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# WELFARE IMPLICATIONS OF MORE ACCURATE RATIONAL FORECAST PRICES

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**Models are constructed to assess the welfare effects for producers, consumers and society of producers using forecast prices based on more accurate estimates of variables causing shifts in the demand for and supply of commodities. The basic model is a stochastic cobweb model in which producers' forecast price is the rational forecast price. The model is extended for many commodities, for partial producer response to more accurate forecast prices, and to include stock holding. In terms of economic surplus, producers and consumers gain from more accurate estimates of demand shift variables, producers gain and consumers lose from more accurate estimates of supply shift variables, and in both cases there is a net society gain.**

## *Introduction*

This paper evaluates the welfare effects for producers, consumers and society of more accurate rational forecast prices in terms of more precise knowledge about factors causing shifts in the demand for and supply of agricultural commodities.[1] The agricultural producer makes decisions committing resources to production several months, and in some cases several years, before the output is realized and sent to market. Because of imperfect knowledge about factors causing shifts in the demand for and supply of commodities after production decisions have been taken, e.g. seasonal conditions, the level of economic activity and government policies, production decisions must be based on forecasts of what price will be obtained at the time the output is sent to market. An appealing procedure by which forecast prices might be formed is the rational forecast price model pioneered by Muth [3].[2] Basically, since forecast prices are informed predictions of future prices, the rational forecast price is the market clearing price predicted from the theory of the demand for and supply of a commodity. The rational forecast price model offers an operational framework within which more accurate forecast prices can be generated and their welfare effects evaluated.

[1] The models developed have potential applicability to other markets including minerals and labour as well as agriculture.

[2] Unfortunately there is little direct information about the way in which agricultural producers form forecast prices. On the basis of a survey of U.S. farmers, Heady and Kaldor [1, p. 35] concluded: '. . . no single procedure was employed by all farmers . . . A rather common procedure appeared to start the process of devising expected price from current price. The current price then was adjusted for the expected effects of important supply and demand forces.' No comparable survey of Australian farmers is known to the author. Many econometric studies of aggregate supply response behaviour specify producers' forecast price as some weighted average of current and lagged prices. Usually, the underlying reasoning is of an *ad hoc* nature. Muth [3] has noted that in some situations the rational forecast price is given by a special type of distributed lag function. Summarising, the limited empirical evidence neither confirms nor denies the hypothesis that producers' forecast prices are rational forecast prices.

The format of the paper is first to present and discuss in some detail a simplified basic model and then to consider some avenues for extending the basic model. The basic model considers a single commodity for which market behaviour is characterized by a stochastic cobweb model of the type used by Massell [2], Turnovsky [5] and others to study buffer stock schemes and by Smyth [4] and others to study the price stabilizing effects of public forecast prices.[3] The model allows for production lags and for imperfect knowledge about future period prices associated with random variables causing shifts in the supply and demand curves after production decisions have been taken. More accurate rational forecast prices associated with additional market outlook information are specified in terms of reductions in the variances of the forecasts of the random variables. The welfare effects of more accurate forecasts are evaluated as changes in the areas of consumers' surplus and producers' quasi-rents.

As an indication of the results derived, the principal findings from the basic model are as follows. In all cases producers' use of more accurate rational forecast prices in their production decisions increases social welfare in the sense that the gainers could more than compensate the losers. Both producers and consumers gain from more precise information about variables causing shifts in the demand curve with the former's gain being larger if the demand curve is more elastic than the supply curve, and vice-versa. In the case of more precise information about variables causing shifts in the supply curve, consumers lose while producers gain economic surplus.

In subsequent sections the basic model is extended in three directions. One section considers the case of many commodities in which price interdependencies at the supply and the demand level are permitted. Special consideration is given to a two commodity world with competitive interdependencies at the supply level. A second extension considers the situation in which producers' supply decisions are based only in part on the rational forecast price. The third extension includes an inventory or stock-holding behavioural equation. The extensions considered provide examples of ways in which the basic model might be adapted to the particular needs of a variety of applications.

