Chapter 19

Optimal price intervention policies when production is risky*

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The authors have previously argued (Hazell and Scandizzo, 1975) that when agricultural production involves stochastic yields, then reasonable specification of the market structure leads to the result that optimally distorted prices are more efficient for social welfare than competitive market equilibrium prices. This paper provides a brief review of that finding, as well as providing a generalization to the multiproduct case within the framework of agricultural programming models. Results are also presented on the magnitudes of the optimal price distortions and associated welfare gains obtained from a linear programming model of agricultural production at a subsector level in Mexico.

1. OPTIMAL PRICE DISTORTIONS

Consider the following market structure for a single commodity.

$$S_t = \lambda \varepsilon_t P_t^* \qquad (1)$$

$$D_t = a - bP_t \qquad (2)$$

$$S_t = D_t \qquad (3)$$

*The opinions expressed in this chapter do not reflect those of the World Bank.

and

$$E(\varepsilon_t) = \mu, \; V(\varepsilon_t) = \sigma^2, \; \mathrm{Cov}(\varepsilon_t, P_t^*) = 0 \text{ for all } t,$$

where P_t^* is the price anticipated by producers at the time of making production decisions, ε_t is stochastic yield, and a, b, and λ are positive constants.

This model has the following key features.

(i) Anticipated price, P_t^* is the relevant forecast of P_t made by producers at the time of committing their inputs for period t. Typically, in agricultural production, there will be a lag between such decisions and the realization of production. As such, P_t^* incorporates anticipations about both actual yield ε_t and about total supply S_t. The assumption that $\mathrm{Cov}(\varepsilon_t, P_t^*) = 0$ rules out the possibility of perfect forecasts (in which case the model would collapse to a simultaneous specification) and implies that no knowledge is available about ε_t other than that the parameters μ and σ^2 are known.

(ii) The stochastic yield term ε_t is multiplicative. This specification is preferred to the more conventional additive[1] model for two reasons. First, because it is the input decisions which are assumed to be price responsive (see (i) above), so that the basic behavioral relationship on the supply side is anticipated supply $E(S \mid P_t^*) = \lambda\mu P_t^*$. Actual supply in period t is then $S_t = \lambda(\mu + r_t)P_t^*$ where r_t is the yield deviation from the mean in the tth period, that is, $\mu + r_t = \varepsilon_t$. Second, the multiplicative specification leads to an increasing rather than a constant variance of total output with increasing input use, that is,

$$V(S_t) = \lambda^2 P_t^{*2} \sigma^2 \;,$$

and this increases with anticipated price. However, the coefficient of variation is constant and equal to σ/μ.

If the yield term ε is bounded on some positive interval $\varepsilon_m \leqslant \varepsilon \leqslant \varepsilon_x$, then the market structure can be portrayed as in Figure 19.1. The anticipated supply function $E(S|P^*) = \lambda\mu P^*$ is linear, and passes through the origin. In the diagram, if producers anticipate $P_t^* = \rho_t$, then they will plan production for period t so that the expected market output is $S_t^* = \lambda\mu\rho_t$. However, because ε_t is stochastic, the actual supply function can rotate in a random way around $E(S|P^*)$ to any position contained in the funnel defined by $S|\varepsilon_m = \lambda\varepsilon P_m^*$ and $S|\varepsilon_x = \lambda\varepsilon_x P^*$. Hence, if expected supply in period t is S_t^*, actual supply could take on any value on the line AB. Clearly, actual market price is stochastic with ε_t, and the actual price in period t may take on any value between P_t^m and P_t^x.

[1] An additive specification subsumes all the yield stochasticity into an intercept term for supply. Such specification is common in the literature (Massell, 1969; Oi, 1961; Turnovsky, 1974; Waugh, 1974).

