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UNDERWRITING AGRICULTURAL COMMODITY PRICES

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Underwriting schemes are increasingly being used as a basis for price policy in Australian agricultural industries. These policies simultaneously increase average returns and reduce the risk faced by producers. In this paper, conditions are discussed under which such a combination of policy targets may be desirable. The optimality properties of underwriting schemes in achieving these targets are examined and compared to those of alternative schemes. Aspects of underwriting scheme design are discussed.

Introduction

Underwriting is becoming increasingly popular in Australia as a form of assistance to industries faced with fluctuating prices. Underwriting schemes have been proposed or implemented for a number of industries, including dairying, wheat and apples. Similar schemes have been employed overseas under a variety of names, including 'deficiency payments', 'target prices', and 'supplementary minimum prices'. Despite this, relatively little work has been done to compare underwriting with other forms of assistance. Authors writing on the subject have dealt mainly with the operational characteristics of various schemes and the empirical analysis of supply response (Just 1975; Gallagher 1978).

In this paper, the optimality properties of underwriting schemes are analysed in an attempt to rationalise their intuitive appeal. This will enable the formulation of some guidelines, which will assist an assessment of whether underwriting should be a preferred method of assistance to a particular industry, or whether some other option, possibly non-intervention, is preferable. Essentially, these guidelines require that both a case for an output-oriented subsidy and a case for government intervention to reduce risk must be made before underwriting is considered. In this analysis, underwriting will be compared to fixed subsidies and to stabilisation schemes based on buffer funds.

A delineation of the essential differences between underwriting and stabilisation schemes is made in the next section. Then the arguments for subsidies to agricultural industries and for government intervention to reduce risk are discussed. In circumstances where these conditions apply, underwriting schemes are shown to be optimal within the class of pure subsidy schemes and to result in increased output for all risk-averse producers. Finally, some aspects of underwriting scheme design are considered.

Underwriting and Stabilisation

The crucial characteristic of an underwriting scheme is the formulation of a guaranteed minimum price. If the market price falls below this minimum, government payments are used to make up the difference. Underwriting schemes differ from the older-style stabilisation schemes in that the latter are, at least theoretically, contributory. In important cases, such as that of wheat, the stabilisation schemes were intended to be approximately self-financing in the long run.

The discussion of underwriting and stabilisation has been clouded by a number of essentially accidental differences between the operational details of the two types of schemes. First, where the parameters of the recent stabilisation schemes applicable to wheat and other industries, such as the home consumption price, were fixed in advance for five years at a time, the guaranteed prices of the underwriting schemes have usually been based on a three-year moving average of past, present and forecast future prices. Thus, while underwriting schemes have been oriented toward dealing with risk (unpredictable variations in prices), stabilisation schemes have eliminated a great deal of instability (predictable variation in prices) and generated the associated costs of resource misallocation.[1] In some cases, these costs have been increased by the use of cost of production formulae, rather than expected prices, as the basis for setting 'target' prices. These differences in scheme design reflect changes in thinking about price policy, which have happened to coincide with a move from stabilisation to underwriting in Australian price policy.

Second, whereas underwriting schemes have mainly been funded out of general revenue, that is, by transfers from taxpayers to producers, most stabilisation schemes have involved transfers between consumers and producers through home consumption pricing, often combined with import embargoes. Indeed, in some cases, 'stabilisation' schemes have been little more than a cover for the extraction of monopoly rent from domestic consumers (Sieper 1982). It is apparent that there would be little difficulty in organising similar schemes within an 'underwriting' framework.

Third, underwriting schemes come into operation only in years where the market price falls below a particular level. By contrast, stabilisation schemes have usually involved intervention wherever the price diverged from the target level. As has been argued by Quiggin and Anderson (1979), the former approach will generally yield a given reduction in risk at a lower cost, in terms of the degree of intervention and the loss of useful price information. This point will be developed further in the present paper. For the moment, it is sufficient to note that buffer-fund stabilisation schemes based on a price-band approach are similar, in this respect, to underwriting schemes.