## *Basic Model*

Suppose a model of market behaviour for a single commodity for a discrete period with the following characteristics. The demand function allows for costless flexibility in adjustment of quantity demanded to price within the current period. The supply function assumes that current price has no effect on quantity supplied in the current period. Rather, reflecting the production lag, quantity supplied is a function of producers' forecast price formed on the basis of information available in the previous period. The supply and demand curves are assumed to be linear with known parameters on the price variables and with random intercept terms. The intercept terms reflect the effects of all other variables on the demand for and supply of the commodity. They include some

[3] In the interests of brevity no detailed discussion is given to the assumptions of the stochastic cobweb model other than to note that it is widely used in the study of agriculture.

variables whose values were not known when the production decision affecting the current period's supply was taken. Each period the predetermined supply is priced to clear the market. In algebraic terms the market is represented as:

(1) $$q_t^d = -bp_t + x_t$$

(2) $$q_t^s = ap_t^f + y_t, \text{ and}$$

(3) $$q_t^d = q_t^s = q_t$$

where $q_t^d$ is quantity demanded, $q_t^s$ is quantity supplied, $p_t$ is realised market price, $p_t^f$ is producers' forecast price formed in period $t - 1$, $a$ and $b$ are known positive parameters, and $x_t$ and $y_t$ are random indexes of other variables influencing quantity demanded and supplied.

In the situation of perfect foresight, producers' forecast price and the realised market price coincide. The perfect foresight price and quantity, $p_t^*$ and $q_t^*$, are given by

(4) $$p_t^* = (x_t - y_t)/(a + b), \text{ and}$$

(5) $$q_t^* = (ax_t + by_t)/(a + b).$$

In preparing a rational forecast in period $t - 1$ on which to determine the production decision influencing quantity supplied in period $t$, the producers require forecasts of the random terms $x_t$ and $y_t$ in the demand and supply equations of (1) and (2), respectively. It is assumed that producers' information about these terms can be represented by a distribution function with mean and variances

(6) $$E(x_t) = \mu_x, E(y_t) = \mu_y, \text{Var}(x_t) = \sigma_{xx}$$
$$\text{Var}(y_t) = \sigma_{yy} \text{ and } \text{Cov}(x_t y_t) = \sigma_{xy}.$$

Of course, the parameters of the distribution may change over time. Now, given the market structure of (1), (2) and (3) and producers' information about (6), producers' rational forecast price is

(7) $$p_t^f = E(p_t) = (\mu_x - \mu_y)/(a + b)$$

Then, substituting terms, the realised market price and quantity associated with the forecast price of (7) will be given by

(8) $$p_t = (x_t - y_t - ap_t^f)/b$$

and by $q_t$ in (2).

The welfare effects of producers using perfect foresight prices, $p_t^*$ of (4), rather than the rational forecast price, $E(p_t)$ of (7), in forming their production decision are evaluated in terms of changes in the areas of consumers' surplus and producers' quasi-rents. The measures are interpreted as the lump sum transfers consumers and producers would exchange for a shift from the information state represented by the statistics of (6) to a state of perfect foresight about the terms $x_t$ and $y_t$, and still retain the level of welfare obtained under the realised market price and quantity. The limitations of the measures are well known and must be borne in mind in considering the results of the model. To illustrate the measures, consider Figure 1 which describes a situation where producers' forecast price is less than the realised price, i.e. $p_t^f < p_t$. Comparing the realised market outcome associated with $p_t$ and $q_t$ with the perfect foresight market outcome associated with $p_t^*$ and $q_t^*$, there is a change in consumers surplus by area $ZCp_t^* - ZBp_t = p_tBDp_t^* + BCD$ and a change in producers' quasi-rents by the area $p_t^*CX - p_tBGX = -p_tBDp_t^* + DCG$. Aggregating, the net change in social surplus is

