market power, and farmers' producer surplus analytically using a two-stage game-theoretic model. The analysis contributes in three areas: (1) We establish two ways in which lower transportation costs contribute to raising farmers' producer surplus--(a) by directly reducing transportation cost and, thus, the farm-wholesale price spread, and (b) by increasing competition between traders and determine the relative importance of the two effects. (2) We show that, although competition increases when transportation costs are reduced, traders can also benefit from lower transportation cost in some cases due to expanded supply of the farm product. (3) We study use of an endogenous finance mechanism to reduce transportation costs, namely the use of varying forms of taxation to generate funds to improve transportation infrastructure, and determine the optimal level and characteristics of such taxation. The assessments we discuss could either be levied through government or by a producer cooperative, in which case the tax would have the character of retained patronage-based income. To preserve the generality of our revenue-generating mechanism, we henceforth refer to the revenue generator as simply the “authority”.

Stage 2 in the game-theoretic model is a simple production and pricing stage, and is adapted from the spatial model of Zhang and Sexton (2000, 2001), who studied farmers’ interactions with duopsony marketing firms. In this stage, the marketing firms engage in a Nash-Bertrand competition, setting FOB prices to farmers, given the level of tax revenue and, thus, transportation costs.

The level of transportation costs is exogenous in the Zhang-Sexton model and similar spatial models, but it is determined optimally in stage 1 of our generalized model. Specifically, in stage 1 the tax rate is set by the authority so as to maximize producer surplus, and the funds collected are expended to improve roads and other transportation infrastructure, thereby impacting marketing costs and the oligopsony competition in stage 2. The tax is levied with rational expectation of how it will impact the subsequent stage 2 competition. Given the outcome of the game, we then study the welfare implications for both producers and marketing firms.

In section 2, the model setting is described. Section 3 describes the equilibrium of the two-stage game for duopsony competition. In section 4, we analyze the equilibrium for alternative values of the market parameters while section 5 contains concluding comments.

1. The Model

Consider a region in the hinterland of a developing country where farmers reside uniformly over a line of interval [0, 1] with density D=1. A trader $i = a, b$, is located at either endpoint of the market, as illustrated in figure 1. The farmers can sell their production to either trader, but there is a natural advantage doing business with the trader who is more proximate to the farmer's location. Each trader offers a mill or FOB price P_i $i = a, b,$ to farmers so that the farmers bear the transportation cost (even though traders may perform the actual transportation, they charge the cost to each farmer).[1] The cost per unit of distance of transporting one unit of the commodity is γ, which makes the total cost necessary to transport one unit of the commodity γx_j, where $x_j \in [0,1]$ is the distance of farmer j from market A. The price that a farmer j receives from trader i net of transportation cost and before any tax is $w_j^i = P_i - \gamma x_j$.

We assume initially that each farmer has an inelastic supply of the farm product, and without further loss of generality, normalize that supply to unity—each farmer supplies one unit of the product to whichever trader offers the higher net price, as long as this price exceeds the farmer's reservation utility $\underline{U}$, and supplies none otherwise. Here $\underline{U}$ is the value of the product in subsistence consumption and is set at zero for simplicity.

We denote $Q_{i,}$ as the total amount that farmers sell to trader $i = a,b$. We assume that traders are price-takers in the output market, so output price R is exogenous, and traders

[1] The primary alternative to mill pricing is uniform-delivered (UD) pricing, where the marketing firms pay each producer the same net price and bear nominally the transportation costs themselves. Equilibria in a duopsony market with UD pricing ordinarily involves mixed strategies (add cites from ZS), and, thus, FOB pricing is preferred in our analysis due to the convenience of working with pure strategy equilibria.

incur per-unit marketing costs, c. The variable $\rho = R - c$ denotes the price traders receive net of their unit marketing costs, and without loss of generality this net price is set to $\rho = 1$ via a normalization.