None of these differences will be considered in the comparison between underwriting and stabilisation schemes. Instead, underwriting will be compared to price-band stabilisation schemes on the assumption that the methods of financing and parameter setting are independent of the choice of scheme. While this approach assists in the abstract analysis of policy, it does mean that the comparisons offered here do not apply to the actual shift in price policy which has occurred over recent years, but to only one aspect of this shift.

In a similar vein, it is noted that both underwriting and stabilisation schemes have frequently been presented as part of a 'package' of measures. In assessing such packages it is necessary to take account of in-

[1] Quiggin and Anderson (1979) give a detailed discussion of the distinction between risk and instability, while Longworth and Knopke (1982) examine the resource costs of schemes which remove predictable instability.

teractions between policies, rather than assessing each element in isolation. Nevertheless, to the extent that underwriting and price stabilisation policies are interchangeable elements of policy packages, the comparison presented here will be a useful one.

The Case for Underwriting

Underwriting schemes involve both a net subsidy and a design oriented to risk reduction. Thus, for underwriting to be a preferred policy, two conditions must be satisfied:

(a) there must be a case for providing a subsidy to the industry; and
(b) there must be a case for intervention to reduce risk.

If condition (a) is not satisfied, underwriting schemes will be dominated by self-financing price-band stabilisation. If condition (b) is not satisfied, a simple fixed subsidy will normally be preferred to underwriting.

In recent years, the most widely advocated basis for subsidy assistance to rural industry has been the tariff compensation argument (Harris 1975). The version of this argument put forward by Harris, which may be denoted the 'efficiency' version, is that tariff protection causes rural industries to produce less than their optimal output. In the absence of any likelihood of tariff reductions, assistance to rural industries is seen as a 'second-best' option. An alternative, 'equity' version of the argument has been put forward (Balderstone et al. 1982). Their agnostic view on the efficiency consequences of tariff compensation was stated as (p. 39): 'there is insufficient evidence to conclude that tariff compensation should be provided to agriculture on the grounds of improving resource allocation'. However, they argued that assistance was justified on equity grounds to offset the effects of protection on farmers' incomes.

Both arguments have been the subject of wide debate, which will not be reviewed here. Other grounds for assistance could be considered, for example, the view that farmers are inherently deserving of assistance. The most important point to note is that underwriting is a price policy which acts to increase output and gross revenues, rather than to raise directly farm incomes. Indeed, it will be shown below that an underwriting scheme will always call forth an increase in output from risk-averse producers. Thus only the 'efficiency' version of the tariff compensation argument is really consistent with a case for underwriting. Equity or welfare arguments would imply a preference for policies which operate directly on incomes.

The debate over the desirability of assistance to reduce risk is a complex one. Some writers, such as Hirshleifer (1966), have suggested that, in the absence of a perfect capital market, fixed unit subsidies may be justifiable on risk grounds alone. Arrow and Lind (1970) refuted this claim, pointing out that the costs of risk-bearing were real to the private entrepreneur and that a subsidy did not change them. Only risk-spreading, either through a capital market or government taxation would do this. Edwards (1979) formalised this argument in an agricultural context.

With the refutation of the idea that risky activities *per se* merited a subsidy, the focus of the debate shifted to stabilisation policies. The desirability of these policies has been debated by Blandford and Currie

(1975, 1978), Colman (1978), Rees (1978) and Quiggin and Anderson (1979). Two main points emerge from this debate. First, there is a need to distinguish between risk and instability. If stabilisation policies act to mask predictable changes in prices, they may lead to substantial misallocation of resources. A particularly important case for the debate over underwriting is that of a continuing downward trend in prices. Here the problem is clearly one of instability rather than risk.