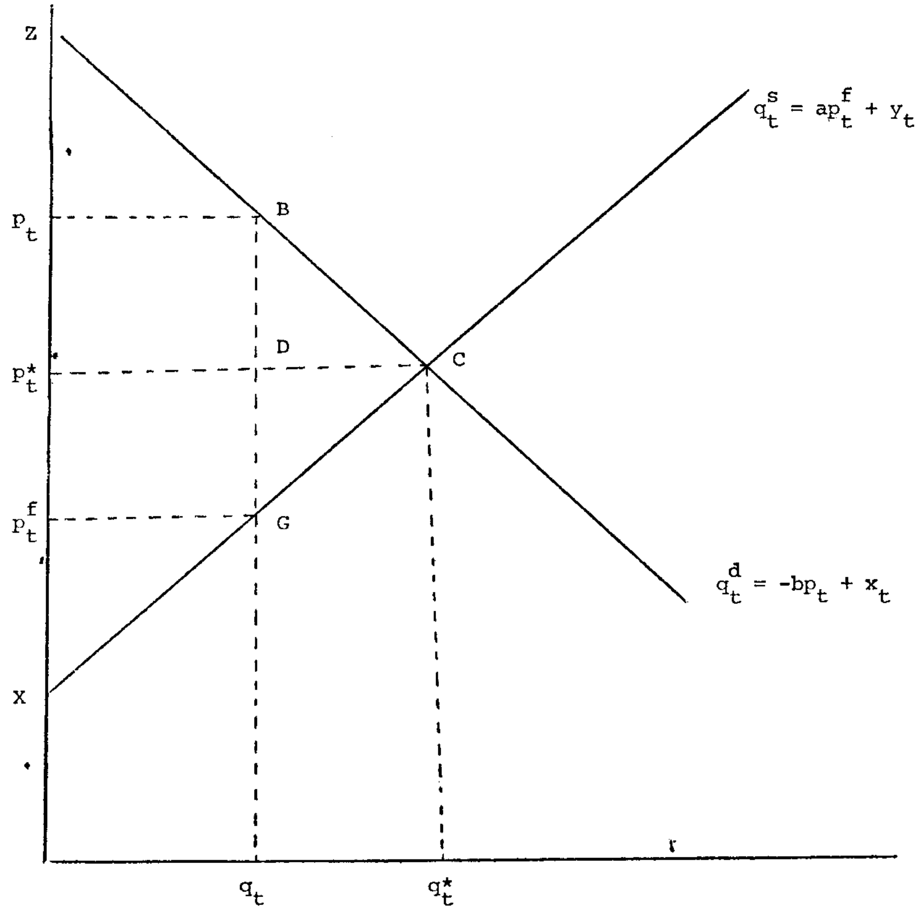


FIGURE 1

given by area *BCG*. A similar analysis can be made for the situation in which producers' forecast price is greater than the realised price. More generally, the welfare effects on consumers, producers and society of producers using the perfect foresight price $p_t^*$ relative to the forecast price $p_t^f$ in their production decision can be measured in terms of the areas of rectangles and triangles as

$$(9) \qquad W_c = (p_t - p_t^*)q_t + \tfrac{1}{2}(p_t - p_t^*)(q_t^* - q_t),$$

$$(10) \qquad W_p = -(p_t - p_t^*)q_t + \tfrac{1}{2}(p_t^* - p_t^f)(q_t^* - q_t) \text{ and}$$

$$(11) \qquad W = W_c + W_p = \tfrac{1}{2}(p_t - p_t^f)(q_t^* - q_t)$$

where $W_c$ denotes change in consumers' welfare, $W_p$ denotes change in producers' welfare, $W$ denotes change in social welfare, $p_t^*$ and $q_t^*$ are the perfect foresight market price and quantity, $p_t^f$ is producers' forecast price, and $p_t$ and $q_t$ are the realised market price and quantity associated with $p_t^f$.