We now introduce the concept that transportation costs can be reduced through investments in transportation infrastructure and, in addition, consider a per-unit or excise tax s levied by the authority for the purpose of collecting funds to expend for such investments. We subsequently discuss extension of the model to incorporate other forms of taxation. The ability of such funds to reduce transportation costs depends upon the technology available to the developing country, and, given the extant technology, such expenditures will have a diminishing marginal productivity. We parameterize these essential features of transportation improvements through the following simple functional relationship: $\gamma = T - \alpha\sqrt{B}$, where $T>0$ is the unit transportation cost if no road improvement is made, $\alpha >0$ represents the technology of road improvement, and B is the total tax revenues or budget collected for the improvement, where $B = s(Q_a + Q_b)$. The technology parameter α is expected to be high for more developed countries, which have access to better technologies, relative to poorer, less-developed countries.

2. Duopsony Competition

Given our interest in the effects of transportation costs on competition for the raw product, we focus on the case when transportation costs, absent any tax-funded improvements, are sufficiently low that the traders' market areas overlap. If transportation costs are sufficiently high relative to the value of the output being produced, the traders' desired market radii do not overlap, each operates as an isolated monopsonist, and producers located between the endpoints of the two monopsony radii have no market outlet, and can produce only for subsistence needs—the missing markets case discussed by Taylor and Adelman (2003), among others. A farmer will sell to trader a if he gains more than his reservation utility from selling, i.e., $P_a - \gamma X_{Ma} > \underline{U} \equiv 0$. Thus the location of the last farmer willing to sell to trader a is $X_{Ma} = \frac{P_a}{\gamma}$. In the monopsony setting firm a maximizes profit with respect to choice of P_a, taking into account the effect of its choice on the market area it can serve:

$$(1) \qquad \underset{\{P_a\}}{Max} \ \Pi = (1 - P_a)\left(\frac{P_a}{\gamma}\right).$$

The solution to (1) is $P_a^M = \frac{1}{2}$ with monopsony market radius $X_{Ma}^* = \frac{1}{2\gamma}$. Because traders a and b are symmetric, similar results apply for trader b. Thus, each firm acts as an isolated monopsonist when $1 \geq \frac{1}{\gamma} \Leftrightarrow \gamma \geq 1 \Leftrightarrow T \geq 1$. If T, the base level of transportation costs, is greater than or equal to 1, the market is served by two isolated monopsonists, while duopsony competition prevails otherwise. To focus the analysis on the duopsony case, we assume that $T < 1$ holds and later discuss the implications of the model for the monopsony case when $T \geq 1$.

Stage 2: The model is solved recursively, beginning with the stage 2 equilibrium. The two traders engage in Nash-Bertrand competition to procure the raw product from farmers. The amount supplied to each trader can be derived by finding the farmer j (located at point Y in figure 1) who is indifferent between selling to trader *a* or trader *b* because his net price from either is the same:

$$P_a - \gamma x_j - s = P_b - \gamma(1 - x_j) - s.,$$

This gives an expression for point *Y*, the market boundary, and, given the assumptions on supply, the two traders' market share.

$$Q_a = Y = \frac{P_a - P_b + \gamma}{2\gamma} \qquad \text{and} \qquad Q_b = 1 - Y = \frac{P_b - P_a + \gamma}{2\gamma} \ .$$

Given these supply functions, trader A maximizes profit by choosing P_a,

(2a) $$\underset{\{P_a\}}{\text{Max}} \ \prod_A (P_a, P_b) \ = \ (1 - P_a)Q_a = (1 - P_a)\frac{P_a - P_b + \lambda}{2\gamma}.$$

Similarly, trader B maximizes profit by choosing P_b,

(2b) $$\underset{\{P_b\}}{\text{Max}} \ \prod_B (P_b, P_a) \ = (1 - P_b)\frac{P_b - P_a + \gamma}{2\gamma}.$$

From the first-order conditions we derive the traders' reaction functions as

$$P_a^*(P_b) = \frac{P_b - \gamma + 1}{2} \ \text{ and } \ P_b^*(P_a) = \frac{P_a - \gamma + 1}{2}.$$