It may be noted that price-band stabilisation schemes limit both upward and downward fluctuations in prices. If they operate to remove predictable variations in prices, they will choke signals in both directions as well as eliminate unpredictable fluctuations. Thus, as far as resource allocation is concerned, underwriting is likely to do both less good and less harm than price-band stabilisation.[2]

Second, government intervention to reduce risk must be a response to some form of failure in the private capital market. In the case of a large number of uncorrelated risks, risk-spreading and risk-pooling should operate in a perfect capital market to eliminate the costs of risk-bearing. If risks are highly correlated, this will not be completely effective. However, risks faced by farmers are generally not very highly correlated with those faced by the rest of the community. Thus, a perfect capital market, which could, by definition, spread these risks costlessly across the community, should yield small risk premiums. (Note that the term risk premium is used here to denote the pure cost of risk-bearing, as opposed to the actuarial allowance for default risk.)

It seems to be generally agreed that farmers face significant risk even after taking advantage of the market mechanisms available to reduce risk (see, for example, IAC 1978, pp. 19-22). If farmers are risk averse, this will imply that output will be lower than if risk could be costlessly spread across the entire community. A number of studies have been made of farmers' risk attitudes both through questionnaires (Officer and Halter 1968, Bond and Wonder 1980) and through empirical observation of supply response to risk (see Just 1975 and the papers cited there). These studies have found that farmers are generally risk averse and that this results in reduced output. However, there are significant disagreements over the degree and importance of risk aversion.

The limitations of market risk reduction are partially due to existing government intervention in the capital market, such as controls on interest rates. However, deregulation proposals such as those of Campbell et al. (1982) seem unlikely to change the situation fundamentally. This is because most capital market instruments involve significant 'transactions costs'. For example, loans from banks and other bodies (including governments) involve costs associated with 'moral hazard' on the part of borrowers. As has been pointed out by Stigler (1967), the existence of these costs does not imply that capital market institutions are 'inefficient', or that the instruments in question should be operated by governments rather than private institutions. However, it does mean that alternative risk-reduction instruments, including those provided by government intervention, have the potential to enhance social welfare, provided the associated costs are sufficiently small.

In assessing the costs of risk reduction through underwriting, it is

[2] I am indebted to a referee for this point.

necessary to assume that a subsidy is to be paid in any case, for tariff compensation or other reasons. In this situation, it may be argued that there is very little cost involved in paying the subsidy out in 'counter-cyclical' fashion so as to reduce risk. This argument is formalised in the following sections. First, it is shown that an underwriting scheme is an optimal method of subsidy payment to reduce risk, in the sense that it maximises the value of a plausible objective function. Second, it is shown that an underwriting scheme yields a greater improvement in producer welfare than any other subsidy scheme with the same average unit payout.

These results must be qualified in a number of ways. First, they apply to a situation of pure risk-reduction as opposed to reductions in predictable instability. Second, underwriting schemes are optimal only within the class of pure subsidy schemes; they may be dominated by contributory schemes, based, for example, on price bands. Third, if other market failures are present, there may be substantial opportunity costs involved in orienting assistance toward risk reduction. It may, for example, be more cost-effective to provide assistance through increased expenditure on research.

The debates over tariff compensation, and the desirability of government intervention to reduce risk, are unlikely to be resolved rapidly. The discussion above shows that both a case for an output-increasing subsidy and a case for intervention to reduce risk must be made before underwriting can be considered as an appropriate policy. In the following section, it is shown that, if these conditions are met, underwriting may be an optimal policy, at least within the class of pure subsidies.

An Illustrative Model

A simple model can be used to illustrate the optimality of underwriting as a method of risk-reduction, within the class of unit subsidy schemes. The model applies to the case of an export country which is a price-taker on world markets. The world price in period t is denoted $P_w(t)$.

Producers are subject to pure risk in their output decisions. This may be modelled by assuming that production decisions for period t are made one step ahead, in period $t-1$. On the basis of the information available in period $t-1$, producers form a subjective price distribution for period t. It is assumed that $P_w(t)$ is independently and identically distributed for all t, and has mean, P_w^*. Thus, there are no predictable variations in P_w, and producers are faced with risk only. The effects of relaxing this assumption will be considered below.