Adopting a proposal by Muth [3, pp. 316-318] that producers' rational forecast prices will be approximately unbiased, and by implication that the mean estimates of $x_t$ and $y_t$ will be unbiased, useful expressions for the expected values of the welfare measures of (9), (10) and

(11) may be derived.[4] Then, following a number of algebraic manipulations (which may be obtained from the author), the expected welfare effects on consumers, producers and society of producers using perfect foresight prices relative to the rational forecast price in supply decision making can be derived as

$$(12)\quad E(W_c) = \frac{a}{2b(a+b)^2}\{a\sigma_{xx} - (a+2b)\sigma_{yy} + 2b\sigma_{xy}\}$$

$$(13)\quad E(W_p) = \frac{a}{2b(a+b)^2}\{b\sigma_{xx} + (2a+3b)\sigma_{yy} - (2a+4b)\sigma_{xy}\},$$

and

$$(14)\quad E(W) = \frac{a}{2b(a+b)}\{\sigma_{xx} + \sigma_{yy} - 2\sigma_{xy}\}$$

where $E(W_c)$ denotes expected consumers' welfare effect, $E(W_p)$ denotes expected producers' welfare effect, $E(W)$ denotes expected social welfare effect, and all other terms are as defined above.

The three expressions (12), (13) and (14) may be used to evaluate the expected welfare effects on consumers, producers and society of producers using rational forecast prices in their production decisions which are based on more accurate information about factors influencing the demand for and supply of a commodity. More accurate information is measured in terms of reductions in the variances $\sigma_{xx}$ and $\sigma_{yy}$.[5] That is, additional and more accurate information about factors affecting demand for the commodity, e.g. the levels of economic activity, would be reflected in a reduction of $\sigma_{xx}$, and more accurate information about factors affecting the supply of the commodity, e.g. future seasonal conditions, would be reflected in a reduction of $\sigma_{yy}$.

The magnitude and distribution of the welfare effects of reductions in the variance terms can be ascertained with the aid of the partial derivatives reported in Table 1. More precise estimates of either the demand or supply curve shift variables result in a net gain of social welfare. The gain is greater the greater the price elasticities of demand and supply. Both producers and consumers gain from more accurate information about the demand curve shift variables with producers gaining more than consumers if $b > a$, i.e. if the demand curve is more elastic than the supply curve, and vice-versa, and in the limiting case of a perfectly elastic demand curve, i.e. $b \rightarrow \infty$, all the gains go to producers. More precise information about the supply curve shift variables will improve the welfare of producers and worsen that of consumers, with the consumers' loss being smaller the more elastic the demand curve and in the limiting case of a perfectly elastic demand curve, i.e. $b \rightarrow \infty$, the consumer loss becomes zero. In all cases the welfare gains or losses are strictly proportional to changes in the variances $\sigma_{xx}$ and $\sigma_{yy}$.

[4] The unbiasedness asumption can be relaxed. In the expressions for E(W) in (14) the right hand term in {} brackets would become

$$E\{(x_t - \mu_x)^2 + (y_t - \mu_y)^2 - 2(x_t - \mu_x)(y_t - \mu_y)\}$$

which will include bias as well as variance terms. The expressions for producers' and consumers' welfare effects are more complex.

[5] In some applications it may be desirable to consider also changes in the covariance $\sigma_{xy}$. Here we ignore $\sigma_{xy}$ for simplicity.

TABLE 1

*Marginal Welfare Effects of More Accurate Market Outlook Information*

| | Expected Producer Welfare $E(W_p)$ | Expected Consumer Welfare $E(W_c)$ | Expected Society Welfare $E(W)$ |
|---|---|---|---|
| Demand Curve Shift Factors: $\partial E(W_i)/\partial\sigma_{xx}$ | $a/2(a+b)^2$ $>0$ | $a^2/2b(a+b)^2$ $>0$ | $a/2b(a+b)$ $>0$ |
| Supply Curve Shift Factors: $\partial E(W_i)\partial\sigma_{yy}$ | $(2a^2+3ab)/$ $2b(a+b)^2$ $>0$ | $-(a^2+2ab)/$ $2b(a+b)^2$ $>0$ | $a/2b(a+b)$ $>0$ |

## *Many Commodities Model*

While the basic model discussed above was a partial equilibrium model focussing on a single commodity, many potentially interesting applications require some consideration of the interdependent relationships between the demand for and supply of different commodities. Here the basic model is extended for a situation of $n$ commodities in which the supply of and demand for a commodity may be influenced by the prices of other commodities as well as its own price.