Solving them simultaneously, obtains,

$$P_a^* = P_b^* = 1 - \gamma.$$

Note that this result applies only for ranges of γ such that the market is covered, i.e., the market is a duopsony. Thus, we must have

$$w^a_{j=1/2} = w^b_{j=1/2} = 1 - \gamma - (1/2)\gamma \geq 0 \Leftrightarrow \gamma \leq 2/3 \Leftrightarrow T \leq 2/3.$$

Substituting the equilibrium prices into the objective functions (2a) and (2b), the traders' total profits are

$$(3) \qquad \Pi^* = \Pi_A^* + \Pi_B^* = 2\left[(1-P^*)\frac{1}{2}\right] = \gamma.$$

Stage 1**:** The authority's objective is to maximize farmers' producer surplus through the optimal choice of the tax rate *s* as follows.

$$\begin{aligned}
\underset{s_{DP}}{\text{Max}}\ \ PS &= PS_A + PS_B = q_j^a \cdot \int_0^Y w_j^a dx + q_j^b \cdot \int_Y^1 w_j^b dx \\
&= \int_0^{1/2} (P^* - \gamma x_j - s)dx \ + \ \int_{1/2}^1 (P^* - \gamma(1-x_j) - s)dx \\
&= 1 - s - \frac{5}{4}\gamma.
\end{aligned}$$

Given that the market is fully covered in the duopsony case, $Q_a^* + Q_b^* = 1$, and, thus, $\gamma = T - \alpha\sqrt{s}$. Using this relation, the authority's program becomes,

$$(4) \qquad \underset{\{s\}}{\text{Max}}\ \ PS = 1 - s - \frac{5}{4}\cdot\left[T - \alpha\cdot\sqrt{s}\right],$$

with Kuhn-Tucker conditions:

$$\frac{\partial PS}{\partial s} = -1 + \frac{5\alpha}{8\sqrt{s}} \le 0, \frac{\partial PS}{\partial s}s = 0, s \ge 0.$$

For an interior solution, these conditions yield the optimal tax rate, s^*, and the resulting transportation cost, γ^*, as,

$$s^* = \frac{25\alpha^2}{64} \qquad \text{and} \qquad \gamma^* = T - \frac{5}{8}\alpha^2.$$

Equilibrium price for the raw product is

$$P^*(s^*) = 1 - T + \frac{5}{8}\alpha^2.$$

Substituting the equilibrium results into the objective function (4) yields the optimal producer surplus as

(5) $$PS^{*}=1-\frac{25\alpha^{2}}{64}-\frac{5}{4}\left[T-\frac{5}{8}\alpha^{2}\right]=1-\frac{5}{4}T+\frac{25}{64}\alpha^{2}.$$

Similarly, we apply the optimal *t* in equation (3) to obtain the traders' profit at the optimal tax rate:

(3') $$\Pi^{*}=T-\frac{5}{8}\alpha^{2}.$$

3. Analysis of the Equilibrium

The base duopsony model has two exogenous parameters. T measures the base level of transportation costs *relative* to the net value $\rho = R - c$, of the finished commodity. Thus, T represents the relative importance of transportation costs in the market. Larger values of T represent markets where transportation costs are high relative to the value of what is being produced with the farm product. To interpret the technology parameter α, we express it in terms of the elasticity of the transportation costs with respect to expenditures on transportation. Denote this elasticity as ε, where $\varepsilon=\frac{\partial\gamma}{\partial B}\frac{B}{\gamma}$. Given the duopsony model, the transportation budget is just $B = s$. We compute this elasticity, evaluate it at the model's equilibrium, and solve for α as a function ε and T to obtain:

$$\alpha=\sqrt{\frac{2T\varepsilon}{(5/8)(2\varepsilon-1)}}.$$

Table 1 shows how the price, traders' surplus, and farmers' producer surplus change with respect to a marginal increase in the model parameters, α and *T,* for the duopsony case.

