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Producers' Price Expectations and the Size of the Welfare Gains from Price Stabilisation*

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This paper uses a simulation model to measure the size of the social welfare gains from price stabilisation within the general setting of a non-linear, multiplicative risk and lagged expectations model of the market. The size of the gains is found to be relatively small when producers plan on the basis of rational expectations, but it can be quite substantial for other types of expectations behaviour, including those commonly assumed in empirical supply analysis. We conclude that, in many cases, improved market information services may more economically provide the substantial part of the social benefits of price stabilisation.

Introduction

In the literature on the welfare analysis of price stabilisation, it is well established that society generally gains from the establishment of costless price stabilisation schemes, at least when producers are assumed to be risk neutral.[1] This result was initially demonstrated by Massell (1969) within the context of a linear model of market behaviour in which both supply and demand were subject to additive risk terms and in which producers and consumers were assumed to have perfect information about the market at the time of making their decisions. Subsequent writers have extended this finding to nonlinear specifications of the market with multiplicative formulations of the risk terms (Turnovsky 1976) and, at least in the linear case, to the more realistic situation in which producers must act on the basis of price and yield forecasts rather than having perfect information about the market (Turnovsky 1974). Wright (1979) has recently provided an approximate solution to the lagged nonlinear case in which demand has additive risk, supply has multiplicative risk and producers hold rational price expectations. Additional results obtained by Massell (1969), Waugh (1944) and Oi (1961) concerning the distribution of the gain between producers and consumers have proved to be less robust under alternative model specifications, and few generalities have emerged (see Turnovsky (1978) for a recent review).

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* Views contained in this paper are those of the authors, and should not be attributed to the institutions with which the authors are or were affiliated. The work was done when the authors were at the World Bank, Washington, D.C., before the seminal work of Newbery and Stiglitz (1981) appeared. Peter Hazell is now with the International Food Policy Research Institute, Washington, D.C. 20036 U.S.A.

[1] Newbery (1976) has given an example in which risk-averse behaviour can lead to society being made worse off through costless price stabilisation. The short-run Marshallian suplus analysis does not necessarily imply risk neutrality (for example, see Hazell and Scrandizzo (1974)), but it is implied when price stabilisation is evaluated without allowing for any changes in the risk costs charged to producers as part of the area under the supply schedule.

While these findings are of inherent interest, they offer limited guidance as to how large the social gains from price stabilisation might be, or about how they might vary with differences in key parameters describing the market structure. Some numerical results can be obtained from the algebraic expression of the social gain offered in the literature, but such results apply to specialised market structures and do not permit the kind of systematic analysis from which more general quantitative conclusions might emerge.

In this paper, a Monte Carlo simulation model is used to evaluate the size of the social gain from costless price stabilisation in the general setting of a nonlinear, multiplicative risk and lagged expectations model of the market with intervention via a buffer stock scheme (i.e., alternative schemes such as buffer funds are not considered here). In addition to exploring systematically the effects of changes in key market parameters, we also report on the consequences of alternative specifications of producers' price forecasting behaviour. Our results show that the social gain is typically small for realistic parameterisations of the market if producers plan on the basis of rational expectations, but that the gain can be quite substantial for other types of price expectations behaviour, including those commonly assumed in empirical supply analysis. We conclude that, in those situations where the social gain from price stabilisation is large, the greatest part of that gain might more economically be obtained through improving market information services.

Our model of the market is discussed in the next section. We then proceed to prove some general propositions about the relationship between producers' price forecasting behaviour and the social gains from price stabilisation. Finally, we report on our simulation study of some particular specifications of the market model and show how the magnitude of the social gain from price stabilisation, as well as its distribution between producers and consumers, is related to the coefficient of variation in yields, to the elasticities of supply and demand and to different types of price expectations behaviour.

The Market Structure and Welfare Measures

Our market model can be written as follows:

(1) demand function: $D_t = u_t f(P_t)$,

(2) supply function: $S_t = v_t g(P_t^*)$,

(3) market clearing condition: $D_t = S_t$,

where $f(.)$ and $g(.)$ denote any continuous, twice differentiable functions, P_t is market clearing price in period t, P_t^* is the price expectation held by producers for period t at the time of making their decisions, and u_t and v_t are stochastic variables. The term v_t is a stochastic yield, and u_t arises from stochastic shifts in consumers' incomes and tastes.

We also assume the following:

(i) that u_t and $v_t \geq 0$ and their means and variances exist and are finite; (without any loss in generality, we assume $E[u_t/t] = E[v_t/t] = 1$, all t);

(ii) that u_t, v_t and P_t^* are independently distributed and serially uncorrelated; and

(iii) that the first derivatives of $f(.)$ and $g(.)$ satisfy the usual conditions $f' \leq 0$ and $g' \geq 0$ for P_t and $P_t^* \geq 0$.

