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CONTRADICTORY PREDICTIONS ON SUPPLY RESPONSE UNDER STABILIZATION: A RECONCILIATION

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Abstract

Two separate bodies of literature on stabilization give radically different results, yet these contradictions do not appear to have attracted any attention until now. The first arises from the neoclassical theory of stabilization and predicts that beneficial stabilization will always attract positive supply response. The second arises from the work of Newbery and Stiglitz and predicts 'perverse' supply response for highly risk-averse producers. In this paper, the differences which yield these results are described and some suggestions are made for a generalized model.

CONTRADICTORY PREDICTIONS ON SUPPLY RESPONSE UNDER STABILIZATION: A RECONCILIATION

One of the major grounds for proposing price stabilization schemes is the belief that, in the absence of stabilization, producers subject to risk will hold output below the socially optimal level. This belief is based on the neoclassical model of the firm under uncertainty, due to Sandmo (1971). A debate about the validity of this rationale for stabilization (Blandford and Currie, Colman, Quiggin and Anderson 1979) has proceeded in parallel with the large literature on buffer stock stabilization arising from the work of Waugh, Oi and Massell, in which risk considerations were largely ignored.

The publication of a major work on the theory of buffer stock stabilization by Newbery and Stiglitz has put risk, and its effects on supply, at centre stage in the analysis of stabilization. However Newbery and Stiglitz do not refer to the neoclassical literature on stabilization and risk-reduction arising from the work of Sandmo. Results derived using the Newbery-Stiglitz framework differ in important respects from those which were taken as common ground by participants in the debate over the risk-reduction rationale for stabilization.

Perhaps the most important area of divergence is that of supply response to stabilization, where the two frameworks yield directly contradictory results. For example, Quiggin (1983), using the neoclassical model, shows that price underwriting will always yield a positive supply response when producers are risk-averse. By contrast, Fraser (1988) using a Newbery-Stiglitz model, shows that underwriting will yield a negative supply response for sufficiently risk-averse producers. Similarly, Quiggin and Anderson (1981) show that price band stabilization will always yield a positive supply response when producers are risk-averse. Once again, the Newbery-Stiglitz model yields a contrary result (Fraser 1989).

A number of the key results in the Newbery-Stiglitz framework depend on the surprising fact that individuals with a constant coefficient of relative risk aversion greater than 1 will display 'backward bending' supply of labor. This linkage between the theory of choice under uncertainty and the theory of labor supply under certainty is vitally important for the analysis of the long-run effects of stabilization.

The purpose of this note is to examine the results of Newbery and Stiglitz and to compare their results with those which arise from an alternative formulation of the theory of the firm under uncertainty, due to Sandmo. It is shown that although the latter model supports the view that beneficial stabilization increases output, it is also possible for price policies which make producers worse off to yield increased output, and for policies which initially benefit producers to make them worse off in the long run.

The Newbery-Stiglitz and neoclassical models

Labor supply plays a key role in the analysis of stabilization undertaken by Newbery and Stiglitz, based on the assumptions that labor is the sole factor of production and has a zero opportunity cost (apart from the disutility of effort). The optimal labor supply problem may be written as

(1) $\text{Max}_x \; W = U(y) - v(x),$

where:

(2) $y = p(z,\square)\square x$;

- y is gross revenue;
- x is labor input;
- U is a von Neumann Morgenstern-Utility function;
- v is the disutility of effort;
- □ is a random yield parameter;
- □ is a random parameter affecting demand;
- p is output price; and
- z is a parameter reflecting the degree of stabilization ($z = 0$ corresponds to no stabilization, $z = 1$ corresponds to complete stabilization).

Because the Newbery-Stiglitz model contains only a single-input, there is no distinction between input, yield and price uncertainty in this model. For simplicity, and without loss of generality, attention will be focused on the case of demand side instability, where □ is identically equal to 1.

The crucial results of the Newbery-Stiglitz model depend on the coefficient of relative risk-aversion, given by $R = -U''(y)y/U'(y)$, which is normally assumed to be constant. The coefficient of relative risk-aversion is a measure of willingness to bear risks expressed as a proportion of wealth or income. Note that R is meaningful only for positive values of y.

