Transportation, State Marketing, and the Taxation of the Agricultural Hinterland

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In raising revenues, governments of poor countries affect farm gate prices for export crops. Because agriculture is dispersed, interventions have spatial effects, leading to an integrated analysis of taxation, marketing, and transportation. Policies to be used singly or together include land, export, and transportation taxes/subsidies and variants of state marketing, in which only government procures crops. An export tax and a transport subsidy may be optimal. With state marketing, important aspects of buying depots are numbers, locations, spatial pattern of prices paid, and movement of output toward or away from the ultimate market. These policies also affect transport investment strategies.

I. Introduction

Many governments of developing countries intervene in ways that affect the prices received by farmers for the crops they produce for export. In many cases, these price interventions raise a significant amount of revenues for the governments or affect the incentives of producers to produce and the welfare of producers. This paper concerns alternative price interventions and their consequences. Among the government's options that I consider are land taxes, export taxes, transportation taxes/subsidies, and various forms of state marketing, in which the government has exclusive right to procurement of the export crop in the countryside.

Part of the research for this paper was funded under U.S. Agency for International Development grant 650-0071-C-00-4038-00. I thank Michael Katz and David M. G. Newbery for comments on an earlier draft.

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Because agricultural production takes place over space, the availability and cost of transport are important in determining the location and level of agricultural output. Although rural transport may be viewed as one of many inputs to agricultural production, its role can be modeled more precisely than simply as another factor of production in a neoclassical production function. In this paper, I shall build on the important work of Walters (1968, chap. 5) on the Ellet model to develop a framework that explicitly uses information about the technology of transportation and the associated geographical pattern of production in the agricultural sector. In this way, the effects of price interventions on government’s revenues and on producers’ decisions and welfare can be seen to derive from their impact on the spatial structure of agricultural activity.

While this type of explicit modeling of agriculture and transportation is important for evaluating tax policies, especially when these influence the cost of transportation, it is really essential in considering state marketing schemes. Only in this type of model can one analyze the effects on government revenues and producer welfare of spatially dispersed buying depots run by state agencies. Among the aspects of depots are the effects of their numbers, their locations, the prices paid at them, and the movement of output past depots toward or away from the point of export (forwardhauling and backhauling, respectively).

Different price policies require getting out into the countryside to contact producers to different degrees. Some policies have the advantage that they can be enforced exclusively from the point of export. Other interventions imply a direct presence in the countryside, by either tax authorities or marketing agencies. Another important advantage of a spatially oriented model of agriculture and price interventions is, therefore, the ability to think about the relative advantages of different price policies in these terms. Tax administration is often entirely neglected in the theory of public finance, and it is

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1 I adopt Walters’s basic model in Secs. II and III. The main difference in assumptions in these sections is that Walters assumes that output per acre is a constant, so that there is no intensive margin of cultivation, and therefore all elasticity in behavior derives from changes in the boundary of cultivation, the extensive margin of cultivation. He analyzes a wide range of issues not touched on by me: a truncated road, road sections of different quality, two-way traffic, inelastic demand for output, movement of off-road transport in all directions, and feeder roads, all topics of importance to the assessment of road projects and public finances in an explicitly spatial framework. On the other hand, Walters considers only the maximization of revenues with respect to either export taxes or transport taxes but does not discuss the optimal combination of these two instruments or the optimal tax problem. Nor does he look at any aspects of marketing, as discussed here in Secs. IV and VI. There are also some analogies between my analysis and the literature on spatial monopoly, which I comment on as they arise.
valuable if something can be said about the costs of implementing various price policies. An explicitly spatial analysis helps to do this.

Sections II and III of the paper describe the behavior of individual farmers and the general equilibrium of the agricultural sector as a whole. Section IV analyzes various aspects of state marketing when purchases are made at a continuum of depots. Section V discusses price interventions that are conventionally termed taxes and subsidies on exports and on transport, as well as combinations of these instruments, and compares these policies with the state marketing scheme of Section IV. Section VI returns to the question of state marketing, but when only a discrete number of depots is feasible. Section VII discusses panterritorial pricing, a frequently adopted policy in Africa that seeks to provide all producers with the same farm gate price regardless of their location. Section VIII summarizes the major findings and suggests priorities for further research.

II. Equilibrium of the Smallholder in the Countryside

The smallholder in this economy makes choices about production in a very straightforward way, by maximizing rents per acre, \( \pi(x, y) \), on land located at the point \((x, y)\). He does so by varying the amount of a single input, labor, which he applies at the rate of \( L(x, y) \) per acre. He pays this labor a wage per unit of \$w\, which does not depend on location, and he takes this wage as exogenously given. This wage is also given exogenously at the level of the export sector as a whole, which is small relative to the entire economy.

Output per acre, \( Q(x, y) \), depends on labor input as specified by a standard neoclassical production function, \( F \), with \( F' > 0 \) and \( F'' < 0 \):

\[
Q(x, y) = F[L(x, y)].
\] (1)

Output is sold where it is produced at a farm gate price of \( \$k(x, y) \), so that rents, \( \pi \), per acre at location \((x, y)\) are given by

\[
\pi(x, y) = kF(L) - wL.
\] (2)

The maximization of rents by farmers then implies the standard condition:

\[
F'[L(x, y)] = \frac{w}{k}.
\] (3)

This condition in turn implies

\[
Q(x, y) = \Omega \left[ \frac{k(x, y)}{w} \right]
\] (4a)
\[ \pi(x, y) = w \Phi \left[ \frac{k(x, y)}{w} \right], \tag{4b} \]

with \( \Omega(0) = \Phi(0) = 0. \)

So much for the equilibrium of each smallholder at any location; I next turn to the aggregate picture.

### III. Spatial Equilibrium of the Countryside as a Whole

Figure 1 illustrates the economic geography of the countryside. A road going through land of equal fertility is perpendicular to a straight coastline that it meets at a port, from which agricultural output is exported to world markets. The port is denoted as the origin of the diagram. Every unit of output that is transported to the port is purchased there by foreigners at a fixed price of \( \$p^* \).

Export of output from the location \((x, y)\) requires two types of travel, from \((x, y)\) to the road, at a cost of \( \$b \) per ton-mile, and along the road to the port, at a cost of \( \$a^* \) per ton-mile measured in world prices. Off-road transport may literally involve the headloading of produce to the road or, alternatively, travel by bullock cart or some other simple means of transport. Traditional transport is distinguished economically from modern mechanized transport along the road (by truck or railroad) in two ways: (1) It is much more expensive (i.e., \( a^* \ll b \)). For this reason, I assume that off-road transport occurs only in the direction that is perpendicular to the road for a distance of \( y \) miles and that the then remaining distance of \( x \) miles is on the road.\(^2\)

(2) While on-road transport can be taxed (or subsidized) by the government via fuel and truck taxes or the freight rates implicit in the locational prices paid by state marketing agencies, traditional transport cannot be and is therefore an untaxed good. This distinction embodies the notion that the government cannot get out everywhere in the countryside at will.