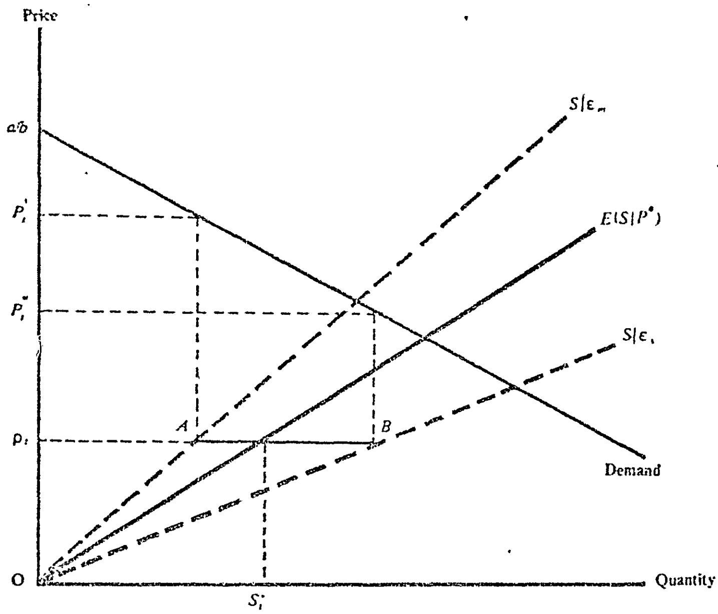

Figure 19.1. A market with multiplicative risk

From equation (3), the market must clear, hence the market clearing price each period is

$$P_t = \frac{a}{b} - \frac{\lambda}{b}\, \varepsilon_t\, P_t^* . \tag{4}$$

Since ε_t is stochastic, then P_t must also be stochastic, so that we shall consider an equilibrium price, if it exists, to be the convergent mean price $\lim_{t\to\infty} E(P_t)$. It is not hard to show that convergence occurs if $\lim E(P_t^*) = \lim E(P_t)$, that is, if farmers on the average settle on the self-fulfilling expectation price (Muth, 1961) as their anticipated price. Under this condition,[2] the market equilibrium price is

$$\lim E\,(P_t) = \frac{a}{b + \lambda\mu} \cdot \tag{5}$$

[2]Sufficient and/or necessary conditions can be derived under specific assumptions about P_t^* (Bergendorff, Hazell and Scandizzo, 1974).

Optimal price distortions arise because this equilibrium price does not maximize the social welfare function defined as the sum of the expected values of the producers' and consumers' surplus.

The consumers' surplus in period t is simply the value of the area under the demand curve and above actual market price P_t. Algebraically,

$$W_t = \int_{P_t}^{a/b} (a - bP)\, dP.$$

Solving, taking the expected value and simplifying,

$$E(W) = \frac{\lambda^2 \mu_2}{2b} \quad [V(P^*) + E(P^*)^2] \tag{6}$$

where μ_2 denotes the second moment of ε around zero, and $V(P^*)$ is the variance of anticipated price.

Producers' surplus in period t is a little more tricky, since production costs depend on anticipated price P_t^* and not on actual price P_t. The surplus, which is really an *ex post* concept in this case, is calculated as

$$\Pi_t = P_t S_t - \int_0^{S_t^*} S/\lambda\mu \, dS$$

where $S_t^* = \lambda\mu P_t^*$ is anticipated supply in period t. Π_t is total realized revenue ($P_t S_t$) less production costs as measured by the area under the anticipated supply function from 0 to S_t^*. In Figure 19.2, where it is again assumed that $P_t^* = \rho_t$ and that actual supply is S_t rather than S_t^*, the surplus is simply the area $OP_tCS_t - OBS_t^*$.

Solving, taking the expected value and simplifying, the expected producers' surplus is,

$$E(\Pi) = \frac{a}{b} \lambda\mu E(P^*) - (\frac{\lambda^2}{b}\mu_2 + \frac{1}{2}\lambda\mu)\, V(P^*) - (\frac{\lambda^2}{b}\mu_2 + \frac{1}{2}\lambda\mu)\, E(P^*)^2. \tag{7}$$

Adding (6) and (7) together, the chosen social measure $E(SW)$ is then expressed as

$$E(SW) = \frac{a}{b} \lambda\mu E(P^*) - \frac{1}{2}(\frac{\lambda^2}{b}\mu_2 + \lambda\mu)\, V(P^*) - \frac{1}{2}(\frac{\lambda^2}{b}\mu_2 + \lambda\mu)\, E(P^*)^2. \tag{8}$$