Our model is quite general with respect to the functional forms of supply and demand. Further, apart from assuming that producers are risk neutral and have no special forecast knowledge about yield v_t at the time of making their price forecast for that period (i.e., $\text{cov}[v_t, P_t^*] = 0$), the model is also quite general with respect to the way in which price expectations are formed.[2]

The specification of a multiplicative risk term in the supply function seems realistic for many agricultural markets (Hazell and Scandizzo 1975; Turnovsky 1976). It is consistent with the observation that crop areas are usually price responsive, whereas supply is area times stochastic yield. A multiplicative risk term is also consistent with the observation that the variance of total output increases with the area grown—a feature which cannot be captured with an additive risk term.

A multiplicative risk term arises on the demand side as a reflection of random changes in income or tastes when necessary restrictions are imposed on the utility function to ensure that the consumers' surplus is a valid measure of consumers' welfare (Turnovsky 1976).

Producers are assumed to know neither the market clearing price P_t nor yield v_t at the time of making their decision, but to act on the basis of an expected price P_t^* and anticipated yield $E[v_t] = 1$, all t, with anticipated outputs which aggregate to $S_t^* = g(P_t^*)$. We shall henceforth refer to $S_t^* = g(P_t^*)$ as the anticipated supply function.

The market clearing price P_t is

$$P_t = f^{-1} [g(P_t^*) \, v_t/u_t]$$

and is stochastic with v_t/u_t and P_t^*. Since v_t, u_t and P_t^* are assumed to be serially uncorrelated, then the market will converge in mean price if the relevant moments of P^* also converge.[3] We shall assume convergence and be interested in two types of "price" expectations behaviour, both of which are self-fulfilling on average. The first are "pure" price expectations, e.g., the weighted cobwebs $P_t^* = \Sigma_i \, P_{t-i} \, \gamma_i$ where the γ'_i s are weights which sum to one. Such expectational models include the Nerlovian-type adjustment models. These expectations have been widely used in empirical supply analysis work. The second are "revenue" expectations of the form $P_t^* = \Sigma_i \, (P_{t-i} \, v_{t-i}/E[v_t]) \, \gamma_i$ which are in price units and, as we shall see, have some important social welfare properties, and provide the rational expectation of the market (Hazell and Scandizzo 1977).

For mathematical purposes it will be more convenient to work with the inverses of the demand and supply functions. Let $F = f^{-1}$ and $G = g^{-1}$, then $P_t = F(D_t/u_t)$ is the market demand function and $P_t^* = G(S_t^*)$ is the anticipated supply function. Since we have assumed $f' \leq 0$ and $g' \geq 0$, then $F' \leq 0$ and $G' \geq 0$.

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[2] We assume that all producers hold identical anticipations about prices and yields.

[3] The market clearing price cannot converge to a unique value because it is stochastic with v_t/u_t and P_t^*. A number of stochastic equilibrium concepts are available in the literature (e.g., Turnovsky (1968)), and we have chosen to use convergence in mean price as our primary criterion.

At time t, producers' expect price P_t^* and plan so that in aggregate they produce an anticipated supply S_t^*, with production costs equal to the area

$$\int_0^{S_t^*} G(Q)\, dQ,$$

i.e., the area under the anticipated supply function. However, when yields are realised, actual output is S_t and the corresponding market clearing price is P_t. The realised producers' surplus, or profit is thus

$$\text{(4)} \quad W_{pt} = P_t S_t - \int_0^{S_t^*} G(Q)\, dQ.$$

This *ex post* measure of the producers' surplus differs from the usual *ex ante* measure defined as the area above the supply function and below price. The latter is more relevant when producers have perfect foresight about prices, i.e., when there is instability but no risk in the market.[4] Consumers' surplus is simply the area under demand and above price,

$$\text{(5)} \quad W_{ct} = \int_0^{S_t} F(Q/u_t)\, dQ - P_t S_t.$$

Assuming that the market has converged in mean price and quantity, then taking expectations over time and summing the producers' and consumers' surplus, the measure of expected social welfare used in this paper is

$$\text{(6)} \quad E[W_t] = E\left[\int_0^{S_t} F(Q/u_t) dQ\right] - E\left[\int_0^{S_t^*} G(Q)\, dQ\right].$$

Price Stabilisation

Consider the establishment of a buffer stock scheme in which the market price is stabilised at a price $\bar{P}$ which ensures that the buffer stock is self-liquidating on average. Clearly, $\bar{P}$ must be the price corresponding to the intersection of expected demand and anticipated supply, i.e., $\bar{P}$ satisfies $f(\bar{P}) = g(\bar{P})$.[5] Market supply and demand each period are still stochastic, $\bar{S}_t = v_t\, g(\bar{P})$ and $\bar{D}_t = u_t\, f(\bar{P})$, but it is presumed that the agency buys the total amount produced each year at price $\bar{P}$ and sells to consumers each year the amount they will buy at price $\bar{P}$. For simplicity, it is assumed that the scheme is run costlessly and that producers are neutral towards risk and thus do not expand anticipated supply in response to the imposed price stability. The assumption of a costless scheme is clearly not realistic, but is acceptable here because our purpose is only to evaluate the size of the welfare gains from stabilisation. Empirical estimates of these costs would have to be obtained if a decision to establish a buffer stock were to be made.