In the absence of any government intervention, the farm gate price is assumed to be given by the difference between the world price at the port, \( p^* \), and the costs of transportation to the port:

\[ k(x, y) = p^* - a^*x - by. \tag{5} \]

\(^2\) For instance, Squire (1973) shows that for some data from the Thai rice trade, which give a value for traditional transport 10 times that of mechanized transport, the cost-minimizing angle of off-road travel is 84° to the road. Similarly, Mears (1981, p. 217) reports data for the Indonesian rice trade that suggest a ratio of \( b \) to \( a^* \) of from 10 to one to perhaps as high as 30 to one. In these cases, the assumption of perpendicular travel is not a bad approximation.
Fig. 1.—Economic geography of the hinterland

What can be said about the boundary of cultivation, the locus beyond which there is no production for export through the port? Certainly, no production occurs beyond the point at which \( k(x, y) = 0 \). If \( F' \to \infty \) as \( L \to 0 \), cultivation occurs right up to this line, and similarly for the special case used by Walters in which \( F = 1 \), so that production per acre is a constant and requires no labor at all. On the other hand, if a strictly positive amount of labor per acre is needed to produce anything at all, the boundary lies inside the locus \( k(x, y) = 0 \). Throughout the paper, I assume that technology is such that the boundary of cultivation is given by

\[
k(x, y) = 0.
\]

(6)

IV. State Marketing and Government Revenues: A Continuum of Depots

Analytically, the policy of state marketing with a continuum of depots represents the greatest flexibility among policies that I consider to be at all economically feasible, and therefore it is a good starting point.\(^3\)

\(^3\) Taxes on land that vary with location embody even greater flexibility; however, this type of tax involves getting out into the countryside to a very great extent. If the government could implement such a tax, it could obtain the absolutely highest level of revenue equal to all rents in the economy when the government does not intervene at
In subsequent sections, I look at the consequences of further constraining government policies.

There are obvious similarities between taxation and the government’s arrogation to itself of the exclusive right to purchase from farmers through a state marketing agency. The two types of policies can always be made definitionally identical because any difference between world prices (net of transport costs) and prices paid by the state can be termed a tax. Thinking in terms of state marketing, however, suggests pricing alternatives not conventionally termed taxation. In particular, state marketing calls to mind notions of physically getting out into the countryside to influence farm gate prices.

One state marketing policy is line of road (or rail) purchase. All output from \((x, y)\) that is brought \(y\) miles to the road \(x\) miles from the port is purchased at the point \((x, 0)\) at price \(p(x)\), which can vary with \(x\).\(^4\) In this case, the net price that farmers receive (the farm gate price) is

\[
k(x, y) = p(x) - by.
\]

The equation \(k(x, y) = 0\) determines the boundary of cultivation. The government then transports the good to the port, at \(a^*\) per ton-mile, and exports the output from the port at the world price, \(p^*\). The government chooses the pattern of prices offered to cultivators at the road either (1) to maximize land rents (the indicator of private welfare in this economy) subject to a revenue constraint of \(R\) or (2) simply to maximize revenue.

Total government revenue, \(r(x, \cdot)\), along the line from \((x, 0)\) to the boundary of cultivation at \((x, p(x)/b)\) is then

\[
r(x, \cdot) = 2 \int_0^{p(x)/b} [p^* - p(x) - a^*x] \frac{p(x) - by}{w} dy, \tag{8a}
\]

while total revenue, \(R\), is

\[
R = \int_0^{p^*/a^*} r(x, \cdot) dx, \tag{8b}
\]

\(^4\) This policy has an analogue in the discriminatory pricing of a spatial monopolist (see Beckmann and Thisse 1986). The spatial monopoly literature gives scant attention to nonlinear demand functions and in any case is not concerned with the problem of maximizing social welfare subject to a constraint on the profits of the spatial monopolist, the analogy to the optimal tax problem that I discuss. Few of their results, therefore, carry over to the topics I discuss, except for the case of Walters technology (the analogy to linear demand) when revenue is maximized without regard to social welfare.
integrated up to \( \frac{p^*}{a^*} \) because it is never profitable to buy beyond \( x = \frac{p^*}{a^*} \). But before \( \frac{p^*}{a^*} \), \( r(x, \cdot) > 0 \) if \( (p^* - a^*x) > p(x) > 0 \). Land rents along the line from \( (x, 0) \) to \( (x, p(x)/b) \) are

\[
\pi(x, \cdot) = 2 \int_0^{p(x)/b} \frac{p(x) - by}{w} \, dy, \tag{9a}
\]

and total rents, \( \Pi \), are

\[
\Pi = \int_0^{p^*/a^*} \pi(x, \cdot) \, dx. \tag{9b}
\]

Equations (8) and (9) embody the assumption that all output produced along the line between \( (x, 0) \) and \( (x, p(x)/b) \) is sold at point \( x \) for price \( p(x) \) rather than elsewhere along the road, say at \( \hat{x} \) for price \( p(\hat{x}) \). For the present, I maintain this assumption, which may be justified in practice by governmental restrictions on the movement of goods on the road by anyone other than the marketing agency. At the end of this section, I discuss (1) whether the schedule of prices determined under this assumption would in fact lead to private incentives to move goods along the road, thereby undermining this price schedule if such movement is not prohibited; (2) whether the government would do better by allowing farmers to move along the road if they wish to; and (3) how to modify the price schedule derived under the assumption that movement by farmers is prohibited when this schedule provides incentives to movement that cannot, in actuality, be prohibited.

The maximization of \( \Pi \) subject to \( R = \bar{R} \) with respect to the pattern of prices, \( p(x) \), is an optimal control problem with an integral constraint. The solution is given by setting to zero the derivative of \( H(x) = \pi(x, \cdot) + \mu r(x, \cdot) \) with respect to \( p(x) \), with \( \mu \) a constant independent of \( x \) but dependent on \( \bar{R} \). After some algebraic rearrangement, it can be shown that

\[
\frac{1}{2} \frac{dr(x, \cdot)}{dp(x)} = \frac{p^* - p(x) - a^*x}{b} \Omega \left[ \frac{p(x)}{w} \right] - \int_0^{p(x)/b} \Omega \left[ \frac{p(x) - by}{w} \right] \, dy \tag{10a}
\]

and

\[
\frac{1}{2} \frac{d\pi(x, \cdot)}{dp(x)} = \int_0^{p(x)/b} \Omega \left[ \frac{p(x) - by}{w} \right] \, dy > 0. \tag{10b}
\]

The \( p(x) \) are chosen so that

\[
\frac{d\pi(x, \cdot)}{dp(x)} + \frac{\mu dr(x, \cdot)}{dp(x)} = 0 \tag{11}
\]

if private welfare (land rents) is maximized subject to a revenue constraint, and equation (10a) is set to zero if revenue is maximized. In the former case, (1) \( \bar{R} > 0 \) and equations (8a) and (8b) imply that \( p(x) < p^* - ax \) for some \( x \), and (2) consequently, equations (10a), (10b),
and (11) imply that \( p(x) \leq p^* - ax \) for all \( x \) and that \((\mu - 1)/\mu > 0\), with \( p(x) = p^* - a^*x = 0 \) for \( x = p^*/a^* \).