This function has its maximum when

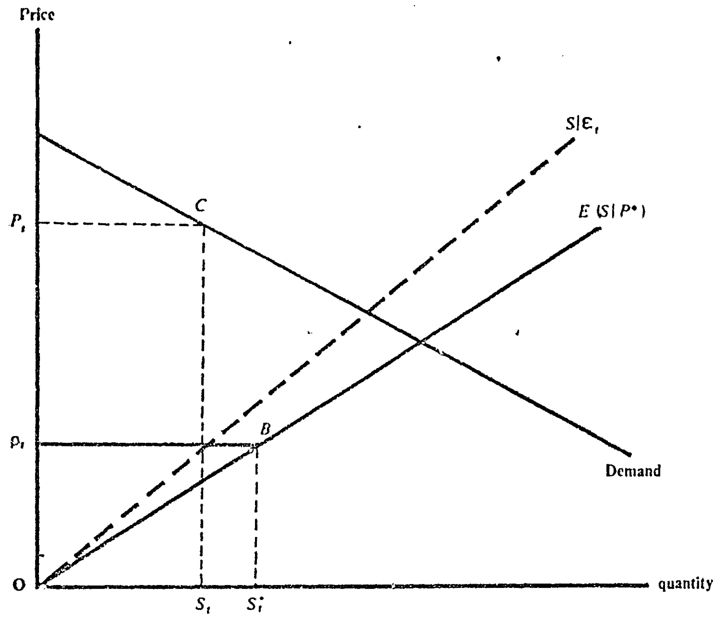

Figure 19.2. Producer's surplus with a negative disturbance term.

$$E(P^*) = \frac{a\mu}{b\mu + \lambda\mu_2} \tag{9}$$

and $V(P^*) = 0$. That is, when farmers anticipate the price $P^* = a\mu/(b\mu + \lambda\mu_2)$ in each and every period.

Assuming (9) is satisfied, then substituting this result into the expected value of (4), expected market clearing price becomes

$$E(P_t) = \frac{a(b\mu + \lambda\sigma^2)}{b(b\mu + \lambda\mu^2)} \tag{10}$$

This price is not the market equilibrium price in (5), but rather, it is an optimally distorted price for the market. It can be shown that (10) is greater than (5) while (9) is smaller than (5), so that the optimal distortion is effected when farmers produce less than an equilibrium quantity on average — corresponding to the lower anticipated price obtained in (9) — and hence realize the higher average market price obtained in (10).

The percentage market price distortion T[3] can be expressed as

$$T = \frac{R^2\,100\%}{|\xi_d|(|\xi_d| + R^2 + 1)}$$

[3] $T = [E(P_t)/\lim E(P_t) - 1]\,100\%$ where $E(P_t)$ is obtained from (10) and $\lim E(P_t)$ from (5).

where $|\xi_d|$ is the absolute value of the elasticity of demand measured at market equilibrium, and R is the coefficient of variation for ε. Clearly, T will never be negative, so that optimal distortions always imply price increases. Further, for fixed R, the distortion is seen to be larger the more inelastic the demand, but it disappears at the limit as the demand elasticity is increased towards infinity. The distortion also increases with R, so that the more risky the production, the greater the optimal market price distortion. In a deterministic market, $R = 0$ and the optimal distortion is 0.

The existence of an optimal distortion price requires some explanation. Basically, it can be attributed to two factors in the model specification. First, because production costs are dependent on anticipated price P_t^* and not on actual market price P_t. This means that there is no fixed relationship between revenue and costs, and that for some P_t^*, the yield ε_t outcome may, in conjunction with the inelasticity of demand, conspire to cause revenue to fall below costs to the extent that there is a net welfare loss to society. In itself, this cost is not sufficient to distort the market.[4] However, because of a second feature of the model, the multiplicative risk term, the variance of market supply S_t increases quadratically as producers move up the expected supply function, so that the possibility of costs exceeding revenue also increases. Clearly, the distortion in the market arises from the tradeoff between the surpluses from higher outputs and the net welfare loss associated with wasted resources.

The authors have explored the magnitudes of the optimal price distortions and associated welfare gains for different values of ξ_d and R within the confines of this simple market model (Hazell and Scandizzo, 1975). It was found that not only can the optimal price distortion be quite large when demand is inelastic (more than 10% with moderate production risks), but important welfare gains (about 2% for $R = 0.5$) may be had from using market intervention policies to introduce the desired distortion.

These results might appear to suffer from the rather stringent simplifying assumptions of the model. However, as shown below, the existence of an optimal distortion generalizes to much more complex market structures, though in these cases it is much more difficult to say anything about the size of the welfare gains without resorting to empirical situations.