The mode of analysis is similar to that adopted in the basic model except that matrix terminology is used. That is, the model of market behaviour of the $n$ commodities is assumed to be

(15) $$q_t^d = -Bp_t + x_t,$$

(16) $$q_t^s = Ap_t^f + y_t, \text{ and}$$

(17) $$q_t^d = q_t^s = q_t$$

where $q_t^d$ is an $n$ vector of quantities demanded, $q_t^s$ is an $n$ vector of quantities supplied, $p_t$ is an $n$ vector of realized market prices, $p_t^f$ is an $n$ vector of producers' forecast prices formed from information available in period $t-1$, $A$ and $B$ are $n \times n$ matrices of known parameters, and $x_t$ and $y_t$ are $n$ vectors of stochastic terms. A typical element of A, say $a_{ij}$, describes the effect of producers' forecast price for the $j$th commodity on quantity supplied of the $i$th commodity. Similarly, a typical element of B, say $b_{ij}$, describes the effect of price $j$ on the demand for good $i$. Note that the signs of $a_{ij}$'s and $b_{ij}$'s are not prespecified, although it is reasonable to treat the diagonal terms as positive. The elements of $x_t$ and $y_t$ include the effects of all non-price variables on the quantities demanded and supplied, respectively. As before, at the time production decisions are taken producers are assumed to have less than perfect knowledge about the elements of the $x_t$ and $y_t$ vectors.

The information available to producers about the unknown elements in $x_t$ and $y_t$ in period $t-1$ when production decisions are taken is assumed to be represented by a distribution function with mean and covariances

(18) $$E(x_{it}) = \mu_{x_i},\ E(y_{it}) = \mu_{y_i},\ \mathrm{Cov}(x_{it}x_{jt}) = \sigma_{x_i x_j},$$
$$\mathrm{Cov}(y_{it}y_{jt}) = \sigma_{y_i y_j} \text{ and } \mathrm{Cov}(x_{it}y_{jt}) = \sigma_{x_i y_j}$$
$$\text{for } i, j = 1, 2, \ldots, n$$

Then, for the market described in (15), (16) and (17) and for producers' information described in (18), the vector of producers' rational forecast prices for the $n$ commodities is given by

(19) $$p_t^f = E(p_t) = [A + B]^{-1} (\mu_x - \mu_y)$$

where $\mu_x = \{\mu_{x_i}\}$, $\mu_y = \{\mu_{y_i}\}$ and all other terms are as defined above.

Following the procedures employed for analysis of the basic model, the expected social welfare effects of producers using the vector of perfect foresight prices rather than the vector of rational forecast prices of (19) in their production decisions can be shown to be

(20) $$E(W) = \text{trace } (E\{[(x_t - \mu_x) - (y_t - \mu_y)][(x_t - \mu_x) - (y_t - \mu_y)]'\}[B'^{-1} A[A + B]^{-1}])$$

where all terms are defined above. Expansion of the right hand term within the expectation brackets will involve the covariance elements of (18). Then, the expected social welfare effects of increases in the accuracy of information about the demand and supply curve shift variables, where the increased accuracy is reflected as reduced variance terms, can be ascertained from finding the partial derivatives of $E(W)$ in (20) with respect to the relevant variance terms.

Unfortunately, for the general case of $n$ (for $n > 2$) commodities the welfare effects of more accurate rational forecast prices are not amenable to easy interpretation in the form of algebraic expressions such as those of (14) for the single commodity case. For the general case it will be necessary to substitute specific values for the parameters of the $A$ and $B$ matrices and consider each numerical situation.