There is a surprising link between risk-aversion under uncertainty and labor supply under certainty. Assume in (1) that p is known with certainty (that is, □ may be observed) at the time production decisions are made. In the terminology of Quiggin and Anderson (1979), p is subject to variability but not to risk. The model is now applicable both to the decisions of a producer facing no uncertainty and to the labor supply decision of a worker facing a known wage offer. The optimal labor supply decision must satisfy the first-order condition:

(3) $\partial W/\partial x = pU'(px) - v'(x) = 0,$

and the second-order condition

(4) $D = \partial^2 W/\partial x^2 = p^2 U''(px) - v''(x) < 0.$

Differentiation of (3) with respect to p yields

(5) $pxU''(px) + U'(px) + \partial x/\partial p\ \partial^2 v/\partial x^2 = 0,$

or

(6) $\partial x/\partial p = -1/D\ (1-R)\ U'(px).$

Since U' is positive, the supply of labor is backward-bending whenever R is greater than unity. Newbery and Stiglitz (p307) derive a related formula in the context of a stability analysis, but do not comment on its implications.

The linkage between risk attitudes and labor supply reflects the fact that, in Expected Utility theory, risk-aversion derives from diminishing marginal utility of income. In a separable utility function with leisure and income as the arguments, this implies that leisure is a superior good. The statement that $R > 1$ means that the income effect of an increase in wages (captured by the term $pxU''(px)$) outweighs the substitution effect (captured by the term $U'(px)$). In the Newbery-Stiglitz model, this implies perverse supply response[1]. This result is by no means a theoretical curiosity, occurring only for extreme levels of risk aversion. Newbery and Stiglitz (Ch 7) consider a range of empirical evidence on risk aversion suggesting values of R between 0 and 2, with most preferred estimates being near 1.

The assumptions of the Newbery-Stiglitz model differ from those of the neoclassical model of the firm under uncertainty (Sandmo)[2] in which all inputs are purchased in competitive factor markets and the objective is to maximize the expected utility of net profits (revenues minus factor costs). In many ways, the Newbery-Stiglitz model seems more

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1 Note that this form of perverse supply response is analytically distinct from that analyzed by Zilberman and Just (1986) which arises only in the presence of multiple sources of uncertainty.

2 A model of this kind is also employed briefly by Newbery and Stiglitz (Chapter 23), though the differences between the two models are not discussed.

appealing than the standard model as a description of the situation facing peasant producers of cash crops, the group for whom the issue of buffer stock stabilization is most relevant. However, most farms will use some inputs other than operator and family labor. Also operator, and especially family, labor will normally have some alternative outlet available.

Moreover, there is at least one commodity, until recently subject to buffer stock stabilization, for which the Newbery-Stiglitz model is clearly less appropriate than the neoclassical model. From 1973 to 1990, the Australian Wool Corporation operated a buffer stock scheme aimed at stabilizing the world price of wool in Australian dollar terms. As Australia is the dominant supplier in this market, accounting for about 65 per cent of total world supply, it has been possible for a stabilization scheme to operate on a unilateral basis. It is clear that the peasant producer model is inappropriate for Australian wool growers.

It is important, then, to consider the implications of a neoclassical model and to see how the results of Newbery and Stiglitz are affected by this change in specification. For simplicity, and ease of comparison with the Newbery-Stiglitz model, attention will be confined to the case of constant scale returns. Also, because input prices are assumed to be known when production decisions are made, cost minimizing production techniques will always be employed, and hence there is no loss of generality in assuming a single composite input. For ease of comparison with the Newbery-Stiglitz model, this input will be referred to as 'labor'.

The neoclassical objective function is

(7) $$W = \mathrm{E}[U(\pi)],$$

where:

(8) $$\pi = y - wx\,;$$
$$y = p(z, \square)x\,;$$

π is net profit; and

w is the opportunity cost of labor;

If this model is to be interesting, it is necessary that $\Pr\{p<w\} > 0$, since otherwise there is no possibility of loss and the firm will produce an infinite amount. But this implies that the simplifying assumption of constant relative risk-aversion, central to the analysis of Newbery and Stiglitz, cannot be applied, since the coefficient of relative risk-aversion is not defined for zero or negative values.

It should be noted that this problem can not be avoided by allowing marginal cost to be increasing in y, as in the Sandmo model. If an equilibrium is to exist, it must be true that

$\Pr\{p<C'(y)\} > 0$ at the equilibrium point [3]. The possibility of negative values of π can be eliminated by assuming an initial wealth W_0, larger than the maximum possible value of $(w-p)x$, or, more realistically, by incorporating bankruptcy. However, even if these options are used, analysis in terms of the coefficient of relative risk-aversion is not tractable. A weaker condition, implied by constant relative risk-aversion, is that of decreasing absolute risk-aversion (DARA), and this is sufficient to obtain strong results in the neoclassical model.

Most of the analysis undertaken using the neoclassical model model has concerned the impact of shifts in mean prices and of mean-preserving changes in the riskiness of prices. It is natural in the context of the theory of the firm to suggest that both increases in mean price and reductions on risk will lead to increases in output.