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[4] The two measures of producers' surplus are also identical when the risk term is additive.

[5] Since the model is non-linear, $\bar{P}$ will typically be different from the expected market clearing price in the pre-stabilised market.

Under this scheme, and using equations (4) and (5), the producers' and consumers' surpluses are

$$W_{pt} = \bar{P}\,\bar{S}_t - \int_0^{\bar{S}} G(Q)\,dQ,$$

and

$$W_{ct} = \int_0^{\bar{D}_t} F(Q/u_t)\,dQ - \bar{P}\,\bar{D}_t.$$

Subtracting the prestabilized surpluses, noting that $\bar{D}_t = u_t\,\bar{S}$ where $\bar{S} = E[\bar{S}_t]$, and taking expected values over time, the average gains or losses from stabilisation occuring to producers and consumers are

$$(7)\ E[\Delta W_{pt}] = E[\bar{P}\,\bar{S}_t - P_t S_t] + E\left[\int_{\bar{S}}^{S^*} G(Q)\,dQ\right],$$

and

$$(8)\ E[\Delta W_{ct}] = E\left[\int_{S_t}^{u_t\bar{S}} F(Q/u_t)\,dQ\right] + E[P_t S_t - u_t\,P\,S].$$

The social gain is measured here by the sum of (7) and (8),

$$(9)\ E[\Delta W_t] = E\left[\int_{S_t}^{u_t\bar{S}} F(Q/u_t)\,dQ\right] + E\left[\int_{\bar{S}}^{S_t^*} G(Q)\,dQ\right].$$

Some Theoretical Propositions

Wright (1979, pp. 1023–7) has provided an approximate proof to the proposition that society always gains from costless price stabilisation, given similar assumptions to our own. Of more interest here are two propositions relating the way in which producers form their price expectations P_t^*, to the size of the social gain from price stabilisation. We begin with a proposition that shows how the size of this social gain is affected by a mean preserving increase in the spread of the producers' price expectation over time.[6]

Proposition 1. For a given $E(S_t^*)$, the social gain from price stabilisation increases with mean preserving increases in the spread of P_t^*.

Proof. Since $S_t^* = g(P_t^*)$ is an increasing function of P_t^*, then increases in the variability of P_t^* will increase the variability of S_t^*. It suffices, therefore, to prove that the social gain from price stabilisation increases with mean preserving increases in the spread of S_t^*.

Following Feder (1977), the random variable S_t^* can be written as $S_t^* = e_t + r(e_t - E[S_t^*])$ where e_t is a random variable satisfying $E[e_t] = E[S_t^*]$, and r is a positive scalar. An increase in r has the effect of increasing the spread of S_t^* but leaves the mean unchanged. Since $S_t = v_t\,S_t^*$ then $S_t = e_t v_t + r v_t\,(e_t - E[S_t^*])$. Note that $E[S_t]$ is not affected by this transformation.

Using (9), the first integral can be partitioned over the intervals S_t to $E[S_t]$ and $E[S_t]$ to $u_t\,\bar{S}$, and since u_t and P_t^* are assumed to be independently distributed, it is clear that only the integral from S_t to $E[S_t]$ is affected by the

[6] The concept of the mean preserving spread as a measure of variability was introduced by Rothschild and Stiglitz (1970).

variability of S_t^*. Similarly, the second integral in (9) can be partitioned over the intervals $\bar{S}$ to $E[S_t^*]$ and $E[S_t^*]$ to S_t^*, and only the latter integral is affected by variability in S_t^*. We therefore only need to show that,

$$(10)\ \frac{\partial}{\partial r}\left\{ E\left[\int_{S_t}^{E[S_t]} F(Q/u_t)\,dQ\right] + E\left[\int_{E[S_t^*]}^{S_t^*} G(Q)\,dQ\right]\right\} \geq 0.$$

Using Leibniz' rule, and our transformations of S_t and S_t^* in terms of e_t, this evaluates as:

$$-E[F(S_t/u_t)\,(e_t - E[S_t^*])\,v_t] + E[G(S_t^*)\,(e_t - E[S_t^*])] \geq 0.$$

But $F(S_t/u_t) = P_t$ and $G(S_t^*) = P_t^*$, and using $E[e_t] = E[S_t^*]$, (10) is equivalent to

$$E[(P_t^* - P_t\,v_t)\,(e_t - E[S_t^*]] \geq 0, \text{ or}$$
$$\text{cov}[P_t^*, e_t] - \text{cov}[e_t, P_t\,v_t] \geq 0.$$

By construction, e_t is a positive linear transform of S_t^*; hence, $\text{cov}[P_t^*, e_t]$ has the same sign as $\text{cov}[P_t^*, S_t^*]$. But since $S_t^* = g(P_t^*)$ and $\partial S_t^*/\partial P_t^* \geq 0$, this implies that $\text{cov}[P_t^*, S_t^*] \geq 0$.[7] Therefore a sufficient condition for (10) to hold is that $\text{cov}[e_t, P_t\,v_t] \leq 0$. This has the same sign as $\text{cov}[S_t^*, P_t\,v_t)$, and since P_t and v_t are distributed independently of S_t^*, this covariance will be negative if $\partial P_t\,v_t/\partial S_t^* \leq 0$ (see footnote 7). This is clearly true under our model assumptions; hence, (10) is positive as required.