What is the shape of the optimal \( p(x) \) schedule as a function of \( x \)? One important characterization of this locus is its slope, given by differentiation of equation (11) and then substitution for \((p^* - p - a^*x)\) from equation (11) as

\[
\frac{dp}{dx} = \frac{a^*}{\left(1 - 2\mu \right)\mu} + \eta \left(\frac{\mu - 1}{\mu}\right) = \frac{a^*}{a^* - \psi(p)} \] (12a)

in which

\[
\psi(p) = \int_0^{p/b} \frac{\Omega(p - b y)}{w} dy = \frac{p^b}{a^*} \] (12b)

and

\[
\eta = \frac{\psi''}{\psi'^2} > 0. \] (12c)

Equation (12a) provides information about several economically relevant properties of the \( p(x) \) locus, namely, (1) backhauling, (2) forwardhauling, and (3) linearity.

**Backhauling.**—Any incentive to farmers to move output along the road calls into question the feasibility of such marketing schemes. By backhauling I mean that there is an incentive to move output from \( x_0 \) to \( x_1 > x_0 \) when such transport can be arranged at \( a^* \) per ton-mile. It involves the marketing agency’s having to move output back over the same part of the road that the output has just traversed. Other things equal, backhauling is obviously socially inefficient because the agency could pay \( p(x_1) \) at \( x_0 \) and the agency and farmers at \( x_0 \) would each gain \( a^*(x_1 - x_0) \) in transport costs. Backhauling also undermines the optimality of the \( p(x) \) since they were calculated on the assumption of no backhauling. If backhauling is to be privately profitable, \( dp/dx \) must be positive. (Although this condition is necessary, it is not sufficient.) The second-order conditions for the government’s constrained maximization problem ensure, however, that the denominator of equation (12a) must be negative. If the second-order condition holds, then \( dp/dx < 0 \), and therefore backhauling is ruled out.

**Forwardhauling.**—Forwardhauling occurs if farmers move output from \( x_j \) to \( x_i < x_j \), something that has been ruled out by assumption up to this point. For farmers to find it profitable to forwardhaul, the

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5 This last result is analogous to the zero taxation of the topmost income bracket in the optimal income tax literature (Mirrlees 1971) and to similar results in the literature on nonlinear pricing (Maskin and Riley 1984).
benefits from the increased price, \( p(x_i) - p(x_j) \), must exceed the additional transport costs, \( a^*(x_j - x_i) \). If the \( p(x) \) are smooth, then this condition is equivalent to \( dp(x)/dx < -a^* \) for some \( x \). That is, if the government does not want to induce forwardhauling, it must choose a schedule that obeys \( dp(x)/dx \geq -a^* \) everywhere. Forwardhauling raises two questions: (1) If the government were to permit forwardhauling, might the government not be able to improve its performance? (2) If the government does not prohibit forwardhauling, what are the consequences and what does it do?

To see if forwardhauling lets the government do better, consider an arbitrary price schedule \( \hat{p}(x) \). It raises some revenues, \( \hat{R} \), and results in some level of aggregate welfare, \( \hat{\Pi} \), and pattern of land rents, the \( \hat{\pi}(x, y) \). Assume that \( \hat{p}(x) \) does indeed involve some forwardhauling. Farmers who forwardhaul from \( x_j \) to \( x_i \) obtain a price net of transportation costs to them of \( \hat{p}(x_i) - a^*(x_j - x_i) \). In figure 2, \( \hat{p}(x) \) has one interval of forwardhauling, by farmers at any \( \hat{x} \) such that \( x_i < \hat{x} \leq x_j \). All these farmers between \( x_j \) and \( x_i \) forwardhaul to \( x_i \). They receive a net-of-transport price \( \hat{p}(x_i) - a^*(\hat{x} - x_i) \) given by the dashed line \( BC \) tangent to \( \hat{p}(x) \) at \( B \) with slope \(-a^*\). These prices exceed the prices from staying put, \( \hat{p}(\hat{x}) \), given by the solid curve connecting \( B \) and \( C \).

While \( \hat{p}(x) \) involves forwardhauling, there always exists another price schedule \( \hat{p}(x) \) that achieves the same values of the only outcomes that matter to the farmers and the government, the \( R, \Pi, \) and \( \pi(x, y) \), and that involves no forwardhauling. The second price schedule \( \hat{p}(x) \) is obtained by construction from the first as follows: For all points \( x_i \) and \( \hat{x} \) with \( x_i < \hat{x} \leq x_j \) from which there is forwardhauling to \( x_i \), replace \( \hat{p}(\hat{x}) \) by \( \hat{p}(\hat{x}) = \hat{p}(x_i) - a^*(\hat{x} - x_i) \). Otherwise, let \( \hat{p}(x) = \hat{p}(x) \). That is, \( \hat{p}(x) \) follows \( \hat{p}(x) \) between \( A \) and \( B \) and between \( C \) and \( D \) but follows the dashed line \( BC \) rather than the curve between \( B \) and \( C \). Farmers are now just indifferent between selling at \( x_i \) and selling at any \( \hat{x} \), and it can be assumed that they sell at each \( \hat{x} \) the amount produced there at price \( \hat{p}(\hat{x}) \).

The old \( \hat{p}(x) \) and the new \( \hat{p}(x) \) schedules are equivalent in all economically relevant respects. In particular, the boundary of cultivation under \( \hat{p}(x) \) is the same as that under \( \hat{p}(x) \) because the land with zero rent at any \( \hat{x} \) is located such that \( \hat{p}(x_i) - a^*(\hat{x} - x_i) - by = 0 \) in either case. The government is also indifferent. In particular, it raises the same amount of revenue from farmers whose land is along the vertical through any \( \hat{x} \) in figure 1, after paying a lower price for their output, \( \hat{p}(\hat{x}) \) rather than \( \hat{p}(x_i) \), but paying correspondingly more in transport costs. The values of all the economically relevant variables, the \( R, \Pi, \) and \( \pi(x, y) \), are therefore the same under the schedules \( \hat{p}(x) \) and \( \hat{p}(x) \). That is, the government can always choose a schedule without forwardhauling that does as well as any schedule that involves
forwardhauling, so that it loses nothing by prohibiting forwardhauling.