An interesting special case which is amenable to algebraic manipulation is one involving two commodities with no demand interrelationships and with a competitive interrelationship at the supply level. Consider the market situation described by

(21.1) $q_{1t}^d = -b_{11}p_{1t} + x_{1t}, \qquad b_{11} > 0$
(21.2) $q_{2t}^d = -b_{22}p_{2t} + x_{2t}, \qquad b_{22} > 0$
(22.1) $q_{1t}^s = a_{11}p_{1t}^f - a_{12}p_{2t}^f + y_{1t}, \qquad a_{11} > a_{12} > 0$
(22.2) $q_{2t}^s = -a_{21}p_{1t}^f + a_{22}p_{2t}^f + y_{2t}, \quad a_{22} > a_{21} > 0$
(23.1) $q_{1t}^d = q_{1t}^s$, and
(23.2) $q_{2t}^d = q_{2t}^s$

where (21), (22) and (23) are special cases of the model described in (15), (16) and (17), respectively. Now, applying (20) and using Cramer's rule to find the inverse matrices $B'^{-1}$ and $[A + B]^{-1}$, the expected social welfare effects of producers using perfect foresight prices rather than rational forecast prices described in (19) may be derived as

(24) $$\begin{aligned} E(W) = {} & \tfrac{1}{2}d_{11}(\sigma_{x_1 x_1} + \sigma_{y_1 y_1} - 2\sigma_{x_1 y_1}) \\ & + \tfrac{1}{2}d_{22}(\sigma_{x_2 x_2} + \sigma_{y_2 y_2} - 2\sigma_{x_2 y_2}) \\ & + \tfrac{1}{2}(d_{12} + d_{21})(\sigma_{x_1 x_2} + \sigma_{y_1 y_2} - \sigma_{x_1 y_2} - \sigma_{x_2 y_1}) \end{aligned}$$

where

(24.1) $d_{11} = |A + B|^{-1}|B|^{-1}b_{22}(a_{11}a_{22} + a_{11}b_{22} - a_{12}a_{21}) > 0,$
(24.2) $d_{22} = |A + B|^{-1}|B|^{-1}b_{11}(a_{11}a_{22} + a_{22}b_{11} - a_{12}a_{21}) > 0,$
(24.3) $d_{12} = -|A + B|^{-1}|B|^{-1}b_{11}a_{12}b_{22} < 0$, and
(24.4) $d_{21} = -|A + B|^{-1}|B|^{-1}b_{11}a_{21}b_{22} < 0.$

The signs of $d_{11}$, $d_{12}$, $d_{21}$ and $d_{22}$ may be derived from the constraints on the parameters $b_{11}$, $b_{22}$, $a_{11}$, $a_{12}$, $a_{21}$ and $a_{22}$ specified in (21) and (22).

From (24) at least three observations are of interest. The welfare gains from perfect foresight are greater if there is a negative correlation between the errors in forecasting either the variables causing shifts in the demand curves for the two commodities and/or the variables causing shifts in the supply curves for the two commodities, i.e. if $\sigma_{x_1 x_2}$ or $\sigma_{y_1 y_2}$ or both are negative, than if the forecast errors are uncorrelated or positively correlated. That is, a tendency to under- or over-forecast shifts in the demand (or supply) curves for two supply-competitive commodities involves a smaller loss of welfare than a tendency to under-forecast for one commodity and over-forecast for the other commodity.[6]

The second observation from (24) is that additional information which results in more precise estimates of any of the variables causing shifts in the demand and supply curves for the two commodities leads to increases in social welfare. As before, the additional information is reflected in reductions of the variance terms $\sigma_{x_1 x_1}$, $\sigma_{x_2 x_2}$, $\sigma_{y_1 y_1}$ and $\sigma_{y_2 y_2}$, and the result follows from the non-negativity of $d_{11}$ and $d_{22}$.