Proposition 1 takes $E[S_t^*]$ as given. This assumes that $E[P_t^*]$, the mean price expectation over time, is also constant. Thus, for example, the proposition states that the social gain from price stabilisation will be smaller if producers adhere to the constant price expectation $P^*_t = E[P_t]$ than if they forecasted last period's price $P_t^* = P_{t-1}$ in the unstabilised market. This is because both price expectations are the same on average, but $P_t^* = E[P_t]$ has zero variability over time, whilst $P_t^* = P_{t-1}$ has the same variability as P_t. However, the proposition cannot be used to compare the welfare effects of variability in different P_t^* drawn from distributions with different means.

By proposition 1, the social gain from price stabilisation will, given the same $E[S_t^*]$, be smallest when producers hold constant price expectations in the unstabilised market. Clearly, not all constant price expectations can be equally good, and it is relevant to search for the constant price expectation, which, if used each period in the unstabilised market, leads to the smallest social gain from the introduction of price stabilisation.

Proposition 2. If, in the pre-stabilised market, producers expect the same price P^* in each and every period, then the social gain from price stabilisation will be smallest when P^* is equal to the (standardised) expected revenue $P^* = E[P_t\,v_t]$, (recalling that $v_t = v_t\ /\ E[v_t]$, since $E[v_t] = 1$).

[7] Let x be a random variable with mean $E[x] = \bar{x}$ and let $f(x)$ be a continuous function of x whose first derivative exists and satisfies $f'(x) \geqslant 0$. Then,

$f(x) \leqslant f(\bar{x})$ iff $x \leqslant \bar{x}$, and $f(x) \geqslant f(\bar{x})$ iff $x \geqslant \bar{x}$. Consequently,

$[f(x) - f(\bar{x})]\,(x - \bar{x}) \geqslant 0$ for all $x \neq \bar{x}$

and $E[(f(x) - f(\bar{x}))\,(x - \bar{x})] = \text{cov}[f(x), x] \geqslant 0$.

Similarly, $f'(x) \leqslant 0$ implies $\text{cov}[f(x), x] \leqslant 0$.

The authors are grateful to Richard Just for this proof. Extension to the case of two random variables is trivial providing the variables are independently distributed.

Proof. Let $A = g(P^*)$, then (9) can be written as

$$E[\Delta W_t] = E\left[\int_{v_t A}^{u_t \bar{S}} F(Q/u_t)\, dQ\right] + E\left[\int_{\bar{S}}^{A} G(Q)\, dQ\right].$$

Our proposition states that $P^* = G(A) = E[P_t\ v_t]$ is the price which minimizes $E[\Delta W_t]$.

The first-order condition for a minimum is:

$$\partial E[\Delta W_t]/\partial A = -E[F(v_t\ A/u_t)v_t] + G(A) = 0.$$

But $F(v_t A/u_t) = P_t$ given P^*, and $G(A) = P^*$, hence $P^* = E[P_t\ v_t]$ as required.

The second-order condition for a minimum is:

$$\frac{\partial^2\ E(\Delta W_t)}{\partial A^2} = -E[F'\ (v_t A/u_t)\ (v_t^2/u_t)] + G'\ (A) \geq 0, \text{ or}$$

(11) $G'\ (A) \geq E[(v_t^2/u_t)\ F'\ (v_t A/u_t)]$.

Since $G' \geq 0$, $F' \leq 0$ and u_t, $v_t \geq 0$, then (11) is always satisfied.

Corollary A. Since (11) is satisfied for all values of A and hence P^*, it follows that $E[\Delta W_t]$ is convex in P^* and hence that the social gain from price stabilisation will be greater the more a constant price expectation P^* deviates from the revenue expectation in the pre-stabilised market.

Corollary B. Since social welfare in the stabilised market is the same irrespective of the kind of price expectation held in the unstabilised market, then of all possible constant price expectations in the unstabilised market, the revenue expectation has the property of maximising the welfare function defined in (6).

Corollary B generalises the findings of Hazell and Scandizzo (1975, 1977) to the nonlinear case, and provides the rationale for our interest in the "revenue" expectation as a price forecast. Since the social gains from price stabilisation are smallest with the revenue expectation, we shall be particularly interested in comparing the size of the social gain with this formulation against the gains from alternative price expectation models.