The government provides a unit subsidy $g(t)$ which depends only on $P_w(t)$. The average unit level of the subsidy, denoted by g^*, is assumed to have been determined in advance on welfare or efficiency grounds. This acts as a constraint in the determination of the optimal policy. The producer return, $P_r(t)$, is the sum of the world price, $P_w(t)$, and the unit subsidy, $g(t)$. As was stated above, producers are subject to risk in making their output decisions. The production level, $Q(t)$, which is determined before the values of $P_w(t)$ and $g(t)$ become known, depends on the subjective probability distribution for $P_r(t)$ and, particularly, its mean, which is given by:

$$P_r^* = P_w^* + g^*. \tag{1}$$

The objective of reducing risk with respect to the output price, P_r, may be embodied in an objective function, V. In traditional formulations, deviations from the mean value would be penalised by a quadratic loss function of the form $k(P_r - P_r^*)^2$, where k is a cost parameter. This procedure may be generalised to any of a range of convex loss functions $V(P_r - P_r^*)$ taking a minimum at zero, that is, when $P_r = P_r^*$.

The choice of output price, rather than producers' incomes, as the target variable for stabilisation deserves some comment. As has been pointed out above, underwriting is a policy instrument oriented to improving resource allocation and increasing output rather than to improving the welfare of producers. If the main concern with risk is its effect on farm households, then policy instruments acting directly on incomes are to be preferred to price instruments.

Given this objective function, the problem of choosing an optimal scheme design may be written as one of minimising the expected value of the loss function $E[V(P_r - P_r^*)]$, subject to the requirements that $E[g] = g^*$, and that g is non-negative. (Time subscripts are dropped for convenience.)[3]

By virtue of the linearity of the expectations operator, this minimisation problem may be written in the form of a Kuhn-Tucker problem for each P_w:

$$\text{(2)} \qquad \text{Min } K = V(P_r - P_r^*) + \lambda(g(P_w) - g^*) + \mu g(P_w).$$

In this representation, λ is a Lagrange multiplier corresponding to the constraint that the expected value of g must equal g^*, while $\mu \leq 0$ is a Kuhn-Tucker multiplier corresponding to the constraint that g be non-negative. Equation (3) may be minimised with respect to g, yielding two necessary conditions:

$$\text{(3)} \qquad \partial V/\partial P_r + \lambda + \mu = 0, \text{ and}$$

$$\text{(4)} \qquad \mu g = 0.$$

Since $\mu \leq 0$, the second constraint incorporates the requirement that g be non-negative. This respresentation leads to a natural division of the solution set into two subsets; that for which intervention takes place, and that for which it does not. In the first case, $g > 0$, and equation (4) implies that $\mu = 0$. Substituting back into equation (3) yields:

$$\text{(5)} \qquad \partial V/\partial P_r = -\lambda.$$

On the other hand, if no intervention takes place, g is zero, and μ may take any non-positive value, so that:

$$\text{(6)} \qquad \partial V/\partial P_r \geq -\lambda.$$

Since V is convex, $\partial V/\partial P_r$ is increasing in P_r, and equation (5) is satisfied only at a unique value of P_r, which will be denoted P_o. Condition (6), which applies whenever $g = 0$, is equivalent to the requirement that $P_r \geq P_o$. Equation (5) states that, whenever g is non-zero, $P_r = P_o$.

[3] Strictly speaking, there should also be a term representing the costs associated with making subsidy payments. However, if these costs are linear in g, the constraint $E[g] = g^*$ means that the expected value of these costs will be independent of the scheme design.

Since g must be non-negative, these conditions can be satisfied only by a scheme such that:

$$(7) \qquad \begin{aligned} P_r &= P_o \quad P_w < P_o, \text{ and} \\ P_r &= P_w \quad P_w \geq P_o. \end{aligned}$$

Thus, the optimal solution is an underwriting scheme with trigger price P_o. For world prices greater than P_o, no intervention takes place. If the world price is less than P_o, subsidy payments are used to make up the difference, so that:

$$(8) \qquad g = \begin{cases} P_o - P_w & P_w < P_o, \text{ and} \\ 0 & P_w \geq P_o. \end{cases}$$

For each average subsidy level g^*, there is a uniquely determined intervention price P_o.