Sandmo shows that DARA is a sufficient condition for an increase in mean price to yield an increase in supply. Coes examines the case of a multiplicative reduction in risk which may be represented as a transformation of the distribution of p from an initial distribution p_0 to $(1-z)p_0 + z\mathrm{E}[p_0]$, where z is a parameter representing the degree of stabilization. He shows that DARA is a sufficient condition for an increase in z to yield an increase in output. Quiggin (1991) describes a more general class of reductions in risk for which this is true.

Thus, whereas the Newbery-Stiglitz model yields negative supply response to both increases in mean price and mean-preserving reductions in risk whenever the (constant) coefficient of risk-aversion is greater than 1, the neoclassical model yields positive supply response for both types of change. However, the analysis of Newbery and Stiglitz raises the important point that stabilization will not normally result in a mean-preserving change in the distribution of prices. They focus attention on the relationship between (short-run) welfare effects, that is, the effects of the change in the distribution of prices on producers' welfare derived on the assumption of constant effort, and output changes. In this context the natural hypothesis is that changes in the distribution of prices which increase welfare will lead to increased output. These results given above are not sufficient to show that, in the neoclassical model, welfare-increasing changes in the distribution of prices will generally lead to an increase in expected output. This conjecture will be examined below.

A Generalized model

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[3] Provided this condition is satisfied as y approaches infinity, very weak conditions on the utility function suffice to ensure the existence of a finite optimum output (Quiggin 1982a).

It has been shown above that the Newbery-Stiglitz and neoclassical models give radically different predictions of supply response under stabilization. A useful way of comparing the two models is in the context of a generalized model of the form[4]

(9) $\quad \text{Max}_x \; W = E[V(x,y)],$

where

(10) $\quad y = xp(z, \square)$ is gross revenue.

This model has the first-order condition

(11) $\quad \frac{\partial W}{\partial x} = E\,[V_1] + E\left(V_2 \frac{\partial y}{\partial x}\right) = E[V_1] + E[p\, V_2] = 0,$

where V_i denotes the partial derivative of V with respect to its i-th argument, and second-order condition

(12) $\quad D = \frac{\partial^2 W}{\partial x^2} = E\,[V_{11}] + E[p^2\, V_{22}] < 0.$

Now suppose theprice is stabilized by a change in p. Then,

(13) $\quad \frac{\partial W}{\partial z} = E\left(\frac{\partial V}{\partial p}\frac{\partial p}{\partial z}\right) = x\, E\left(V_2 \frac{\partial p}{\partial z}\right).$

Differentiating (11) with respect to z yields

(14) $\quad \frac{\partial^2 W}{\partial x \partial z} = E\left(V_2 \frac{\partial p}{\partial z}\right) + x\, E\left(p\, V_{22} \frac{\partial p}{\partial z}\right) + E\left(x\, V_{12} \frac{\partial p}{\partial z}\right) + \frac{\partial^2 W}{\partial x^2}\frac{\partial x}{\partial z} = 0,$

and, on rearrangement

(15) $\quad \frac{\partial x}{\partial z} = -\frac{1}{D}\left(E\left[\left(V_2 + xp\, V_{22}\right)\frac{\partial p}{\partial z} + x\, V_{12}\frac{\partial p}{\partial z}\right]\right).$

It is at this point that the difference in the two models becomes crucial. In the Newbery-Stiglitz model,

(16) $\quad V(x,y) = U(y) - v(x),$

so

(17) $\quad V_{12} = 0,$

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[4] A related model is examined by Dardanoni (1988) who does not, however, consider the issues raised here.

and it is straightforward to derive

(18) $$f(\partial x,\partial z) \;=\; \_\; (1/D)\; b(E\; bbc[(b\; ((1-R)\; V_2)\; f(\partial p,\partial z))) \;,$$

and, assuming constant relative risk-aversion

(19) $$f(\partial x,\partial z) \;=\; \_\; (1/D)\; b(1-R)\; (E\; bbc[\; (\; V_2\; f(\partial p,\partial z))\;)$$

$$=\; \_\; (1/D)\;\; (1/x)\;\; (1-R)\; f(\partial W,\partial z) \;\; .$$

Since -(1/*D*) is positive by (12), this yields the Newbery-Stiglitz (p 311) result that the short-run impacts of changes in *z* (the level of price stabilization) on welfare and on output are of the same or opposite sign as relative risk-aversion is less than or greater than unity.