That farmers have the option to forwardhaul does, however, impose a constraint on the price schedules that the government can choose, namely that these schedules cannot have \( dp(x)/dx < -a^* \).\(^6\) Otherwise farmers will forwardhaul, which, as has just been proved, is equivalent in terms of \( R, \Pi \), and \( \pi(x, y) \) to some price schedule with \( dp(x)/dx \geq -a^* \).\(^7\) This in turn implies that giving the option of forwardhauling to farmers can never increase the choices available to the government; the government can always choose a price schedule that does not involve forwardhauling (the \( \hat{p}(x) \)) that is equivalent to one that does (the \( \tilde{p}(x) \)).

The strategy for calculating the optimal price schedule therefore involves three steps: (1) Use equation (11) to calculate the optimal \( \hat{p}(x) \), disregarding the constraint imposed by forwardhauling. (2) Check from equation (12a) that \( dp(x)/dx > -a^* \); if so, the forwardhauling constraint is not binding and the optimal \( p(x) \) are correctly

\(^6\) This constraint is analogous to the self-selection constraint of the literature on monopoly with incomplete information (e.g., Maskin and Riley 1984, eq. 8).

\(^7\) The border case occurs whenever the aggregate supply along the road at any point \( x, \psi(p) \), is locally exponential so that \( \eta = 1 \) and \( dp/dx = -a^* \). Smithies (1941) analyzes the demand analogue of this special case for the discriminating monopolist.
determined by equation (11). Because \((\mu - 1)/\mu > 0\), \(dp(x)/dx \geq -a^*\) is equivalent to \(\eta \leq 1\), a condition that is satisfied for many production functions including Cobb-Douglas. If \(dp(x)/dx < -a^*\) anywhere along the price schedule given by equation (11), then the prices given by equation (11) are not sustainable in the absence of a physical prohibition of forwardhauling. In this case, a third step is then necessary. (3) The price schedule must be rederived by maximizing \(\Pi\) subject to a constraint on \(R\) and the constraint \(dp(x)/dx \geq -a^*\).\(^8\) Note that when the government maximizes private welfare subject to a revenue constraint and \(dp(x)/dx \geq -a^*\) is binding, private welfare is lower than if forwardhauling could be prohibited. This outcome occurs because, by assumption, the marketing authority would have chosen a different price schedule if it could have prohibited forwardhauling, while the equivalence of the \(p(x)\) and \(\hat{p}(x)\) schedules means that there is nothing that forwardhauling helps the marketing authority to achieve.

**Linearity.**—If the \(p(x)\) were linear in \(x\), they could be implemented without all the cumbersome machinery of state marketing. Specifically, the government can obtain the same results with an appropriately chosen domestic price for exports from the port, \(p\), and domestic price for transport, \(a\), so that \(p(x) = p - ax\). But when will the \(p(x)\) calculated from equation (11) be linear?

In fact, only Cobb-Douglas technology \((F(L) = L^a)\) produces a linear pattern of prices, the \(p(x)\), that can be exactly replicated by an optimal \(p\) and \(a\) policy. This is easily seen from equation (12a): A linear price pattern requires a constant \(\eta\). If \(\Omega(0)\) is restricted to be zero, a constant \(\eta\) is consistent only with an \(\Omega(k/w)\) function of the form \((k/w)^\beta\), with \(\beta\) a constant.\(^9\) This, in turn, occurs if and only if the production function, \(F\), is Cobb-Douglas.

**V. Taxation of the Agricultural Hinterland**

The use of state marketing with a continuum of depots along the road may not be feasible, or it may be prohibitively expensive in terms of the cost of the depots, so far ignored. By contrast, taxes (or subsidies) on exports \((p^*-p)\) and transportation \((a-a^*)\) actually are implemented in many developing countries, although not necessarily at

\(^8\) Note that this constraint will, in general, result in new values for prices at every point \(x\), in contrast to the monopolist’s problem discussed by Maskin and Riley (1984, pp. 186–87), in which flat portions can be inserted into the unconstrained price schedule to satisfy the constraints. This difference results from the fact that the marketing authority is, in general, raising a fixed amount of revenue while maximizing private-sector welfare rather than maximizing revenue as the monopolist is.

\(^9\) See Pollak (1971) for the solution for \(\psi(p)\) of differential equations of the form \(\eta = \text{constant}; \Omega(0) = 0\) imposes the additional constraint \(\psi(0) = 0\).
optimal levels. If both these price interventions may be used, aggregate revenues are given by

$$R = 2 \int_0^{p/a} \int_0^{(p-ax)/b} \left[ p^* - p - (a^* - a)x \right] \Omega \left( \frac{k}{w} \right) \, dy \, dx,$$

(13)

while aggregate land rents, \( \Pi \), are given by

$$\Pi = 2 \int_0^{p/a} \int_0^{(p-ax)/b} \pi(x, y) \, dy \, dx$$

(14)

because the boundary of cultivation is given by \( k = p - ax - by = 0 \).

The government’s optimal tax policy is to set the derivative of \( \mathcal{L} \),

$$\mathcal{L} = \Pi + \mu(R - \bar{R}),$$

(15)

to zero, in which \( \mu \) is a Lagrange multiplier. Alternatively, the government may simply wish to obtain the most total revenue possible, \( R_{\text{max}} \), a degenerate case of the problem above with \( \bar{R} = R_{\text{max}} \), but one that has special interest. As is clear from the discussion of linearity in Section IV, if technology is Cobb-Douglas, these problems are identical to the problems of Section IV, while otherwise the imposition of a linear restriction on the \( p(x) \) is binding and results in a lower value of the objective function.

The elements necessary to the government’s (constrained) maximization program are given by

$$\frac{1}{2} \frac{\partial \Pi}{\partial a} = -\int_0^{p/a} \int_0^{(p-ax)/b} x \Omega \left( \frac{k}{w} \right) \, dy \, dx,$$

(16a)

$$\frac{1}{2} \frac{\partial \Pi}{\partial p} = \int_0^{p/a} \int_0^{(p-ax)/b} \Omega \left( \frac{k}{w} \right) \, dy \, dx,$$

(16b)

$$\frac{1}{2} \frac{\partial R}{\partial a} = -\frac{1}{2} \frac{\partial \Pi}{\partial a} - \int_0^{p/a} \frac{x}{b} \left[ p^* - p - (a^* - a)x \right] \Omega \left( \frac{p - ax}{w} \right) \, dx,$$

(17a)

and

$$\frac{1}{2} \frac{\partial R}{\partial p} = -\frac{1}{2} \frac{\partial \Pi}{\partial p} + \int_0^{p/a} \frac{1}{b} \left[ p^* - p - (a^* - a)x \right] \Omega \left( \frac{p - ax}{w} \right) \, dx.$$  

(17b)

Finally,

$$\frac{\partial \mathcal{L}}{\partial a} = \frac{\partial \Pi}{\partial a} + \mu \frac{\partial R}{\partial a} = 0,$$

(18a)

$$\frac{\partial \mathcal{L}}{\partial p} = \frac{\partial \Pi}{\partial p} + \mu \frac{\partial R}{\partial p} = 0.$$  

(18b)
These expressions have straightforward interpretations. For instance, equation (17a) shows that an increase in \( a \) has a direct positive impact on revenue by increasing the tax (or cutting the subsidy) per ton-mile and an indirect negative effect on revenue, via decreased total output, as long as positive revenue is earned on output, that is, if \( p^* - p - (a^* - a)x > 0 \).