2. GENERALIZATION TO AGRICULTURAL PROGRAMMING MODELS

An increasing number of formal agricultural sector models are now being built using mathematical programming techniques. Many of these models are

[4] In an additive risk model, for example, with the same kind of lagged specification, a price distortion does not arise (see Turnovsky, 1974).

also structured to provide the perfect competition solution to all product markets when both prices and quantities are endogenous. In the deterministic case, and with suitable restrictions on demand, this is easily achieved by maximizing an objective function defined as the sum of consumers' and producers' surplus in all markets (Duloy and Norton, 1975; Samuelson, 1952; Takayama and Judge, 1964, 1971). For example, in a simple model of annual crop production based on a single aggregate farm facing the demand structure $P = A - BWX$,[5] the appropriate model maximand can be written as

$$\text{Max } \Pi = X'W(A - 0.5BWX) - C'X \tag{11}$$

where

X = an $n \times 1$ vector of crop acreages grown
W = an $n \times n$ diagonal matrix of crop yields per acre
C = an $n \times 1$ vector of costs per acre

and A and B are $n \times 1$ and $n \times n$ matrices of demand coefficients, respectively.

The term $X'W(A - 0.5BWX)$ is simply the sum of areas under the demand schedules, while $C'X$ is total production costs, or equivalently, the sum of areas under the supply functions. The difference between these two is, therefore, the sum of the consumers' and producers' surplus.

The maximand assumes farmers are profit maximizers, and provides equilibrium prices and output levels such that market prices equal marginal costs. Typically, (11) is maximized subject to a set of linear programming constraints of the form

$$DX \leqslant b. \tag{12}$$

The authors have generalized this model to the risk case in which yields are stochastic and farmers are risk averse (Hazell and Scandizzo, 1974). In particular, if farmers maximize the utility function $U = M - \phi S$ where ϕ is a risk aversion parameter and M and S denote, respectively, the expected value and standard deviation of income, then under quite reasonable assumptions, the expected values of prices and quantities in a competitive equilibrium can be approximated by using the maximand

$$\text{Max } U = X'W(A - 0.5BWX) - C'X - \Phi(X'\Gamma X)^{1/2}. \tag{13}$$

Here, W denotes the diagonal matrix of expected yields, Γ is an $n \times n$ covariance matrix of crop revenues (price times quantity), and Φ is a suitable average of individual farm risk parameters.

[5]The procedure requires that the demand matrix B be symmetric (Takayama and Judge, 1971; Zusman, 1969).

This maximand is identical to (11) except that a new production cost, $\Phi(X'\Gamma X)^{1/2}$, has been added. This is simply the compensation demanded by farmers for taking risks, and which is to be added to the area under the supply functions. The maximand can, therefore, still be considered as a sum of producers' and consumers' surplus over all product markets. In fact, it is the sum of surpluses as measured above the anticipated supply functions (Hazell and Scandizzo, 1974).

That (13) provides an equilibrium solution can be shown from the necessary Kuhn-Tucker conditions of the Lagrangian function

$$L = X'W(A - 0.5BWX) - C'X - \Phi(X'\Gamma X)^{1/2} + \nu'(b - DX)$$

where ν is a vector of dual values. These necessary conditions evaluate at

$$W(A - BWX) \leqslant C + \Phi\Gamma X(X'\Gamma X)^{-1/2} + D'\nu. \qquad (14)$$

Since $E(P) = A - BWX$, the condition requires that for each crop, expected marginal revenue per acre, $WE(P)$, be equal or less than the expected marginal cost. Expected marginal cost comprises own marginal cost C, plus the marginal risk cost $\Phi\Gamma X(X'\Gamma X)^{-1/2}$ plus marginal opportunity costs as reflected in the dual values of the resources used by that crop $D'\nu$. For those crops which are nonzero $(X_i > 0)$, then by the complementary slackness conditions, (14) holds as an equality, in which case the expected values of marginal revenues and cost are equated.

Despite the specificity of this model, it does provide a good forum for generalizing the optimal distortion results, as well as providing a framework for empirical experimentation.

Theoretically, the model is appealing because it assumes the multiplicative yield structure: – output = yield multiplied by area planted, where area planted (the X variables) are price responsive. Further, since the supply structure is embedded in the model through a set of choice variables and resource constraints, the model incorporates nonlinearities, as well as such multiproduct considerations as covariances between crop revenues (the off-diagonal elements of Γ) and substitution in demand (the off-diagonal elements of B).

Before considering these generalizations, it is worth noting, that in as much as (13) can be interpreted as a welfare function,[6] it is an *ex ante* welfare measure. The producers' surplus, in particular, is simply the excess of expected utility as measured by the function $U = M - \phi S$. This type of welfare function has frequently been used to analyze intervention policies in risky markets

[6] A welfare interpretation of (13) is not necessary for obtaining a competitive equilibrium solution. Rather (13) can be viewed simply as a computational device or trick.