Table 1: Marginal Effects on Price, Traders' Surplus, and Farmers Producer Surplus in the Duopsony Model

with respect to	α		T	
	effect	sign	effect	sign
Price	$\frac{5}{4}$	+	-1	−
Traders Surplus	$-\frac{5}{4}\alpha$	−	1	+
Farmers' PS	$\frac{25}{32}\alpha$	+	$-\frac{5}{4}$	−

In the duopsony model with FOB pricing, traders cannot benefit from reductions in transportation costs, and, indeed, benefit from higher transportation costs in the range of $\mathrm{T} \leq 2/3$ because it enhances their market power by diminishing the intensity of the duopsony competition. Thus, traders' surplus is increasing in the base transportation cost, T, and decreasing in the technology parameter, α. Lower transportation cost from investments funded from the tax revenues increases the competition between traders at the market boundary, and this competition leads to higher FOB prices offered to all farmers.

The marginal effect of increasing the parameter α, which represents the technology of road improvement, is to increase producer surplus. Thus, countries endowed with better technology to improve transportation have more opportunity to improve producer welfare through endogenous investments in the transportation infrastructure and at the optimum should levy a higher excise tax for that purpose.

To obtain perspective on the magnitude of the benefits available to producers from the optimal investment in transportation infrastructure, figure 2 depicts the percent change in producer surplus from the optimal investment relative to the initial equilibrium as a function of the transportation cost parameter, T, and for three alternative values of ε. The opportunity to benefit producers from the optimal investment is increasing in T over the range $T \in (0, 2/3)$ consistent with duopsony competition. The benefit to producers is also increasing in the absolute value of ε, which in turn is associated with higher values of α, demonstrating the aforementioned proposition that the greatest potential to improve producer welfare through investments in transportation lies with those economies endowed with the infrastructure to effectively spend the money collected through the tax. On balance, the welfare gains for this model are relatively modest, on the order of one to two percent for larger values of T and ε.

Finally, we depict the optimal excise tax rate in figure 3. s^* depends only on the efficiency parameter, α. For comparison purposes, we show the optimal tax rate from the perspective of maximizing producer surplus and in terms of maximizing total market surplus, which in this model consists of producer surplus and trader profits (there are no consumer effects due to the price-taking assumption). Because much of the producer gain comes at traders' expense due to improved farm prices, the optimal tax rate is much lower when our criterion is total welfare, as might be true when government was the taxing authority, versus when our criterion is producer surplus, as might be true when revenues were collected from a producer cooperative.

4. Extensions

The analysis can be extended in many promising directions. A key limitation of the duopsony model with inelastic producer supplies is that supply is fixed for all parameterizations that sustain the duopsony equilibrium. In this environment improvements in the transportation infrastructure can never be beneficial to the trading firms—the quantity shipped to the market is fixed, and improvements in transportation only serve to intensify the duopsony competition between the traders, causing them to offer higher prices to farmers and earn lower profits. Quantity produced can be made endogenous through either of two extensions of the model: (1) allowing transportation costs to be sufficiently high, $T > 1$, that the market is not covered and the traders operate as monopsonists, and (2) introducing upward sloping farm supply curves into either monopsony or duopsony models

In the former instance, reducing transportation costs will enable more producers in the interior of the market area to sell to one of the traders. In this market environment, transportation improvements funded from taxes on the producers who are selling to the market benefit those producers by reducing their shipping costs but do not engender higher FOB prices as long as the trading firms remain isolated monopsonists. The investments also benefit those producers who find it profitable to sell to the market, in light of lower transportation costs, and they also benefit the traders, who obtain greater access to the farm product, while preserving their monopsony power. Clearly, in this environment, equity considerations dictate that that the traders contribute to any tax revenues generated for transportation improvements.