As previously noted, this analysis can only be applied if income is positive in every state of the world. This condition does not apply in the neoclassical model. Instead,

(20) $$V(x,y) = U(\pi) = U(y-wx),$$

so that

(21) $$V_2 = \; U'(\pi),\; V_{12} = -\; w\; U''(\pi),$$

and a more natural approach is to break up (15) as

(22) $$f(\partial x,\partial z) \;=\; \_{\,(1/D)}\; b((1/x)\; f(\partial W,\partial z) + x\; E\; bbc[(\; U''(\pi)\; (p-w)\; f(\partial p,\partial z))\;)\; .$$

It is apparent that the second expectation term will be positive provided $\partial p/\partial z$ and (*p*-*w*) have opposite signs. This will be the case for partial price-band stabilization, for example.[5] More generally, we may refer to a class of schemes involving a shrink towards the break-even point *p*⊟⊡*w*, in which *p* is increased (or unchanged) if $p<w$ and reduced if $p>w$. Any welfare-improving stabilization scheme which produces a shrink towards the break-even point will lead to an increase in output.

This result is somewhat unsatisfactory, since the break-even price is likely to differ between farmers. Using the assumption of decreasing absolute risk-aversion, it is possible to go further by observing that $U''(\pi) = -A\; U'(\pi)$, where *A* is the coefficient of absolute risk-

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5 Quiggin and Anderson (1981) proved this result for the special case of mean-preserving price band stabilization. See also Meyer and Ormiston.

aversion. Quiggin (1991) shows that, given DARA, the expectation term will be positive whenever $\partial p/\partial z$ is decreasing in □. This condition may be regarded as a defining characteristic of a stabilization scheme, since it means that high prices are reduced and low prices are increased. This terminology permits us to state that any welfare-improving stabilization scheme will yield an increase in output.

The condition that the scheme yield an increase in welfare is sufficient, but not necessary. At least some schemes which produce a reduction in risk at the expense of a reduction in mean price, sufficient to make producers worse off over all, will nevertheless yield an increase in output.[6] This implies that the long-run equilibrium will have an even lower mean price and the adverse impact on producers will be greater in the long term than in the short term. Also, it is possible for producers' supply response to result in a change of sign in the welfare effect from the short term level. This may be shown by considering a scheme where the short-run welfare effects are exactly neutral. As the discussion above indicates, such a scheme will lead to an increase in supply, and the long-run equilibrium must involve a reduction in producer welfare.

Thus, although the basic neoclassical model yields the results that supply will respond positively to increases in mean price and to reductions in risk, it does not support the natural hypothesis that supply will always respond positively to increases in welfare. Rather, it indicates that price risk has a supply-reducing effect over and above its effect on producer welfare.

One approach to the resolution of the differences between the two models is to combine them into a model in which the operator and family labor is allocated between farm activities and off-farm employment. Thus, the decision problem is

$$\text{(23)} \qquad \mathrm{Max}_{x1,\,x2}\ \mathrm{E}[U(\pi)] - v(x_1 + x_2),$$
$$\pi = y + wx_2$$
$$y = p(z)x_1$$

where:

- x_1 is on farm-labor;
- x_2 is off-farm labor; and
- w is the off-farm wage.

Three cases of interest arise in this model. First, there is the case where $w \geq \mathrm{E}[p]$, so that all labor is allocated to the off-farm activity. This yields a simple model of labor supply

[6]Conversely, changes in the price distribution which yield higher welfare along with increased risk may elicit negative supply response.

under certainty. Second, there is the case where both x_1 and x_2 are positive. In this case, the model is essentially identical to the neoclassical model, since the first-order conditions

(24a) $$E[\, pU'(\pi)] \; -v'(x_1 + x_2) = 0$$

and

(24b) $$wE[U'(\pi)] - v'(x_1 + x_2) = 0$$

may be combined to yield

(25) $$E[U'(\pi)(p-w)] = 0$$

which is the first-order condition for the neoclassical model. Within this range, an increase in mean prices will lead to an increase in both on-farm labor and leisure at the expense of off-farm labor.

The final case of interest is that where the optimal value of x_2 is zero. The first-order conditions are

(26a) $$E[\, pU'(y)] \; - v'(x) = 0, \text{ and}$$

(26b) $$E[\, pU'(y)] \geq wE[U'(\pi)].$$

The first condition is that of the Newbery-Stiglitz model, while the second is a statement of the requirement that the market wage is below that required to attract any supply of off-farm labor.