(Massell, 1969; Oi, 1961; Turnovsky, 1974; Waugh, 1974), but it is not the relevant welfare measure when production is lagged and yield risks are multiplicative. For this situation, we must return to the welfare measure used in (8). That is, to the sum of expected values of realized (*ex post*) consumers' and producers' surplus.

The appropriate welfare function can equivalently be expressed as the sum of expected values under the demand curves, minus the sum of areas under the anticipated supply functions. In the context of the sector model notation, this becomes

$$\begin{aligned} E(SW) &= E[X'N(A-0.5BNX)] - C'X - \Phi(X'\Gamma X)^{1/2} \\ &= X'WA - 0.5X'E(NBN)X - C'X - \Phi(X'\Gamma X)^{1/2} \end{aligned} \tag{15}$$

where N denotes the diagonal matrix of stochastic yields such that $E(N) = W$.

This welfare function leads to a set of optimally distorted prices. To prove this, consider the Langragian function

$$L = E(SW) + \nu'(b - DX).$$

Apart from the feasibility conditions in (12), the necessary Kuhn-Tucker conditions are

$$\frac{\partial L}{\partial X} = WA - E(NBN)X - C - \Phi\Gamma X(X'\Gamma X)^{-1/2} - D'\nu \leqslant 0 . \tag{16}$$

Now, $E(NBN)X = V(NBN)X + WBWX$ where V is the variance-covariance operator. Substituting this into (16), and rearranging terms,

$$W(A - BWX) \leqslant C + \Phi\Gamma X(X'\Gamma X)^{-1/2} + D'\nu + V(NBN)X.$$

Using the demand equations $E(P) = A - BWX$, we finally obtain

$$WE(P) \leqslant C + \Phi\Gamma X(X'\Gamma X)^{-1/2} + D'\nu + V(NBN)X. \tag{17}$$

This relationship between marginal revenue and cost is very similar to that obtained in (14) for the market equilibrium case. However, a new cost $V(NBN)X$ appears on the marginal cost side, which gives rise to optimal price distortions. Using complementary slackness conditions, it can also be shown than (17) holds as an equality for all crops entering the solution at nonzero levels.

The cost $V(NBN)X$ is highly interesting because it is a social rather than a private cost. The ith element of this cost vector can be written as

$$\sum_i \operatorname{cov}(\varepsilon_i \varepsilon_j)\, b_{ij}\, x_j .$$

Thus, the price of the ith crop is distorted from its equilibrium price by a term which depends on the variance of the yield of that crop and its covariances with the yields of all other crops. The variance-covariance effects are, of course, measured in physical units, but are converted into money costs through the demand coefficients b_{ij}. Since the signs of the covariances and the b_{ij} coefficients may be positive or negative, the distortion effects are indeterminate in sign. It is likely that some prices should be increased above equilibrium prices, but that others should be reduced. However, the size of these distortions and the associated welfare gains, is a purely empirical question, and to this we now turn using a specific agricultural model of Mexico.

3. ILLUSTRATIVE APPLICATION IN MEXICO

3.1. The Model

An agricultural sector model, CHAC,[7] already exists in Mexico and provided a suitable basis for this study. CHAC is a linear programming model which encompasses the supply — domestic and imported — and all demands — domestic and export — for 33 short cycle crops. It does not include livestock, forestry or long cycle crops. The model is an aggregate of regional submodels, which are linked through a national market structure (domestic and foreign) and by some common resource constraints. CHAC is a static equilibrium model and provides the perfect competition solution to all markets for both prices and quantities through use of the kind of maximand detailed in equation (11).

To keep this study within manageable limits, a smaller version of CHAC was used which included only selected areas of irrigated land. These selected areas represent eight of the more than 100 administrative districts of the Mexican Ministry of Water Resources. They are not contiguous districts, but are scattered throughout the arid agricultural areas of Mexico. The districts and their locations are as follows:

Area	District
Pacific Northwest	Culiacán, Comisión del Fuerte, Guasave, Rio Mayo, Santo Domingo
North Central	Ciudad Delicias, La Laguna
Northeast	Bajo Rió San Juan

[7]CHAC, which names after the Mayan rain god, was constructed by the World Bank in collaboration with the Secretaria de la Presidencia in Mexico. A complete description of the model can be found in Duloy and Norton (1973) and Bassoco and Rendón (1973).