The reasoning behind this result is fairly straightforward. The reduction in risk is greatest if attention is focused on the extreme fluctuations in price. Thus, the optimal form of unit subsidy is one which truncates the bottom tail of the price distribution, that is, an underwriting scheme.

The problem is more complex if the requirement that g be non-negative is dropped, so that schemes other than pure subsidies may be considered. In the case of a self-financing scheme, where the government's objective function is symmetric with respect to payments into and out of a buffer fund, Quiggin and Anderson (1981) found that the optimal solution was a price-band stabilisation scheme. If a net subsidy is desired, imposition of the constraint $E[g] = g^*$ induces an asymmetry in the objective function.

With payments to and from government allowed, it is no longer true that the average absolute volume of payments and, hence, the cost of intervention is independent of the choice of scheme design. Thus, in setting up a minimisation problem, it is necessary to impose an explicit cost on payments to and from producers. This may be modelled by dividing the government payment g into its positive and negative parts:

$$(9) \qquad g^+ = \max(g,0),\ g^- = -\min(g,0).$$

With this notation, the Kuhn-Tucker problem (equation 3) may be rewritten as:

$$(10) \qquad \text{Min } K = V(P_r - P_r{}^*) + \lambda(g(P_w) - g^*) + (b + \mu_1)g + (b + \mu_2)g,$$

where, λ is a Lagrange multiplier;
μ_1 and μ_2 are Kuhn-Tucker multipliers; and
b is the cost of intervention.

Similar reasoning to that used for the pure subsidy problem indicates that there are two possible solutions. These are an underwriting scheme, or a non-self-financing price-band scheme, involving a similar net payout. The choice between the two will depend on the variability of P_w, the weight attached to the risk reduction objective and the cost of intervention. If the first two of these are large, so that risk is an important problem, the price-band solution will be preferred. This point may be explained intuitively as follows. If the weight attached to the risk reduction objective is high, then even after the bottom tail of the distribution has been truncated, with an expected expenditure of g^*, further risk reduction will be warranted. This will take the form of a truncation of the upper tail of the distribution matched by an increase in the 'floor' price.

This result illustrates an important problem with the case for underwriting. Even if both a net subsidy and intervention to reduce risk are warranted, there is no guarantee that the two will 'match up'. The subsidy payment, even if used optimally through an underwriting scheme, may achieve only a very small reduction in risk. Conversely, achievement of the desirable degree of risk-reduction through underwriting may involve payments larger than government is prepared to countenance. In this case, a price-band scheme with a partial government subvention will be preferable. If the price-band scheme is not feasible, administratively simpler schemes, such as an underwriting scheme partially financed by a levy, might be considered.

There are a number of other modifications which may be made to the simple model. One of the most important is the incorporation of risk-responsive supply on the part of producers. This will be considered in the following section.

Risk, Output Decisions and Producers' Welfare

The response of risk-averse producers to variable subsidies has not been examined in great detail. Sandmo (1971) examined the impact of a fixed unit subsidy. He showed that producers with decreasing relative risk-aversion would increase their output, but that others might not. It will be shown below that an underwriting scheme will always lead to an increase in output for risk-averse producers.

Assume that producers' inputs determine a cost function $C(Q)$. This function may be concave or convex. For the convex and linear cases, Sandmo showed that any risk-averse producer will have a finite optimal Q. Quiggin (1982a) extended this result to the case of concave functions, that is, increasing returns to scale.

Producers are assumed to maximise $E\ U(\pi)$, where U is a concave, twice-differentiable utility function and profits are determined by:

$$\pi = P_r Q - C(Q). \tag{11}$$

It is shown in Appendix Proposition 1 that the optimal output Q will always be larger for an underwriting scheme such as that set out in equation (8), than in the non-intervention situation where $P_r = P_w$. This result is confirmed by empirical analyses such as those of Just (1975) and Gallagher (1978).