But, and this is the third observation, using the basic or partial equilibrium model to estimate the marginal social welfare gain of an increase in the precision of the rational forecast price will over-estimate the welfare gain. Expanding $d_{11}$ in (21.1) gives

$$d_{11} = \frac{a_{11} - k}{b_{11}(a_{11} + b_{11} - k)} \tag{25}$$

with

$$k = \frac{a_{12}\, a_{21}}{a_{22} + b_{22}} \tag{26}$$

Recall also that $d_{11}$ is the derivative of $E(W)$ in (24) with respect to $\sigma_{x_1 x_1}$ or $\sigma_{y_1 y_1}$. By contrast, for the basic model the derivative of $E(W)$ in (14) with respect to $\sigma_{x_1 x_1}$ or $\sigma_{y_1 y_1}$ is given by $a_{11}/((a_{11} + b_{11})b_{11})$ which is greater than (25) since $k$ in (26) $> 0$. From (25) and (26) the extent of the over-estimate depends on the relative magnitudes of all of the price parameters of the supply and demand curves, however, it approaches zero as either $a_{12}$ or $a_{21}$ or both approach zero.

Before proceeding it should be noted that the three observations are specific to the particular situation of two commodities which have interdependent price relationships at the supply level. It has not been possible to ascertain whether the qualitative results continue to hold for $n$ ($n > 2$) supply competitive commodities. At this stage it would seem necessary to consider each situation as a numerical analysis based on expression (20).

### *Partial Use of Rational Forecast Price*

So far it has been assumed that producers base their supply decisions entirely on the rational forecast price. A potentially interesting variant is to allow producers to use a blend of the rational forecast price and some other price. Examples of the latter include the previous price or some average of recent prices.

[6] The converse result would arise if the pair of commodities were complimentary, i.e. $a_{12}$ and $a_{21}$ would be negative and $d_{12}$ and $d_{21}$ would then be positive.

In algebraic terms the model extension is represented as the basic model described in expressions (1), (2) and (3) with an additional expression for the way in which producers' forecast price is formed, viz.

$$p_t^f = gE(p_t) + (1 - g)p_t^o, \; 0 \leqslant g \leqslant 1 \tag{27}$$

where $p_t^f$ and $E(p_t)$ represent, as before, producers' forecast price and the rational forecast price, respectively, $p_t^o$ denotes some initial forecast price, e.g. the previous periods' realised price, and $g$ is a proportionality constant. In practice $g$ might represent the proportion of producers who believe or are aware of the rational forecast price and use it to determine their production decision.

For the extended model it is useful to distinguish two alternative versions of the rational forecast price. In the first or simpler version the agency generating the rational forecast price proceeds under the assumption that all producers will follow its forecast price, i,e, it is assumed $g =$ unity. Then, $E(p_t)$ in (27) will be given by

$$E(p_t) = (\mu_x - \mu_y)/(a + b) \tag{27.1}$$

where, as before, $\mu_x$ and $\mu_y$ are the mean estimates of the demand curve and supply curve random intercept terms, respectively. In a second and more sophisticated version the agency generating the rational forecast price takes into consideration producers' initial forecast price $p_t^o$ and producers' reaction to its rational forecast price. Then, for the agency's mean estimate of $g$ and $p_t^o$, denoted by $\overline{g}$ and $\overline{p}_t^o$, $E(p_t)$ in (27) will be given by

$$E(p_t) = (\mu_x - \mu_y)/(a\overline{g} + b) - a(1 - g)\overline{p}_t^o/(a\overline{g} + b) \tag{27.2}$$

where all terms are as defined above.