Table 19.1

Average district cropping patterns, 1967/68 to 1969/70
(Harvested hectares*)

Crops	*El Fuerte*	*Culiacan*	*Rio Mayo*	*Guasave*	*Delicias*	*San Juan*	*St. Domingo*	*Laguna*	*Aggregate*	*% of National Production*
Dry alfalfa	1,988	—	2,144	—	6,510	—	285	5,498	16,425	34
Cotton	46,364	—	15,535	—	7,903	1,190	17,585	67,964	156,541	25
Green alfalfa	—	543	—	—	—	—	—	5,224	5,767	2
Rice	11,335	23,568	—	3,480	—	—	—	—	38,383	25
Sugar cane	12,706	24,172	—	—	—	—	—	—	36,878	12
Safflower	4,790	13,374	10,435	3,737	—	—	1,098	—	33,434	29
Barley			112	—	—	—	—	—	112	1
Chillies	386	1,570	—	48	—	—	—	—	2,004	9
Beans	16,224	11,024	—	202	—	—	—	—	27,450	3
Chickpeas	561	938	—	271	—	—	—	—	1,770	1
Tomatoes	3,049	9,563	—	381	—	—	—	—	13,193	37
Sesame	3,010	2,815	8,390	144	—	—	—	—	14,250	—
Maize	10,792	4,302	4,071	2,420	10,053	54,269	1,038	6,213	93,158	2
Cantaloupe	231	397	—	722	—	—	—	—	1,340	4
Potatoes	1,320	—	—	—	—	—	—	—	1,320	5
Cucumbers	—	—	—	8	—	—	—	—	8	0
Watermelons	757	325	—	41	—	74	—	—	1,197	5
Sorghum	24,238	22,795	10,616	1,238	7,719	19,876	—	5,592	92,074	11
Soybeans	16,264	4,392	11,886	—	—	—	—	—	32,543	20
Wheat	23,561	3,057	29,969	5,742	29,668	1,048	11,738	16,150	120,933	16
TOTAL	177,576	122,825	93,158	18,634	61,853	76,457	31,744	106,641	688,888	
Number of farms	16,484	6,224	9,185	2,984	10,710	4,480	647	48,341	99,055	
Available hectarage per farm	10	12	8	6	4	16	47	2	5.8	

*Seeded hectares include significant amounts of double cropping in most districts.

Taken together, the 8 districts account for significant shares of the national production of cotton, tomatoes, dry alfalfa, rice, soybeans and safflower (Table 19.1). They also produce a wide range of cereal crops and vegetables, together with some sugar cane. Some double cropping is practiced in all the districts, but particularly in the vegetable growing areas. The average district cropping patterns for the years 1967/68 to 1969/70 are given in Table 19.1, but excluding a small percentage of land devoted to crops which are not included in the models. Crop production is almost entirely dependent on irrigation in all 8 districts, and small areas of rainfed land have been excluded.

In total, the 8 district models cover 99,000 farms of an average size of 5.8 hectares — a district breakdown is included in Table 19.1. For modeling purposes, each district is treated as a single large farm. The farms are thought to be sufficiently homogenous, that this procedure is unlikely to lead to any serious aggregation bias problems. The model activities provide for the production, in each district, of the crops grown by that district in Table 19.1, each with a choice of 3 mechanization levels and 2 planting dates. A set of labor activities provide flexibility in selecting seasonal combinations of family and hired day labor. Family labor is charged a reservation wage of one-half of the hired day labor rate. Purchasing activities provide for the supplies of mules, machinery and irrigation water. Seasonal constraints are imposed on land and labor, and an annual constraint is imposed on water supplies. Technical coefficients and costs are taken at average levels from 1967/68 to 1969/70. The model constraints are also based on this period. Average yields are based on the 6-year period from 1966/67 to 1971/72, and risk parameters were estimated from time series data spanning the period 1961/62 to 1970/71.

The district models are linked in block diagonal form and integrated into an aggregate market structure, similar to that in CHAC. That is, the market comprises linear domestic demand functions of the form $P = A - BWX$, and has import and export possibilities at fixed prices. To approximate cross-elasticity relationships in demand, the crops are classified into demand independent groups, and linear substitution is allowed between products within each group as rates fixed by base year relative prices.[8] The definition and characteristics of these demand groups are summarized in Table 19.2. The demand curves for each group have the same price elasticities as in CHAC, but are located at mean output levels appropriate for the 8 district aggregates. Export and import constraints are also pro-rated according to the ratio of output from the 8 districts to national output for each product.