So far we have only considered the desired properties of P_t^* from the social welfare point of view. In a competitive market, producers should choose rational price expectations that maximise their own welfare, and these expectations may diverge from those desired for the social good. Fortunately, if producers seek to maximise expected profits, there is a happy and exact coincidence between the results of producers' enlightened self-interest and results of the altruistic dictatorship obtained in Proposition 2.

In maximising expected profits, producers will equate expected marginal revenue to marginal cost. From the assumptions underlying the formulation of the supply function, marginal cost is assumed to have been equated with, and can thus be represented by, P_t^*. Expected, or anticipated marginal revenue is:

$$E[\partial P_t\ S_t/\partial S_t^*] = E[P_t\ \partial S_t/\partial S_t^*],$$

where we have assumed that $\partial P_t/\partial S_t^* = 0$; because, in a competitive environment producers do not expect S_t^* to have any effect on P_t. Then, since $S_t = v_t S_t^*$, the optimal decision rule for producers is:

$P_t^* = E[P_t v_t]$, which is the same revenue expectation as obtained in Proposition 2. In other words, the revenue expectation is the rational expectation of the model as defined by Muth (1961).[8]

A Simulation Experiment

To explore quantitative aspects of the gains from price stabilisation, we constructed a simulation model of our assumed market structure. Our objectives were to provide a simple but plausible representation of the functioning of a risky agricultural market and to discover orders of magnitude for the gains identified in the theoretical analyses and their sensitivity to changes in key parameter values. For modelling simplicity, and in keeping with the theoretical work, we assume complete price stabilisation at $\bar{P}$. With this extreme assumption, the gains in prospect for the more typically attempted stabilisation schemes involving a band of partially stabilised prices should be exaggerated and perhaps readily identifiable. Needless to say, the size of buffer stock initially on hand to ensure that the market could always clear at $\bar{P}$ would be very large in some cases.

Constant elasticity demand and supply functions were used for the simulation. This simplifying assumption implies that expected price $E[P]$ exceeds the intersection or stabilised price $\bar{P}$. The resulting model has the parametric economy of being fully specified by the elasticities and means. In order to keep the results manageable, we also made the assumption that demand is deterministic, leaving yield risk v_t as the prime source of stochasticity in the analysis.[9] While the choice of any particular functional form obviously limits the generality of the results, the representation accords with that frequently used by empirical analysts and, in this sense, might be indicative of more general empirical specifications.

The structure of the simulation experiments can be summarised in four steps. First, values of parameters are specified for demand and anticipated supply, and the completely stabilised price $\bar{P}$ is computed. Second, one of seven models of price expectations behaviour is specified. Third, a yield is drawn pseudorandomly from an approximate normal distribution for v_t with specified coefficient of variation C. Fourth, the quantity supplied and market clearing price are computed. Fifth, values of realised prices, revenues, consumers' and producers' surpluses, and the means and variances (over all previous periods) of these statistics are computed. Given the specification of steps 1 and

[8] See also Hazell and Scandizzo (1975), Newbery (1976) and Wright (1979).

[9] Omission of the stochastic demand term u_t will not effect the results when demand has unit elasticity. Given the constant elasticity functions $D_t = u_t P_t^{-a}$ and $S_t = v_t(P_t^*)^b$ where $E[v] = E[u] = 1$, then equation (9) evaluates as:

$$E(\Delta W_t) = E\left[\int_{S_t}^{u_t\bar{S}} (Q/u_t)^{-1/a}\, dQ\right] + E\left[\int_{\bar{S}}^{S_t^*} Q^{1/b}\, dQ\right]$$

$$= \frac{a}{a-1}\left\{\bar{S}^{\frac{a-1}{a}} - E\left[u_t^{1/a}\, S_t^{\frac{a-1}{a}}\right]\right\}$$

$$+ \frac{b}{1+b}\left\{E\left[S_t^{*\frac{1+b}{b}}\right] - \bar{S}^{\frac{1+b}{b}}\right\}.$$

$E[\Delta W_t]$ is not affected by u_t if $\text{cov}\left[u_t^{1/a}, S^{\frac{a-1}{a}}\right] = 0$, and $E[u_t^{1/a}] = 1$. Since P_t^*, u_t and v are assumed to be independently distributed the former is assumed. Finally, $E[u_t^{1/a}] = 1$ if $a = 1$, i.e., demand has unit elasticity.

2, steps 3 to 5 are repeated, and statistics updated until markets converge to an equilibrium in mean price. As a numerical test of convergence, the program terminates when the mean price for the unstabilised market changes proportionally by less than $C/1000$ between successive periods. In nearly all cases, we found that the mean values of the producers' and consumers' surplus converged before the mean price; hence, the values of these statistics provided the average gains (or losses) obtained with stabilisation as measured under market equilibrium conditions (in the sense defined in footnote 3).