Elastic producer supply presents the interesting but analytically difficult case where improvements in transportation infrastructure can, depending upon the model parameterizations, (i) increase competition between traders, (ii) increase supply among producers already in the market, and (iii) bring into the market farmers who previously produced only for subsistence use. This generalization enables the model to analyze scenarios where transportation investments benefit the widest possible class of market agents—(i) farmers currently selling to the external market, who benefit from increased competition in the duopsony scenario, reduced transportation costs, and the opportunity to increase production in response to higher farm level prices, (ii) farmers currently producing only for subsistence use in monopsony equilibria, who find it profitable to sell to the external market when transportation costs are reduced, and (iii) traders who benefit from increased availability of production, but who are harmed from intensified competition in the duopsony equilibrium. An interesting question in this environment is whether the benefit to traders from access to greater production in the duopsony equilibrium can for some market parameterizations exceed the cost to them from increased competition.

A second class of extensions involves consideration of alternative forms of taxation to the excise tax considered here, including income or profits taxation, with the possibly the taxation of traders' profits because, as noted, traders may benefit from lower transportation costs under several market scenarios. Finally, the analysis could be extended to alternative spatial pricing schemes, including uniform-delivered prices (see footnote 1), or optimal discriminatory pricing (Greenhut, Norman, and Hung, 1987).

5. Conclusion

The model presented in this paper demonstrates the interactive roles of transportation costs and oligopsony power in determining farmers' income in a prototype developing economy setting and introduces an endogenous mechanism for farmers to strategically increase welfare in the liberalized market economy through investing in improvements in the transportation infrastructure. We derived the optimal level of producer taxation through a two-stage model in which a taxing authority sets the tax rate in stage 1 in rational anticipation of its impact on the duopsony competition in stage 2. Investments in transportation infrastructure improve producer welfare in two dimensions—by directly reducing the cost of shipping commodity from the farm to processing plant or seaport and indirectly by increasing competition between traders. In a more general model setting traders may also benefit from these investments through access to greater supplies of the farm commodity.

Figure 1: Spatial Market (Duopsony Case)

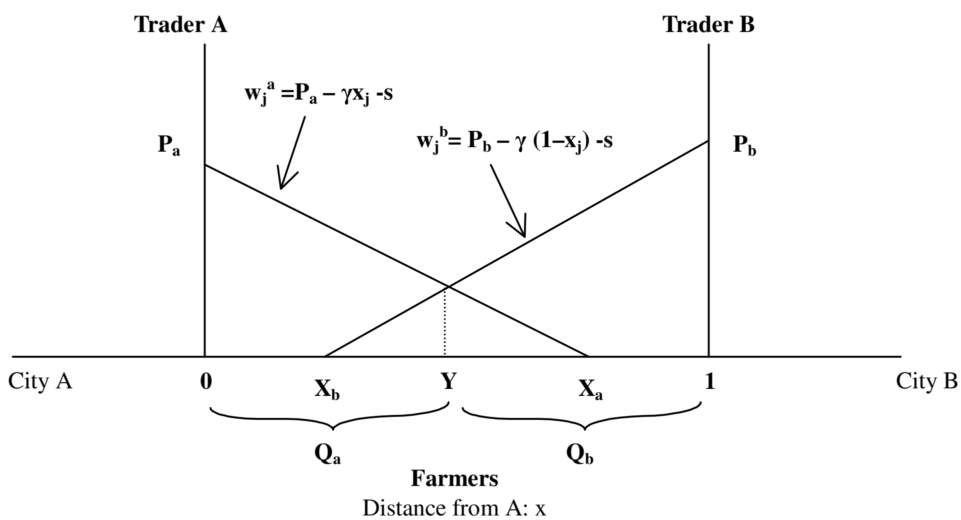
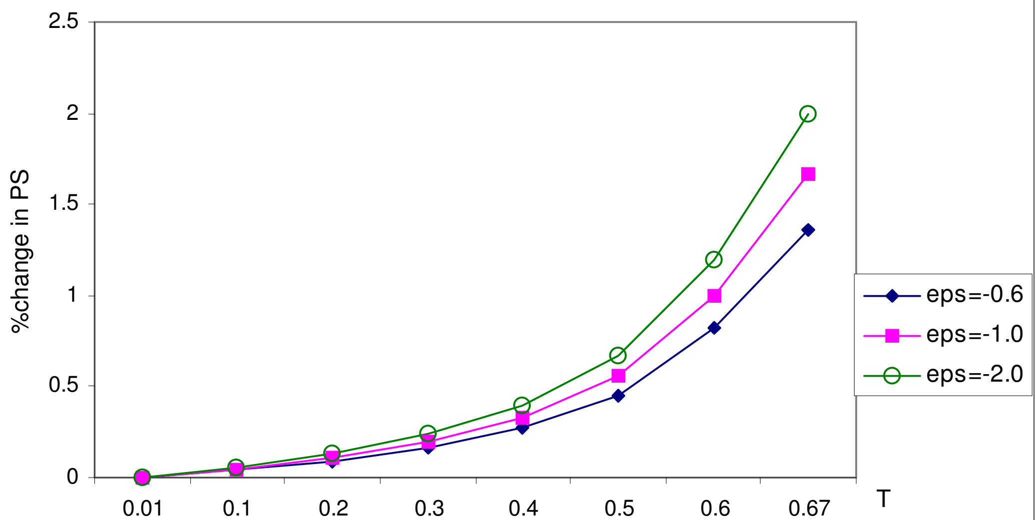