The resultant model was solved for equilibrium values of expected prices and quantities using the type of maximand detailed in equation (13). That is, assuming farmers maximize $M - \phi S$ utility. The model was also solved for optimal price distortions using the welfare function defined in equation (15) as

[8] For a more detailed description, see Duloy and Norton (1973, 1975).

Table 19.2

Characteristics of demand groups

Demand group	Commodity	Base period price: Commodity	Base period price: Group index[a]	Own price elasticity
		(Pesos/ton)		
1	Sugar cane	70	70	–0.25
2	Tomatoes	1150	1150	–0.4
3	Chillies	1500	1500	-0.2
4	Cotton fiber	5770	5770	–0.5
5	Dry alfalfa	400	446	–0.3
	Green alfalfa	100		
	Barley	930		
	Chickpeas	990		
	Maize	860		
	Sorghum	630		
6	Rice	1220	1285	–0.3
	Beans	1830		
	Chickpeas	990		
	Potatoes	930		
7	Maize	860	817	–0.1
	Wheat	800		
8	Cantaloupe	680	741	–2.0
	Watermelons	780		
9	Safflower	1550	1164	– 1.2
	Sesame	2410		
	Cotton oil	830		
	Soybeans	1600		
10	Cucumbers	590	590	–0.6

[a] Group price indices are computed using base year quantity weights (Duloy and Norton, 1973, 1975).

the model maximand. In both cases, the aggregate risk aversion parameter Φ was varied in order to evaluate the effects of different levels of risk averse behavior on the model solutions. Solutions for $\Phi=0$ correspond, of course, to the risk neutral case in which farmers simply maximize expected profits.

3.2. The Results

In Table 19.3, the values of social welfare, as measured by equation (15), are reported for both the equilibrium and optimally distorted solutions for different values of Φ.

These welfare gains are much larger than suggested by the earlier theoretical analysis for the single product case. For $\Phi=0$, for example, optimal market distortion policies could increase social welfare by as much as 6.4 per cent or an equivalent of 270 million pesos. Since it can be shown that the welfare gain accrues entirely to producers (Hazell and Scandizzo, 1975), this would be equivalent to an average gain of 2,727 pesos per farm.

The welfare gain obtainable from optimal distortion policies diminishes as Φ increases. This suggests that private risk costs are positively correlated with the social risk term responsible for the distortions, the former tending to substitute for the latter as Φ increases. Indeed, when $\Phi=2.0$, the gains from optimal distortion policies are quite trivial at 20 million pesos. Private risk aversion might therefore be considered desirable because it tends to restore competitive market efficiency.

The optimal price distortions are summarized in Table 19.4 for different values of Φ. Since the relative prices of commodities within demand groups are fixed at base year values, only the group price indices are reported. Table 19.4 reports the value of these price indices at market equilibrium for each value of Φ, as well as the percentage distortion required to maximize social welfare.

As expected, most of the distortions involve price increases and, hence, reductions in domestic market supplies. A few negative price distortions do occur, particularly for larger values of Φ, and which have their origin in negative yield covariances both between crops and between irrigation districts.

Many of the price distortions are quite large despite opportunities for world trade at fixed prices. In fact, only the price of cotton fiber (group 4) is consistently pegged at its export value. The price distortions are largest for low volume specialist crops — chillies (group 3), cantaloupes and watermelons (group 5) and cucumbers (group 10) — and smallest for the important food and wage good crops — wheat and maize (group 7). The magnitude of the distortions tends to diminish as Φ increases, but they do not disappear when $\Phi = 2.0$, even though the welfare gain becomes very small.