For any run, two groups of initial conditions were required. Of the first group, values of lagged endogenous variables were required in some expectations models, and these were taken to be initially as the computed $\bar{P}$. Also, a seed for the pseudorandom generator has to be drawn for each run. The second group consisted of the market parameters: elasticity of demand (expressed as a positive number), e_d; elasticity of supply, e_s; and coefficient of variation of yield, C. An experimental design was used to explore the influence of these parameters over a range of plausible values. A complete factorial design including all 27 combinations of three factors was used; namely, $e_d = 0.5, 1, 1.5$; $e_s = 0.5, 1, 2$; $C = 0.1, 0.25, 0.4$. Gains from stabilisation are measured by changes in consumers' surplus and producers' *ex post* surplus as defined in equations (7), (8) and (9). The surpluses are computed by integration of areas under the respective curves although, in the case of the constant-elasticity demand curve, it is necessary to impose a strictly positive lower quantity bound on the range of integration in estimating consumers' surplus. This was taken as the quantity demanded corresponding to four times the stabilised price $\bar{P}$.

Some results are presented for the design points ($e_d = 0.5$, $e_s = 0.5$, $C = 0.1, 0.25, 0.4$) in Table 1. These include estimates of the gains from stabilisation for seven alternative supply price specifications: (i) producers anticipate the intersection price $P_t^* = \bar{P}$, (ii) expected price ($P_t^* = E[P]$), (iii) past year price ($P_t^* = P_{t-1}$), (iv) a weighted average of past prices ($P_t^* = 0.5P_{t-1} + 0.3P_{-2} + 0.2P_{t-3}$), (v) past year "revenue" ($P_t^* = P_{t-1}v_{t-1}$), (vi) a weighted average of past "revenues" (with weights, as in (iv)), and (vii) expected "revenue" ($P_t^* = E[P\ v]$).

We now overview the tabular results by reference to some statistics from the experiment. For the sake of brevity, only a 1/9 portion of the results are reported in Table 1. The result apparent in the simulations is that the average welfare gains or losses are generally considerable and tend to be quite large for the case of high relative variation (coefficient of variation equal to 0.4).

There are two ways to look at the gains (or losses) of consumers and producers from stabilisation. First, the surpluses can be viewed as compensating variations—in the case of positive gains, as the amount of money that the consumers, the producers, or both would be willing to pay to enact a complete stabilisation scheme. Second, some form of relative benefits can be considered such as, for example, the gains as ratios of the associated stabilisation costs.

Because stocks and costs were not modelled, we adopted the procedure of expressing gains as proportions of total consumers' expenditure in the stabilised market. Such a procedure generates both an absolute and relative measure of gains in the following sense. Given a percentage gain, the absolute level of the compensating variation for each group of agents can be computed for a market of any size having the same elasticity and stochastic characteristics. This can be done by simply multiplying the percentage gains as given in Table 1 by an estimate of the total expenditure in the market of interest. Stabilised total expenditure represents the value of the market transactions that would occur under complete stabilisation and is used in this case as a measure of market size. For this purpose, it has the added advantage of remaining constant for given values of the market parameters, regardless of the type of price expectations held by producers in the unstabilised market.

From an alternative point of view, the percentage gains are obviously a relative measure of benefits from stabilisation. For each \$100 transacted in the stabilised market, they represent how much the consumers, the producers, or both would be willing to pay, on average, for the stabilisation scheme.

In relative terms the total gains to society range from a few percentage points for the cases of low elasticities and/or low relative variations, to more than 100 per cent for the more extreme cases of naive lagged expectation models. In absolute terms these percentage gains imply, for example, that, in a market of the size of the international wheat market (about \$8 billion of recorded transactions) and depending on the type of expectations held by producers, costless stabilisation could achieve gross gains ranging from a few hundred million dollars to several billion dollars.

Such a conclusion, though seemingly favourable for stabilisation, is tempered by the observation that, in many of our simulation runs, a large proportion of the social gain from stabilisation occurs because producers make improper price forecasts. Proposition 1 predicts that the social gain will be larger the greater the variability in P_t^*, but the numerical importance of the proposition can be quite surprising. For example, even given a low value of the coefficient of variation of yields of 0.1, the social gain from price stabilisation is 30 per cent of consumers' expenditure in the stabilised market if producers plan on the basis of last period's price (i.e., $P_t^* = P_{t-1}$). But the gain is only 1.5 per cent of stabilised expenditure if producers plan on the basis of the mean equilibrium price ($P_t^* = E[P]$). Since $E[P^*]$ is the same in both cases, the large difference in the relative welfare gains is due solely to differences in the variability of P_t^*. A similar result holds with revenue expectations. Again selecting $C = 0.1$, the social gain from stabilisation is 10 per cent of stabilised expenditure when producers expect last period's revenue ($P_t^* = R_{t-1}$), but is only 1.7 per cent when $P_t^* = E[R]$. Again $E[P^*]$ is the same in both cases, and the larger social gain from stabilisation arises when the variability in P_t^* is non-zero. Of course, one-year lagged price or revenue expectations are exceedingly naive and have high variability over time. The weighted lagged forecasts (expectations models (iv) and (vi) in Table 1) are considerably less variable over time and, for example when $C = 0.1$ and $P_t^* = f(P_{t-i})$, the social gains are not much larger than the gains obtained with constant price expectations. However, such relative differences do translate into significant money amounts in realistically sized markets.