When technology is Cobb-Douglas,\(^\text{10} \) equations (16)–(18) imply that the optimal values of \( a \) and \( p \) satisfy

\[
\frac{a}{a^*} = \frac{p}{p^*}. \tag{19a}
\]

Furthermore, if this result substitutes for \( a \) in equation (13), the value of \( p \) can be found from

\[
\bar{R} = \frac{(1 - \alpha)^2}{3 - 2\alpha} \left( \frac{w}{\alpha} \right)^{\alpha/(\alpha - 1)} \frac{p^{1/(1 - \alpha)}}{ba^*} (p^* - p)p^*, \tag{19b}
\]

so that if \( \bar{R} > 0 \), \( p < p^* \) and exports are taxed while fuel is subsidized because \( a < a^* \) from equation (19a). Given that \( b \) cannot be affected by government policy, the isoelastic property of the Cobb-Douglas function means that it is optimal to have an equiproportionate decrease of the prices along the road, as initially given by \( (p^* - a^*x) \). It is for this reason that (1) the \( p(x) \) are linear, (2) they are equivalent to an export tax and a transportation subsidy with \( a/a^* = p/p^* \), (3) the boundary of cultivation pivots through the point \( x = p^*/a^* = p/a \), and (4) forwardhauling is ruled out (by \( a < a^* \)). The value of aggregate rents corresponding to any value of \( \bar{R} \) (and \( p \)) is given by

\[
\Pi = \frac{\bar{R}[(1 - \alpha)p]}{(2 - \alpha)(p^* - p)}. \tag{20a}
\]

The maximization of revenue when both \( p \) and \( a \) are used and use of the expression for \( R^{\text{max}} \) in equation (19b) produce an alternative implicit equation for \( p \):

\[
\frac{\bar{R}}{R^{\text{max}}} = \frac{(p^* - p)(2 - \alpha)^{(2 - \alpha)/(1 - \alpha)}p^{1/(1 - \alpha)}p^*(\alpha - 2)/(1 - \alpha)}{1 - \alpha}. \tag{19b'}
\]

This is a useful form that relates \( p \) to the proportion of the maximum possible revenue that has to be raised. Note that equation (19b) can have more than one root, the Laffer-Dupuit curve in this model; it is then optimal to choose the highest \( p \) consistent with \( \bar{R} \) because aggregate rents increase with an increase in \( p \) (even given that it is accompanied by an increase in the value of \( a \) because eq. [19a] holds).

\(^{10} \) In the Cobb-Douglas case \( F(L) = L^\alpha \), \( \Omega(k/w) = (\alpha k/w)^{\alpha/(1 - \alpha)} \).
For $\alpha = 0$, the Walters case, equation (19b’) has the solution for its largest root of

$$
\frac{p}{p^*} = \frac{1}{2} \left( 1 + \sqrt{1 - \frac{R}{R_{\text{max}}}} \right). 
$$

(19b’)

The ratio of $p/p^*$ is a simple monotonic function of the ratio of the revenue that has to be raised, $R$, to the maximum revenue that could be raised, $R_{\text{max}}$. This formula is used below to obtain some benchmark figures.

What about the properties of the optimal combination of the instruments, $p$ and $a$, that is derived from equations (18a)–(18b) when the production function is of a general form? Clearly, the combination $p > p^*$ and $a < a^*$ cannot raise a positive level of revenue and is ruled out by $R > 0$. But more can be said because $R > 0$ implies that $p - ax$ cannot exceed $p^* - a^* x$ for every $x$ (i.e., the boundary of cultivation after revenue is raised must lie somewhere within the original boundary of cultivation). This in turn implies that if $p > p^*$, $p/a$ must be less than $p^*/a^*$ so that $a \gg a^*$.

The preceding statements are, however, all that can be made on a priori grounds. Possible policy combinations are (1) $p < p^*$, $a < a^*$, and $p/a \leq p^*/a^*$; (2) $p < p^*$, $a > a^*$, and $p/a < p^*/a^*$; and (3) $p > p^*$, $a \gg a^*$, and $p/a < p^*/a^*$. The reason is that when technology is not Cobb-Douglas, a combination of $p$ and $a$ can only approximate the optimal $p(x)$ locus of Section IV and may in general do so with $p$ and $a$ in several different relationships to $p^*$ and $a^*$, depending on the shape of $p(x)$. On the other hand, there is a strong appeal to the notion that the optimal policy package is an export tax combined with a transport subsidy. By itself, an export tax of a given amount at the port, $(p^* - p)$, translates into a higher and higher tax as a percentage of the farm gate price at the road, $t(x, 0) = (p^* - p)/(p^* - a^* x)$, as distance from the port increases. There seems to be no inherent reason to expect that it is optimal to increase the tax rate spatially in this way. To offset this pattern requires a transport subsidy. In the Cobb-Douglas case with its constant elasticity of supply, the intuition is exact and the optimal transport subsidy is such as to equalize the tax rate at the farm gate for the farms at the roadside.

While the optimal policy using $p$ and $a$ is in general only a two-parameter approximation to the first-best optimal $p(x)$ policy, even this class of policies may not be feasible. On the one hand, it is easy to

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11 These cases can all be produced by examining the effect of an increase in $R$ on $p$, $a$, and $p/a$ about the equilibrium in which $R = 0$ and therefore in which $p = p^*$, $a = a^*$, and $p/a = p^*/a^*$. To do so, simply totally differentiate eqq. (18a) and (18b) and eq. (13) with $R = \tilde{R}$ to obtain the signs of $dp/d\tilde{R}$, $da/d\tilde{R}$, and $d(p/a)/d\tilde{R}$ and thereby the cases 1–3.
imagine situations in which the government chooses not to affect \( a \). For instance, it may not be possible to confine fuel subsidies to transport of the export crop, so that subsidized fuel is diverted to other types of transport as well as perhaps to cooking or other purposes. In this case, the government chooses \( p \) by setting equation (18b) to zero and leaves \( a = a^* \). On the other hand, there may be instances in which the government can affect only \( a \), although they seem less likely in practice. In this case the government chooses \( a \) by setting equation (18a) to zero and leaves \( p = p^* \).