The expected-utility approach may also be used to make more precise the (limited) optimality of underwriting schemes. In fact, it can be shown that the distribution of prices from an underwriting scheme second stochastically dominates the distribution of any other subsidy scheme with the same average unit payout (where the payout is constrained to be non-negative). That is, any risk-averse individual would prefer the first distribution to the second (see Appendix Proposition 2).

While the analysis here has used expected utility theory, similar results could be derived from a number of other approaches to the problem of decisions under uncertainty. For example, the theory of Shackle (1952) and others, that the worst possible outcome should be given especially close attention, would certainly yield results favourable to underwriting.

The idea that extreme outcomes should be overweighted, relative to an expected utility analysis, is given some theoretical and empirical support in Quiggin (1981; 1982b).

Aspects of Underwriting Scheme Design

The principal objective in designing an underwriting scheme should be to maximise the extent to which it acts to eliminate unpredictable, rather than predictable, fluctuations in prices. There is, however, a fundamental difficulty here. Price fluctuations which are unpredictable twelve months before they occur may be quite predictable six months later. Quiggin and Anderson (1979, p. 194) illustrate this process with a diagram of the evolution of the subjective probability distribution for prices.

In the model presented above, this difficulty did not arise because all production decisions were assumed to be made at a single point in time. In reality, decisions affecting final production levels range from capital investments made years in advance, right up to the time of harvesting. Price policies that reduce the risk to which early decisions are subject, may eliminate profitable opportunities for adjustment to subsequent variations in expected prices. Thus, no 'pure' risk-reduction scheme is possible.

One response to this problem would be to focus the risk-reduction objective on a particular decision, such as the area planted, on the assumption that opportunities for subsequent variations in production levels were sufficiently limited to be ignored. The outcome of this approach would be to set the intervention price in relation to the best available forecast at the time planting decisions were made.

This approach has not been adopted in many Australian underwriting schemes. Instead, the risk-reduction objective has been applied in relation to a range of decisions, by means of a moving-average intervention price. This is usually announced about a year in advance and is a weighted average of past, present and forecast prices. This approach means that the scheme reduces both predictable and unpredictable variations in prices for all the decisions which it affects, though in differing proportions for decisions made at different times.

If such a moving-average approach is adopted, the optimal time-period over which to form the moving average will depend on the time-pattern of production decisions. For annual crops, the inclusion of past years' prices will alter significantly the expected price at the time of planting. The weight attached to these past years should, therefore, be low. On the other hand, crops such as sugar involve longer production lags and may, therefore, justify the use of moving averages formed over longer periods.

The timing of announcement is also important. A number of underwriting schemes have involved announcement of the intervention price after the major decisions on planting areas have been made. This involves a significant loss in risk-reducing capacity for only a small improvement in the accuracy of price forecasts. Even though farmers may be able to form better estimates of the intervention price than of the ultimate market price, it would seem desirable to announce the intervention price shortly before decisions on area planted are made.

A subsidiary aspect of scheme design is the choice between nominal and real prices in the formulation of a moving average. The use of nominal prices in an inflationary period has certain 'cosmetic' qualities which may appeal to policy makers. Since the price estimate is generally biased downwards by the inclusion of past prices, the intervention price may be stated to be a larger proportion of the estimated price than would be possible if real prices were used, or if inflation was lower. Also, the weight given the past years' prices is somewhat lower when nominal prices are used. Thus, the scheme may be more closely oriented to pure risk-reduction than it appears.

On the other hand, if there are significant unanticipated fluctuations in the rate of inflation, the use of nominal prices will impair the risk-reducing properties of underwriting. An exception may arise when farmers have significant debt at fixed nominal interest rates, or other costs which are non-neutral with respect to inflation. The use of nominal prices will also increase the risk borne by taxpayers. For example, schemes with the trigger price equal to 90 per cent of the moving average price could be very expensive in the absence of an inflationary bias.