The international trade results are summarized in Table 19.5. The optimally distorted solutions call for greater levels of exports and imports, and a larger trade surplus, for all values of Φ. This result arises in part because export and import prices are fixed and nonrisky in the model. More realistic

Table 19.3
Welfare gains with various Φ values

Item	Values of Φ				
	0.0	0.5	1.0	1.5	2.0
Social welfare					
Equilibrium model (billions of pesos)	4.21	4.04	3.97	3.83	3.83
Distorted model (billions of pesos)	4.48	4.27	4.10	3.96	3.85
Gain from distortion (%)	6.4	5.7	3.3	3.3	0.5
Gain to average farm (pesos)	2727.0	2323.0	1313.0	1313.0	202.0

Table 19.4
Optimal distortions in domestic prices for various Φ values

Demand group[a]	Φ = 0.0		Φ = 0.5		Φ = 1.0		Φ = 1.5		Φ = 2.0	
	P[b]	T[c]	P	T	P	T	P	T	P	T
1	68	10.3	68	7.3	70	5.7	68	7.3	69	7.2
2	330	29.7	705	7.2	1071	7.3	1319	5.2	1636	5.7
3	700	318.1	741	302.2	748	310.6	828	290.5	965	250.3
4	5770	0.0	5770	0.0	5770	0.0	5770	0.0	5770	0.0
5	410	18.5	415	6.3	432	–1.0	445	–3.8	456	–2.2
6	1279	28.4	1200	36.9	1158	36.5	1167	29.4	1194	28.9
7	991	–1.6	931	0.0	938	0.2	983	–3.7	1006	–3.5
8	309	101.9	368	62.2	434	13.8	547	4.6	533	6.8
9	1052	7.8	1037	7.6	1089	4.1	1263	–1.9	1368	–2.2
10	569	1.8	681	3.1	838	–65.3	790	–86.4	317	–98.1

[a]The demand groups are in Table 19.2.
[b]P denotes the equilibrium price index for a commodity group in pesos/ton.
[c]T denotes the optimal market price distortion for a group from its equilibrium value P expressed in per cent.

Table 19.5

International trade results
(million of pesos)

Item	Values of Φ				
	0.0	0.5	1.0	1.5	2.0
Equilibrium model					
Value exports	196.96	143.05	133.93	59.54	17.70
Value imports	0.07	0.07	0.07	0.07	6.45
Trade surplus	196.89	142.98	133.86	59.47	11.25
Optimally distorted model					
Value exports	213.66	213.67	201.36	84.57	84.57
Value imports	8.46	2.79	0.64	7.94	8.58
Trade surplus	205.20	210.88	200.72	76.63	75.49

assumptions might have reduced the levels of trade in the optimally distorted solutions, but only if world prices are at least as risky as domestic prices.

4. CONCLUSIONS

In this chapter, we have attempted to demonstrate, within the bounds of an agricultural subsector model, that competitive market equilibria may be far from efficient in terms of social welfare when production is risky. The potential welfare gains to be had from optimal intervention policies are surprisingly large, in fact, far greater than might be anticipated from simple algebraic models. We have not considered the distributional aspects of the welfare gain in this chapter, suffice to say that the main benefits lie with the farmers, while consumers tend to lose. Implementation of an optimal distortion scheme might need to be supplemented with some kind of taxation scheme to obtain appropriate redistribution of the gains.

The results in this chapter do, of course, hinge on the welfare measured used. The measure of producers' surplus presents few problems (it is simply average realized profits), but the expected consumers' surplus is more objectionable. Basically, it ignores the income effects incurred by consumers from increasing food prices, and which, in a country like Mexico, must be expected to be quite large, especially for the magnitude of price changes envisaged here. We are encouraged, however, by the fact that the price of the basic wage goods — maize and wheat — are hardly changed in the optimally distorted results. Consequently, the major price effects would impinge upon the incomes of the more prosperous nonagricultural households, effecting an interesting transfer of income to the rural areas.

So far, we have avoided the question of how optimal market distortions could be implemented. An obvious and simple procedure in autocratic societies would be to introduce production quotas at the regional level. However, more sophisticated intervention policies can be devised for free market situations through the design of optimal buffer stock and price stabilization schemes. This, however, is a topic which cannot be embarked upon here.

5. POSTSCRIPT

Newbery, in his comments on this chapter, argues that the distortion results obtain only because it is assumed that farmers plan each period on the basis of independent forecasts about prices and yields. He shows that more rational expectations which take account of negative correlations between prices and yields would lead to market equilibria which are efficient. The authors have subsequently shown (Hazell and Scandizzo, 1977) that there exists an even simpler class of behavioral models which ensure competitive market efficiency, namely those models in which farmers are assumed to act on the basis of a linear lagged function of past (per unit) revenues. The position is now such that results about competitive market efficiency and the need for government intervention policies depend very much on the way farmers actually do forecast enterprise profitability each year when planning their input decisions. Given the magnitudes of the welfare losses demonstrated in this chapter for reasonable but less than optimal behavior, there is a clear need for empirical research to determine how farmers do behave.