In the Cobb-Douglas case, if only \( a \) is used to raise revenue of \( \bar{R} \), \( a \) must satisfy

\[
\bar{R} = \left( \frac{w}{\alpha} \right)^{\alpha/(\alpha - 1)} \left( \frac{1 - \alpha}{2 - \alpha} \right)^{3} \frac{a - a^*}{a^* b} \frac{p^* (3 - 2\alpha)/(1 - \alpha)}{3 - 2\alpha},
\]

while the fact that

\[
\Pi = \frac{a\bar{R}}{a - a^*}
\]

under this policy provides a convenient formula for calculating \( \Pi \) as a function of \( \bar{R} \). Similarly, if only \( p \) is used to raise revenue of \( \bar{R} \) in the Cobb-Douglas case, \( p \) must satisfy

\[
\bar{R} = \left( \frac{w}{\alpha} \right)^{\alpha/(\alpha - 1)} \left( \frac{1 - \alpha}{2 - \alpha} \right)^{3} \frac{(p^* - p)}{p^* \alpha b} \frac{p^* (3 - 2\alpha)/(1 - \alpha)}{3 - 2\alpha},
\]

while the corresponding value of aggregate land rents is

\[
\Pi = \frac{\bar{R}[(1 - \alpha)p]}{(3 - 2\alpha)(p^* - p)}.
\]

To gain some idea of what values the different tax instruments take and their effects on \( R \) and \( \Pi \) when used in different combinations, table 1 presents comparisons among the solutions to the problem of maximizing revenues with \( a \) and \( p \), either alone or together for Cobb-Douglas technology. Note that \( b \) plays no role in the optimal values of either \( a \) or \( p \). This result is quite useful because information on \( b \) may be very difficult to obtain. The value of \( a^* \) is irrelevant to that of

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12 When revenue is maximized, this tax policy is analogous to mill pricing by a spatial monopolist (see Beckmann and Thisse 1986).

13 For purposes of comparison, a location-specific tax on land rents in the Cobb-Douglas case could raise a maximum amount of revenue given by \( \Delta \), the normalization factor in table 1. That is, all values for \( R \) and \( \Pi \) in table 1 are expressed relative to \( \Pi \) of eq. (14) evaluated at \( p^* \) and \( a^* \).

14 This result does not carry over to the maximization of \( \Pi \) subject to a revenue constraint, however; see eqq. (19b)–(19d). In these cases, the parameter \( b \) plays the role of a scaling factor.
p, as is \( p^* \) to the value of \( a \).\(^{15}\) As \( \alpha \) increases, \( p \) rises, as does \( a \) when it is used with \( p \); when farmers can also adjust on the intensive margin, revenue-maximizing price interventions must be moderated. When only \( a \) is used to maximize revenue, \( \alpha \) is irrelevant, it is only the extensive margin that matters,\(^{16}\) and \( a \) is set at the rather high value of \( 2a^* \). Finally, when \( a \) is used alone, \( \Pi \) exceeds \( R_{\text{max}} \) by a good amount (a factor of two), while for the other two problems, \( \Pi < R_{\text{max}} \).

Table 2 calculates relative values for two cases of \( \alpha \), \( \alpha = 0 \) and \( \alpha = 0.5 \). These results suggest that the solutions to the problems of revenue maximization using \( p \) with or without \( a \) are quite similar especially for \( \alpha = 0.5 \), and both differ quite markedly from the solutions to this problem when \( a \) is used alone. Another way of looking at these differences in instruments, however, is to ask how \( \Pi \) would differ when \( a \) is and is not used to raise the same \( \bar{R} \). To do so requires a return to the more general optimal tax problem of raising a given amount of revenue while maximizing private welfare. In particular, for \( \alpha = 0 \) and \( \bar{R} = 0.444 \) (the maximum revenue that can be raised using \( p \) alone), equation \( (19b''') \) can be used to calculate \( p \) and \( a \) when both are used to raise revenue, and thence \( \Pi \) from equation \( (20a) \). The answers are that \( p = 0.667p^* \) and \( \Pi = 0.445 \). It turns out, therefore, that revenue maximization with \( p \) and \( a \) is highly nonlinear because a relatively

\(^{15}\) Nor does this result carry over to the maximization of \( \Pi \) subject to a revenue constraint; see eqq. \((19b)\)-(\(19d)\).

\(^{16}\) Again, this result does not hold when \( \Pi \) is maximized subject to a revenue constraint; see eq. \((19c)\).
TABLE 2

Maximizing Revenue, $\alpha = 0, .5$

<table>
<thead>
<tr>
<th></th>
<th>$a$ Only</th>
<th>$p$ Only</th>
<th>$a$ and $p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha = 0$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{\text{max}}$</td>
<td>.250</td>
<td>.444</td>
<td>.500</td>
</tr>
<tr>
<td>$\Pi$</td>
<td>.500</td>
<td>.296</td>
<td>.250</td>
</tr>
<tr>
<td>$\alpha = .5$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{\text{max}}$</td>
<td>.250</td>
<td>.422</td>
<td>.444</td>
</tr>
<tr>
<td>$\Pi$</td>
<td>.500</td>
<td>.316</td>
<td>.296</td>
</tr>
</tbody>
</table>

Note.—See table 1.

small decrease in the revenue that is raised from 0.500 to 0.444 results in a very large increase in aggregate rents from 0.250 to 0.445. In other words, the shadow cost of raising additional revenue in terms of aggregate land rents forgone, $\mu$, is rising very steeply as a function of $R$. Correspondingly, the advantage to farmers of the government’s using both $p$ and $a$ to raise revenue of 0.444 in comparison to $p$ alone is considerable because aggregate rents are 0.445 rather than 0.296.

These models can also be extended to analyze the benefits from road improvements. The important lesson is that these benefits can be assessed only in conjunction with the tax system.\(^{17}\) The partial (beneficial) effect of a decrease in $a^*$ consequent on an improvement in road quality is

$$-\frac{\partial L}{\partial a^*} = -\mu \frac{\partial R}{\partial a^*} = 2\mu \int_0^{P/a} \int_0^{(P-aX)/b} x\Omega\left(\frac{k}{w}\right)dydx. \quad (17c)$$

If $a$ is optimally chosen by setting equation (18a) to zero, then this effect is the only one. On the other hand, if $a$ is neglected as an instrument so that $a = a^*$ and equation (18a) is not set to zero, then

$$-\frac{dL}{da^*} = -\frac{\partial L}{\partial a^*} - \frac{\partial L}{\partial a} \quad (18c)$$

measures the total benefit from a road improvement, with $\partial L/\partial a$ given by equation (18a).