By Proposition 2, the social gains from price stabilisation must be smallest when producers plan on the basis of expected revenue (the rational price expectation). Consequently, the social gains reported for expectations model (vii) in Table 1 are the smallest gains possible for each value of C over all other expectations models. Larger gains than these are directly attributable to inferior price forecasting behaviour in the unstabilised market, and those additional gains could be obtained by improving producers' forecasting behaviour without setting up a price stabilisation agency. The rightmost three columns of Table 1 show the differences between the gains with each of the different expectations models and the gains with the expected revenue expectation. These figures measure directly the gains and losses arising from the removal of inferior forecasting behaviour. They are, of course, zero for the expected revenue expectation but, in many cases, the largest part of the stabilisation gain can be achieved merely by improving producers' price forecasts. This is particularly true in the cases where producers plan on the basis of lagged prices or revenues. Surprisingly though, $P_t^* = \bar{p}$, the price corresponding to the intersection of demand and anticipated supply, performs about as well as the expected revenue expectation.

With such improved forecasting, however, the distribution of benefits between producers and consumers could substantially change. For the two cases of expected price and weighted lagged price expectations, for example, a strategy of improved forecasts would shift from consumers to producers a considerable part of the gains that might be achieved via a buffer stock policy. In most other cases, the transfers between consumers and producers via stabilisation are either zero or small. With the exception of the intersection price model and the naive model, consumers and producers either both gain from stabilisation or both lose insignificant amounts.

In our discussion of results so far we have concentrated on those for the inelastic markets reported in Table 1. Market structures of great diversity were included in the complete experiment, and we turn now to explore what generalisations are possible when a wide range of elasticities is considered. To overcome the difficulty and tedium of reporting a great bulk of results, we elected to summarise the information by means of some regression equations. We took the gains to producers, consumers, and society expressed as percentages as in Table 1 as separate dependent variables and, for each model of expectations behaviour, related these in least squares regression to a complete second-order response model (i.e., with intercept, linear, quadratic, and interaction terms) in the three experimental factors; namely, e_d, e_s, and C.

The regressions are not reported because of their bulk.[10] They permit prediction of relative gains at any specified point within the design space and description (via partial differentiation) of the relative changes in welfare with respect to changes in the parameters of the market. The partial derivatives of a complete second-order surface are functions of all the factors so these are evaluated at an arbitrary point for the purpose of our discussion. To complement the statistics in Table 1, we present in Table 2 the marginal effects as evaluated at the experimental point: $e_d = 0.5$, $e_s = 0.5$, $C = 0.2$.

In spite of the variability of these results, and particularly with respect to signs, a few generalisations can be attempted. Consumers' gains are most sensitive to changes in C and least sensitive to changes in e_s. Consumers' gains

[10] Since the observations generated in the simulation are free of statistical errors, we used the adjusted R^2 as a measure of accuracy in the choice of functional form. Obviously, unadjusted R^2s of 1.0 could be obtained with high-order polynomials, but the adjusted R^2 will typically peak at lower values as higher order terms add coefficients faster than they increase the unadjusted R^2. We found that quadratic equations performed well by the adjusted R^2 criterion, and in more than half the cases obtained adjusted R^2s of 0.7 or higher with sample sizes of 27. The revenue expectations models performed least well, with five of the six adjusted R^2s falling in the range of 0.34 to 0.48. The only real problem arose in the regression of producers' gains when $P_t^* = \bar{p}$. The adjusted R^2 was -0.05 for the quadratic model. The results for this equation are reported in Table 2 only for completeness.

from stabilisation increase with increasing C, decrease with increasing e_d (i.e., as demand becomes less inelastic) and tend to decrease with increasing e_s. Producers' gains from stabilisation are affected by changes in e_d, e_s and C in a generally ambiguous manner depending on the nature of their expectations. The gains to society as a whole tend to change systematically with respect to changes in C and e_d, being most sensitive to the former. They typically increase with increasing C (as we would expect from Proposition 1) and decrease with increasing e_d (less inelastic).

Conclusion

What are the practical implications of these results? First, because of the range of coefficients of variation used, the estimated gains from stabilisation should give a reasonable idea of the gains that might be obtained by stabilising prices in typical agricultural markets. Our results show that these gains can be quite large. For example, if demand and supply elasticities are both 0.5 and the coefficient of variation of yields is 0.1 (an approximate parametrisation of the world wheat market), then for each \$200 transacted in the stabilised market (or each tonne of wheat) the social gains from price stabilisation range from \$3 given expected revenue expectations to \$60 when producers expect last period's price. These gains increase to \$18 and \$167, respectively, when the coefficient of variation is 0.25. If producers plan on the basis of a weighted average of past prices or revenues, as is commonly assumed in empirical supply analysis, then the social gain from price stabilisation will take on intermediate but still sizeable values. Our analysis has been based on the assumptions of costless storage and complete price stabilisation, hence these estimates of the social gains must be interpreted as the maximum gross gains attainable from price stabilisation. Nevertheless, there are clearly some plausible market conditions under which more realistically designed stabilisation schemes could return a substantial net social benefit.