A final issue is the practice of underwriting only part of production, say, that destined for particular markets. In assessing schemes of this type, it must be noted that underwriting is first and foremost a subsidy. If a direct subsidy for the markets in question cannot be justified, it is unlikely that underwriting can be.

Concluding Comments

The objectives in this paper have been to analyse formally the features of underwriting schemes which account for much of their intuitive appeal, and to bring out explicitly the assumptions on which the 'case for underwriting' rests. These are the desirability of both an output-increasing subsidy and of government intervention to reduce output price risk.

It has also been noted that many of the gains which have been ascribed to a shift from stabilisation to underwriting could have been achieved without such a shift. These changes include the removal of home consumption pricing as a basis for financing stabilisation, and the adoption of price-setting procedures which focus on extreme and unpredictable fluctuations in prices, rather than eliminating or dampening all price movements. Unless some argument for subsidising rural industries, such as 'tariff compensation' is accepted, a price-band stabilisation scheme will usually be preferable to underwriting.

Only cursory attention has been given here to the question of whether the tariff compensation and risk-reduction arguments for government intervention are justified. However, it is to be hoped that the analysis presented here will encourage participants in the policy process to put forward a clear position on these issues.

APPENDIX

Proof of Proposition 1: It is sufficient to show that any increase in P_o will lead to an increase in Q.

The first- and second-order conditions for an optimum are, respectively:

(A.1) $$E[U'(\pi)(P_r - C'(Q))] = 0, \text{ and}$$

(A.2) $$D = E[U''(\pi)(P_r - C'(Q)) - U'(\pi)C''(Q))] < 0.$$

Differentiating equation (A.1) with respect to P_o and rearranging yields:

(A.3) $$\partial Q/\partial P_o = -1/D\, E[U'(\pi)(P_r - C'(Q))\,\partial P_r/\partial P_o + U'(\pi)\partial P_r/\partial P_o].$$

By the definition of the underwriting scheme:

(A.4) $$\partial P_r/\partial P_o = \begin{matrix} 1 & P_w < P_o \\ 0 & \text{otherwise,} \end{matrix}$$

$C'(Q)$ must be greater than P_o, since otherwise, the firm would be foregoing a certain profit. So, whenever $\partial P_r/\partial P_o$ is non-zero, $U''(\pi)(P_r - C'(Q))$ is positive.

Since $U'(\pi)$ is positive and D is negative, $\partial Q/\partial P_o$ is positive, as required.

In order to prove the stochastic dominance result, it is necessary to state some preliminary results. Hadar and Russell (1969) prove that if x and y are random variables with cumulative distribution functions, F and H, respectively, y second stochastically dominates x if and only if:

(A.5) $$\int_{-\infty}^{s} [F(x) - H(x)]dx > 0, \text{ for each s.}$$

In the case where y is a monotonically increasing function of x, Quiggin and Anderson (1981) prove that:

(A.6) $$\int_{-\infty}^{s} [F(x) - H(x)]dx = \int_{-\infty}^{s} [y(x) - x]F(x)dx + \int_{s}^{y(s)} [F(s) - H(y)]dy.$$

Proposition 2 is: Let F and H be the cumulative distribution functions of P_w and P_r, respectively. Given the constraints:

(A.7) $$E[P_r - P_w] = g^*, \text{ and}$$

(A.8) $$P_r \geq P_w,$$

the setting of P_r according to equation (8) in the text maximises $\int_{-\infty}^{s} (F(x) - H(x)\, dx$ for each s.

Thus, the resulting distribution of returns second stochastically dominates that available from any alterantive choice of P_r.

Proof: For $s < P_o$, $H(s) = 0$. For $s > P_o$, $H(s) = F(s)$, so, from equations (A.6) and (A.7),

(A.8) $$\int_{-\infty}^{s} [F(x) - H(x)]dx = \int_{-\infty}^{P_o} (P_r - P_w)\, dF(P_w) = g^*.$$

This is the maximum value which $\int_{-\partial}^{s} [F(x) - H(x)]dx$ can attain.

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