VI. State Marketing: Discrete Depots

What if the marketing authority is restricted in the number of depots that it can set up so that it does not have full flexibility in implementing a continuum of prices, perhaps because there are fixed costs of

\(^{17}\) I neglect the (construction) costs of improvements in transport, $C(a^*)$, needed to lower $a^*$. These would be included in a modified revenue constraint: $R - C(a^*) = \bar{R}$. 

setting up a depot? First, if technology is Cobb-Douglas, such state marketing with discrete depots is strictly inferior to an exportation tax coupled with a fuel subsidy (which in turn is equivalent to the first-best continuum of depots, in this special case). As mentioned, fuel price interventions may, however, themselves be infeasible. The government may be left with \( p \) as its only choice among the tax instruments discussed in Section V. A policy of discrete depots may then be worth considering even in the Cobb-Douglas case. Second, with other technologies, a policy of discrete depots may be optimal even when both \( p \) and \( a \) are available as interventions because it may allow a closer approximation to the first-best \( p(x) \).

To point up some of the issues involved in a policy of discrete depots as simply as possible, I consider a marketing agency that buys either at the port at price \( p_0 \) or at a depot located on the road \( x_D \) miles from the port, where it pays a price \( p_1 \). Farmers transport their output either to the depot or to the port at $b per ton-mile off-road and $a* per ton-mile on the road. The government transports whatever output it buys at the depot to the port at $a* per ton-mile. Technology is Walters's, \( F = 1 \), and the goal of the government is to maximize revenue.

I first assume that the government can locate a wall at \( x_B \) from the port and that all output to the left of \( x_B \) must go to the port while all output to the right goes to the depot located at \( x_D \). This assumption is meant as an expository device and to provide a benchmark, although it is quite possible that the marketing agency actually can ban road transport from the port side of \( x_B \) to the depot and achieve this outcome.\(^{1130} \) Figure 3 illustrates the pattern of farm gate prices for farms located at the road at point \((x, 0)\) as a function of their position on the road for an arbitrary choice of \( p_0, p_1, x_B, \) and \( x_D \). Total revenue is given by

\[
R = \int_{0}^{x_B} \int_{0}^{(p_0 - a*x)/b} (p^* - p_0)dydx \\
+ \int_{x_B}^{x_D} \int_{0}^{(p_1 - a*(x_D - x))/b} (p^* - p_1 - a*x_D)dydx \\
+ \int_{x_D}^{(p_1/a*)} \int_{0}^{(p_1 + a*(x_D - x))/b} (p^* - p_1 - a*x_D)dydx.
\]

The government maximizes revenue with respect to \( p_0, p_1, x_B, \) and \( x_D \) to produce results given in table 3, column 2. As is intuitively clear,

\(^{1130} \) For instance, if the road crosses a river at or near \( x_B \), the marketing agency might be able to use such a natural obstacle to purchase only on the side of the river that is far from the port while preventing output from crossing the bridge from the port side.
the optimal value of $x_D$ is $x_B$; it never pays to push the (local) peak output occurring at $x_D$ beyond $x_B$, where it costs more to transport back to the port. Note that the pattern of farm gate prices to farmers located at the road is a sawtooth with local peaks at the port and at the depot, where the price $p_1 = 2p^* / 5$ considerably exceeds the price just immediately before the depot of $p_0 - a x_D = p^* / 5$. This latter characteristic of the solution is exactly the opposite of what would be produced by a toll station that imposed a tax at $x_D$. The intuition is the same as that given in Section V to suggest that an export tax and transport subsidy are an optimal combination. Finally, there is a significant increase in total revenues in comparison with purchase only at the port.

In the absence of a restriction such as the wall at $x_B$, farmers near $x_D$ but to the port side of the depot will find it more profitable to ship to the depot because at the depot $p_1 > p_0 - ax_D$. As shown in the second column of table 3, prices do reach a local peak at $x_D$ so that the depot is not redundant. In contrast to Section IV, in which prices are continuously varied along the road (a continuum of depots), discrete depots, therefore, do raise the possibility of backhauling. If $x_B$ (in fig. 3) is reinterpreted as the point at which farmers are indifferent between shipping to the port and shipping to the depot, then $p_0 - a x_B = p_1 - a(x_D - x_B)$ or

$$x_B = \frac{p_0 + a x_D - p_1}{2a},$$

an additional constraint on the maximization of $R$ as given by equation (21).

Differentiation of equation (21) with respect to $p_0$, $p_1$, and $x_D$ (with
TABLE 3

EFFECTS OF DEPOTS ON MAXIMUM REVENUE WITH WALTERS TECHNOLOGY, F = 1

<table>
<thead>
<tr>
<th>Purchase at Port Only</th>
<th>One Depot, No Backhauling</th>
<th>One Depot with Backhauling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p_0</strong></td>
<td>( \frac{2p^<em>}{3} = 0.667p^</em> )</td>
<td>( \frac{3p^<em>}{5} = 0.600p^</em> )</td>
</tr>
<tr>
<td><strong>p_1</strong></td>
<td>( \ldots )</td>
<td>( \frac{2p^<em>}{5} = 0.400p^</em> )</td>
</tr>
<tr>
<td><strong>x_B</strong></td>
<td>( \ldots )</td>
<td>( x_D )</td>
</tr>
<tr>
<td><strong>x_D</strong></td>
<td>( \ldots )</td>
<td>( \frac{2p^<em>}{5a^</em>} = 0.400p^* )</td>
</tr>
<tr>
<td>( R )</td>
<td>( \frac{2(p^*)^3}{27a^<em>b} = \frac{0.74(p^</em>)^3}{a^*b} )</td>
<td>( \frac{2(p^*)^3}{25a^<em>b} = \frac{0.80(p^</em>)^3}{a^*b} )</td>
</tr>
</tbody>
</table>

*Note.*—Values have not been normalized as in tables 1, 2, and 4.

\( x_B \) given by eq. [22]) and some algebraic simplification imply that the optimal values of \( p_0, p_1, \) and \( x_D \) must satisfy

\[
6p_1^2 + 6p_1p_0 - 2p_0p^* + p_0^2 + p^*2 - 6p_1p^* = 0, \quad (23a)
\]
\[
2p_0p_1 - 2p_0^2 + p^*2 + 2p_1p^* = 0, \quad (23b)
\]
\[
2p^* - p_0 - 3p_1 = a^*x_D. \quad (23c)
\]

Numerical solution of these equations (and the discarding of economically irrelevant sets of roots) produces the values given in the third column of table 3.

Revenues are reduced relative to the situation with the wall but are still significantly above those achieved with purchase only at the port; setting up a depot has benefits, even when backhauling cannot be stopped. The corresponding expression for revenue using both \( a \) and \( p \) (or, equivalently, given the assumed production technology, using an infinite number of depots all along the road) is \( p^*3/12a^*b \). In this case, one depot with backhauling closes almost half the gap in revenue between purchase only at the port and the first-best, that is, \( (0.0783 - 0.0741)/(0.0833 - 0.0741) = 0.457 \). As a general rule, the existence and extent of backhauling do not in themselves suggest that pricing and marketing intervention by the government is inappropriate. It depends on what the feasible tax and price instruments are, most especially whether an efficient level of fuel subsidies can be implemented in the Cobb-Douglas case, and, more generally, on the
cost of a continuum of depots when technology is not Cobb-Douglas and the degree to which the optimal $p(x)$ are well approximated by a $p$ and $a$ policy if feasible.