Second, a program of data collection, appropriate forecasting, and information dissemination could achieve a large part of the gains of a buffer stock scheme in situations where producers act on the basis of price forecasts different from the rational expectation. Such a market information service should provide producers with an estimate of the expected revenue given the structural parameters of the market. Our simulation results also show that the intersection price of demand and anticipated supply is about as good a price forecast. If producers consistently use either of these price forecasts then, unless the coefficient of variation of yields is exceptionally high, price stabilisation is unlikely to return an attractive gain in terms of the social welfare measure used in this paper.

[a]*Table* 1: *Welfare Gains from Stabilisation for Alternative Expectation Models and Levels of Yield Variability*

(Supply and demand elasticities both 0.5)

Expectations model	Coefficient of variation for yield	Gains from stabilisation as percentage of consumers' expenditure in the stabilised markets			Gains due to removing forecasting error as percentage of consumers' expenditure in stabilised markets		
		Producers	Consumers	Total	Producers	Consumers	Total
(i) Intersection price forecast, $P^* = \bar{P}$	0.1	0.778	0.974	1.752	2.99	−2.91	0.07
	0.25	−27.142	36.382	9.237	−9.25	9.56	0.31
	0.4	−5.09	27.800	22.711	−2.31	2.17	−0.14[a]
(ii) Mean price forecast, $P_t^* = E[P]$	0.1	−0.762	2.236	1.474	1.45	−1.65	−0.21[a]
	0.25	0.670	11.855	12.526	18.56	−14.96	3.60
	0.4	25.716	3.450	29.166	28.50	−22.18	6.32
(iii) Naive lagged price forecast, $P_t^* = P_{-1}$	0.1	15.495	14.578	30.073	17.70	10.69	28.39
	0.25	49.347	34.045	83.392	67.24	7.23	74.47
	0.4	71.294	39.690	110.986	74.08	14.06	88.14
(iv) Weighted lagged price forecast, $P_t^* = f(P_{t-i})$	0.1	0.038	2.251	2.293	2.25	−1.64	0.61
	0.25	−0.23	16.194	15.963	17.66	−10.63	7.04
	0.4	23.986	13.133	37.119	26.77	−12.50	14.27
(v) Naive lagged "revenue" forecast, $P_t^* = R_{t-1}$	0.1	2.672	7.368	10.040	4.88	3.48	8.36
	0.25	0.996	31.370	32.366	18.89	4.55	23.41
	0.4	9.838	36.452	46.292	12.62	10.82	23.45
(vi) Weighted lagged "revenue" forecast, $P_t^* = f(R_{t-i})$	0.1	−2.470	3.874	1.404	−0.26	−0.01	−0.28[a]
	0.25	−21.280	32.597	11.318	−3.39	5.78	2.39
	0.4	−13.541	39.250	25.706	−10.76	13.62	2.86
(vii) Expected "revenue" forecast or rational price expectation, $P_t^* = E[R]$	0.1	−2.207	3 886	1.679	0.00	0.00	0.00
	0.25	−17.892	26.819	8.927	0.00	0.00	0.00
	0.4	−2.783	25.633	22.847	0.00	0.00	0.00

[a] These figures are slightly negative due to convergence difficulties in the measures of expected social gains.

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Table 2: Marginal Changes in Relative Welfare with Respect to Key Parameters of the Risky Market

Expectations model Table	Change in percentage given to respective groups for a small change in respective parameters [a]								
	Consumers w.r.t.			Producers w.r.t.			Total w.r.t.		
	e_d	e_s	C	e_d	e_s	C	e_d	e_s	C
(i) $P_t^* = \bar{P}$	−28	−3	79	17	1	−40	−11	−2	41
(ii) $P_t^* = E[P]$	−14	−9	17	−14	7	33	−15	−2	50
(iii) $P_t^* = P_{t-1}$	−60	1	49	−191	366	403	−251	454	676
(iv) $P_t^* = f(P_{t-i})$	−9	−7	24	−72	26	62	−81	21	84
(v) $P_t^* = R_{t-1}$	−57	10	75	31	46	−278	−26	55	−203
(vi) $P_t^* = f(R_{t-i})$	−17	−11	72	−83	15	6	−99	13	76
(vii) $P_t^* = E[R]$	−20	−2	60	9	0	−21	−12	2	40

[a] Evaluated at $e_d = 0.5$, $e_s = 0.5$, $C = 0.2$ after partially differentiating the response functions.

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