Figure 2: Changes in Producer Surplus from Optimal Investment



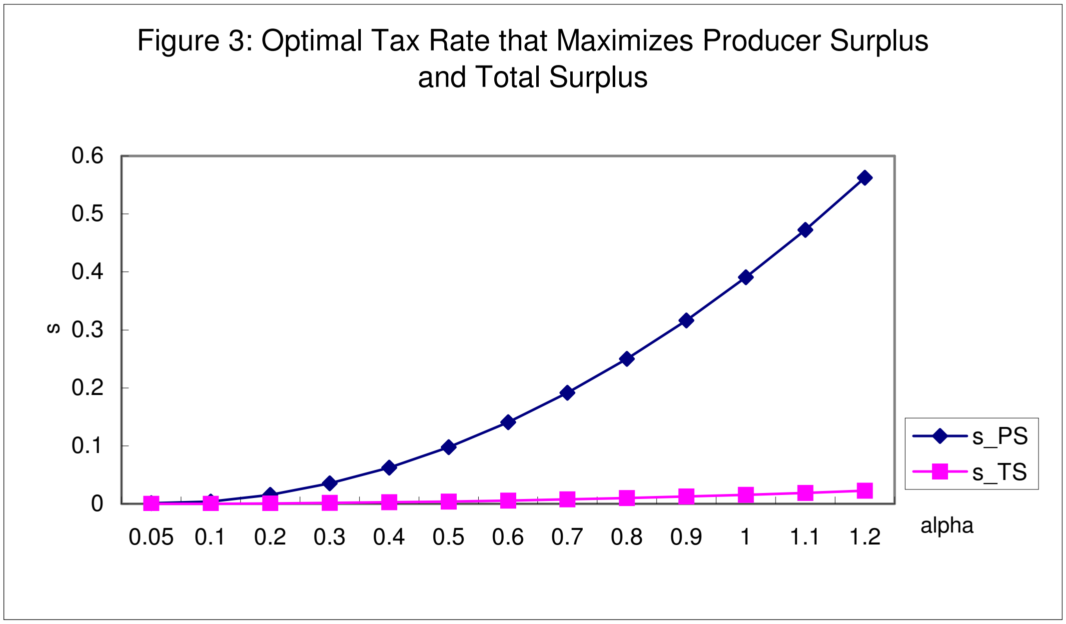


Figure 3: Optimal Tax Rate that Maximizes Producer Surplus
and Total Surplus
0.6
0.5
0.4
0.3
0.2
0.1
0
s
0.05
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
alpha
s_PS
s_TS

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