The welfare effects on consumers, producers and society of producers using perfect foresight prices rather than the forecast price $p_t^f$ specified in (27) in their supply decisions are given by the basic model formulae reported in (9), (10) and (11). That is, the model of analysis remains as for the basic model with the exception that producers' forecast price is given by (27) rather than by (7). While it is not possible to derive simple algebraic expressions of the form of (12), (13) and (14) to evaluate the welfare effects of increases in the accuracy of information about the demand and supply curve shift variables it is apparent that the qualitative results of the basic model continue to hold. That is, that more precise forecasts of the demand shift variables increase the welfare of both producers and consumers, and that more precise forecasts of the supply shift variables increase the welfare of producers and decrease the welfare of consumers with a net social gain. In order to quantify the welfare changes it would seem necessary to conduct simulation experiments using formulae (9), (10) and (11) for different levels of the variance terms $\sigma_{xx}$ and $\sigma_{yy}$.

### *Inclusion of Inventories*

A key assumption of the basic model presented above is that the realised price is set such that the quantity produced each period is purchased for consumption in that period. In effect the assumption rules out changes in the levels of inventories or stocks. For some storable commodities inventory changes may have an important influence on the realised market price. For these situations it is desirable to extend the model to include inventory behaviour.

Here, the basic model is extended to include an inventory behaviour equation and the market clearing identity is altered. Changes in the level of inventories are assumed to be a function of the difference between an expected price and the realised market price and of a random index term representing the effects of non-price factors. The former term is based on the idea of rational profit maximizing behaviour. In algebraic terms the extended model may be represented as

$$q_t^d = -bp_t + x_t, \tag{28}$$

$$q_t^s = ap_t^f + y_t, \tag{29}$$

$$s_t = c(E(p_t) - p_t) + w_t, \text{ and} \tag{30}$$

$$q_t^d + s_t = q_t^s + s_{t-1} \tag{31}$$

where $s_t$ denotes inventory of stocks at end of period $t$, $E(p_t)$ denotes expected price, $c$ is a known positive parameter, $w_t$ is a random term, and all other terms are as specified for the basic model.

For the simplifying assumption that producers' forecast price $p_t^f$ in (29) is approximately the same as the inventory holders' expected price $E(p_t)$ in (30), the extended model (28) through (31) may be restated in the same format as the basic model (1), (2) and (3). At least at the conceptual level the simplifying assumption appears reasonable for a situation of stationary expectations, however, it needs to be considered on its merits for each commodity situation. Accepting the assumption as a reasonable approximation, and substituting and rearranging terms, the model (28) through (31) may be restated as

$$q_t'^d = -b'p_t + x_t' \tag{32}$$

$$q_t'^s = a'E(p_t) + y_t', \text{ and} \tag{33}$$

$$q_t'^d = q_t'^s = q_t' \tag{34}$$

where $E(p_t) = p_t^f$, $b' = (b + c)$, $a' = (a - c)$, $x_t' = (x_t + w_t)$, $y_t' = (y_t + s_{t-1})$, and all other terms are as defined for (28) through (31). Using (32), (33) and (34) the welfare effects of additional information about the random terms $x_t$, $y_t$ and $w_t$ may be analysed using the procedures and results of the basic model.

## *Some Concluding Comments*

The potential welfare gains from providing agricultural producers with more accurate commodity forecast prices stems from the increased efficiency with which resources are allocated to alternative production activities. Realization of the potential gains will depend on the extent to which additional research activities can be used to generate additional information concerning the future demand for and supply of commodities, the extent to which the additional information is conveyed to producers, and to the extent which producers are able and willing to incorporate the additional information in forming the forecast prices on which they base their decisions.

In the context of Australian agriculture it seems more likely that more accurate information can be obtained about factors affecting the demand for than the supply of commodities. The former includes information about such variables as levels of economic activity at home and abroad, stocks at home and abroad, and national and trade policies affecting demand for exports. The most important supply shift variable is seasonal conditions and here improvements in the accuracy of longer-term meteorological forecasts are involved. In this situation additional investment in market outlook activities will benefit both producers and consumers. The share of the benefits between domestic consumers, foreign consumers and producers will depend on the relative elasticities of supply and demand, with producers' gains being relatively more important the more elastic the demand curve, and on the proportion of output exported.

## *References*

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