It is useful now to consider the welfare effects of stabilization, where the effect on the price distribution is to form a weighted average $zp^*+ (1-z)p_0$ of the initial distribution p_0 and some constant value p^*. In the neoclassical case, where both x_1 and x_2 are positive, the welfare effects depend simply on whether $p^*>w$. If this condition is satisfied, then an increase in z combined with a shift from off-farm to on-farm labor will yield a distribution of income which first-order stochastically dominates the original one. Conversely, if $p^*<w$, the distribution resulting from an increase in z is worse (in the sense of first stochastic dominance) than one which could have been obtained with a higher initial level of x_2. Nevertheless, a little stabilization in this case may lead to a shift from off-farm to on-farm labor, although this pattern must be reversed for sufficiently large z.

In the Newbery-Stiglitz case, the discussion above indicates that the requirement for stabilization towards a value p^* to be beneficial in this model may be expressed as the requirement that p^* should be greater than the reservation wage, w^*, which would convert inequality (26b) into an equality. As shown above, the supply response to beneficial stabilization in this case depends only on the sign of (1-R).

Concluding comments

The debate over buffer stock stabilization has been bedevilled by seemingly minor features of the specification that lead to radical differences in the results yielded by different models. Questions of additive or multiplicative disturbances and linear or constant elasticity demand curves, normally regarded as matters of analytical or econometric convenience, have been shown to play a crucial role in determining the distribution of gains from stabilization under certainty.

The differences between the neoclassical model of the firm under uncertainty and the labor-supply model used by Newbery and Stiglitz have more economic content than, say, the differences between additive and multiplicative disturbances. Nevertheless, it is striking to observe the differences in their implications. In particular, whereas Newbery and Stiglitz conclude that producer supply response can be ignored for values of the relative risk-aversion coefficient which are close to unity, and present their estimates on this basis, the neoclassical model yields the conclusion that supply response to beneficial stabilization will always be positive.

The analysis that is presented here supports the view that, in most realistic cases, supply response to risk-reduction will be positive. However, it is necessary to form an accurate model of the decision problem facing producers before assuming positive supply response, or estimating the likely magnitude of supply response. As has been shown here, an incorrect specification may generate estimates of supply response that are not merely inaccurate but have the wrong sign.

References

Blandford, D. and Currie, J.M. (1975), 'Price uncertainty - the case for government intervention', *Journal of Agricultural Economics* 26(1), 37-52.

Coes, D. (1977), 'Firm output and changes in uncertainty', *American Economic Review* 67(2), 249-51.

Colman, D. (1978), 'Some aspects of economics of stabilisation', *Journal of Agricultural Economics* 29(3), 243-56.

Dardanoni, V. (1988), 'Optimal choice under uncertainty: The case of two-argument utility functions', *Economic Journal* 98(2), 429-50.

Fraser, R.W. (1988), 'A method for evaluating supply response to price underwriting', *Australian Journal of Agricultural Economics* 32(1), 22-36.

______________ (1989), 'Evaluating producer benefits from price stabilization', paper presented at 33rd Australian Agricultural Economics Society Conference, Christchurch.

Just, R. and Zilberman, D. (1986), 'Does the law of supply hold under uncertainty?', *Economic Journal* 96(2), 514-24.

Massell, B.F. (1969), 'Price stabilisation and welfare', *Quarterly Journal of Economics* 83(2), 284-98.

Meyer, J. and Ormiston, M. (1983), 'Comparative statics of cumulative distribution changes for the class of risk-averse agents', *Journal of Economic Theory* 31(1), 153-69.

Newbery, D. and Stiglitz, J. (1981), *The Theory Of Commodity Price Stabilisation - A Study In The Economics Of Risk*, Oxford University Press, Oxford.

Oi, W. (1961), 'The desirability of price instability under perfect competition', *Econometrica* 29(1), 58-64.

Quiggin, J. (1982a), 'A note on the existence of a competitive optimum', *Economic Record* 55(161), 174-6.

_______ (1983), 'Underwriting agricultural commodity prices', *Australian Journal of Agricultural Economics* 27(3), 200-11.

_______ ‘Comparative statics for Rank-Dependent Expected Utility theory’, *Journal of Risk and Uncertainty* 4(4), 339-50.

_______ and Anderson, J. (1979), ‘Stabilisation and risk reduction in Australian agriculture’, *Australian Journal of Agricultural Economics* 23(3), 191-206.

______________________ (1981), 'Price bands and buffer funds', *Economic Record* 57(156), 67-73.

Sandmo, A. (1971), ‘The competitive firm under output price uncertainty’, *American Economic Review* 61(1), 65-73.

Waugh, F. (1944), ‘Does the consumer benefit from price instability?’, *Quarterly Journal of Economics* 58(3), 602-14.

Yaari, M. (1987), ‘The dual theory of choice under risk’, *Econometrica* 55(1), 95-115.