VII. Panterritorial Pricing

In contrast to the optimal state marketing schemes just discussed, many African governments pursue a policy of panterritorial pricing.\(^\text{19}\) They mandate that state marketing agencies pay the same price to all producers, regardless of their location (see Ndulu 1980; Arhin, Hesp, and van der Laan 1985). Application of this theory of panterritorial pricing to the unbounded agricultural area of equal fertility summarized in figure 1 would result in an absurd and unsustainable outcome. Agricultural production would spread limitlessly over the plain. The cost to the marketing agency of transporting all this output to the port would result in its sustaining unbounded losses, and the system would break down. Paying for output at a price $p > 0$ with the option to abandon it where purchased would have a similar effect.

In practice, the theory of panterritorial pricing might be saved by being limited within national borders or within certain agroclimatic zones outside of which certain crops just cannot be grown. In these cases, these (economically arbitrary) boundaries to the zone of cultivation might allow the marketing agency to pay the same (positive) price to all producers and at least break even. On the other hand, the marketing agency might still confront insupportable losses if it cannot choose an arbitrarily low price. In this situation the marketing agency may be unable or unwilling to get out and purchase from smallholders. It may not have the funding or choose to make the expenditures for trucks and fuel; it may not provide sacks to smallholders to headload their produce to buying depots; it may not purchase output in a timely fashion, so that farmers experience storage losses and interest costs; and it may not pay for produce for which it accepts delivery. All these things seem to be happening in African countries that pursue panterritorial pricing. I do not, however, know of information on the geographical incidence of these breakdowns. One possibility is that breakdowns occur most frequently in outlying areas, so that producers distant from the port receive a lower effective price (consequent on delays in purchase or payment), even if they receive the same price as elsewhere when they are able to sell something. In effect, the marketing agency uses nonprice methods to avoid the losses implied by buying from all producers at a common price, thereby simulating the

\(^{19}\) In the spatial monopoly literature, this is analogous to uniform pricing.
distance-based pattern of farm gate prices that would be generated by equation (5). In this case, the so-called failures of African marketing agencies may be movements toward the optimum.

All these aspects of panterritorial pricing leave scope for a wide range of implementation. One option available to marketing agencies desirous of avoiding the worst effects of panterritorial pricing is to buy from all producers who get output to the road up to a certain distance from the port, z, and to pay these producers the same price, \( p \), at the road. The marketing agency then chooses \( p \) and \( z \) optimally. To maintain the fiction of panterritorial pricing, other producers may be told that they can sell at \( p \), but the marketing agency just never gets out to buy from them. The situation is illustrated in figure 4. (For ease of calculation, it is assumed that producers beyond the point \( z \) do not transport anything to \( z \), which some would in fact find it profitable to do.) In this case aggregate revenues are given by

\[
R = \int_{0}^{z} \int_{0}^{p/\beta} (p^{*} - p - \alpha x) \Omega \left( \frac{p - by}{w} \right) dy dx \tag{24a}
\]

and aggregate rents by

\[
\Pi = \int_{0}^{z} \int_{0}^{p/\beta} w \Phi \left( \frac{p - by}{w} \right) dy dx. \tag{24b}
\]

For the Cobb-Douglas case, maximizing \( R \) produces values for \( p \) and \( z \) given in table 4. At \( \alpha = 0 \), this optimized panterritorial pricing scheme produces the same aggregate revenue as using only \( p \), an export tax at the port.\(^{20}\) For \( \alpha > 0 \), however, it always produces less revenue. For all \( 1 > \alpha \geq 0 \), this version of panterritorial pricing yields strictly less revenue than maximization with respect to \( p \) and \( a \) (as is obvious because it imposes a strictly suboptimal pattern on the \( p(x) \)). Panterritorial pricing also produces a lower \( \Pi \) than export taxation alone or than export taxation plus a fuel subsidy, and so it is inferior on both \( \Pi \) and \( R \) criteria. In the comparison between the \( p \) and \( a \) policy and panterritorial pricing, the ratio of the two \( \Pi \)’s equals that of the two \( R \)’s. (All these results follow from a comparison of the formulae of table 4 with those of table 2.)

\(^{20}\) With transport by farmers of some output from beyond \( z \) to \( z \), maximal revenues with panterritorial pricing would actually exceed those from an export tax (use of \( p \) alone) if \( \alpha = 0 \). To realize any of this gain in revenue, however, the government would have to reoptimize with respect to \( z \). The reason is that in the absence of transport from beyond \( z \) (the problem of table 4), the optimal \( z \) satisfies \( p^{*} - p - az = 0 \), and so the government just breaks even on output purchased at \( z \). With a mass of output arriving from beyond \( z \), it is optimal to change \( z \) and \( p \), so that positive revenue is made on all output brought to \( z \).
VIII. Conclusions

The adoption of an explicitly spatial model of the agricultural sector allows the ranking of a number of price interventions in terms of their effects on government's revenues and the welfare of producers. If agricultural technology is Cobb-Douglas, an export tax combined with a transport subsidy does better than many other tax and state marketing schemes and as well as the best-performing policy of official buying at a continuum of depots. For instance, a numerical example shows that an export tax combined with a transport subsidy can raise the same revenue with much lower deadweight loss than an export tax alone.

Various programs that use depots can have a role to play if a transport subsidy is ruled out or if technology is not Cobb-Douglas. Forwardhauling or backhauling may occur when the government uses depots but can also often be ruled out a priori, and in any case it need not preclude the optimality of these policies. A numerical example shows that the use of just two depots rather than one (i.e., an export tax alone) can have a significant impact on the revenue that can be raised.

In addition, such models provide clues about the feasibility of implementing these policies and the costs of administration. Finally,
these models point to the importance of an integrated analysis of tax/price policy and the benefits from transportation investments.

There are, however, a considerable number of other topics that are suggested by this framework that I leave as subjects for future research. One set of issues involves the organization of transport. In particular, equation (5) provides a tight link between the price at the port and the farm gate price via the costs of transport. The transport sector may not, however, price its services in this way, and so this link would then be cut. This outcome may arise if transport is not competitively organized, a fear of many African policymakers who favor state marketing.

Another area for further work is the gathering of empirical information on, and testing of, the models. Econometric work on producer behavior and the provision of transportation services is an obvious component to calculations that are more realistic than those provided in this paper. But not all information of value need be econometric; it is also important to know how state marketing agencies implement their mandate. How many depots have been set up, where, and which ones provide reliable marketing services, especially when panterritorial pricing is the ideal?

References


