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A RISK AVERSE PRICE-SETTING MONOPOLIST

IN A MODEL OF INTERNATIONAL TRADE

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ABSTRACT

We construct a partial equilibrium model of a risk averse monopolist who faces an uninsurable uncertain foreign demand and a constant marginal cost, and makes an ex-ante production plan, committing ex-post to the ex-ante price. Optimal government intervention is considered when the good is only exported and income risk aversion differs for the representative consumer and the monopolist. If both agents are not too risk averse, or are identically so, the government should not intervene. If either or both agents are sufficiently risk averse, we find that a production tax will be optimal when the monopolist is more risk averse than the consumer. There is also a sensible range of parameter values for which the government will be indifferent between taxing or subsidising the monopolist. If the good is consumed domestically, the normal monopoly distortion adds a force for a subsidy.

Introduction

Government intervention is required when there are externalities that cannot be discounted by private sector actions. In this paper we bring together a monopoly distortion and uninsurable risk distortions and find that the co-existence of these two distortions can lead to some paradoxical results about the appropriate response of government.

A monopoly producer subjects domestic consumers to the standard distortion of over-priced under-production. The appropriate intervention of government stimulates production by subsidising the monopoly. If domestic households do not participate in the consumption of the product, then this subsidy argument evaporates. However, in the presence of demand uncertainty, we shall demonstrate that there can be a case for a subsidy even if only foreigners demand the monopoly product.

This result should be considered in the light of the conventional wisdom under perfect competition that increased (uninsurable) variability in demand for a product would require a tax intervention to redistribute resources away from that sector. For uncertainty on its own, a well-accepted tenet is that, in the absence of a complete set of risk markets, free trade is generally Pareto sub-optimal (for example, see Newbery and Stiglitz (1984)). In particular, if the representative household is risk averse and the perfectly competitive producer is risk neutral, Brainard and Cooper (1968) showed that a tax intervention is appropriate. We shall widen the analysis by studying the monopolistic distortion in the context of uncertainty, and shall allow for an arbitrary and differing degree of risk aversion of producers and consumers.

In this paper, we develop a partial equilibrium model of a sector which is monopolistic in both the domestic and international market and faces a total demand function for its product which is subject to exogenous multiplicative¹ random shocks that come from abroad. In order to focus on our contribution, we shall neutralise the standard monopoly price distortion by initially assuming that the entire output is exported. We shall show that the pure profit effect produces some surprising results under uncertainty. At the end of the paper we shall discuss the implications of domestic consumption.

The risk averse monopolist is a price-setter in the sense that she is assumed to make an ex-ante production plan and to commit ex-post to the planned price.² In comparison, producers subject to demand risk in a perfectly competitive environment are always quantity-setters in that

they commit ex-post to the planned quantity rather than the price. By association, there may be a general readiness to accept an analysis of the monopolist as a quantity-setter. However, in recent years there has been a growing interest in price-setting in the context of a variety of models (see, for example, Klemperer and Meyer(1986), Leland (1972), Lim (1982), Mankiw (1985) and Galc (1988)).

Although the monopolist pre-selects the price, households are assumed to decide on their consumption ex-post. This assumptions that our model falls into the category of ex-post commodity trade decision models as defined by Helpman and Razin (1978, ch.3).

On national welfare, we focus upon the welfare of that (sub)aggregate of households - called the representative consumer - that is critical for determining the choices of the ruling government. This representative consumer is also assumed to be risk averse and we allow for the possibility that the risk preferences of the producer and the consumer are different. There is no compelling reason to assume that they are identical - the household's interests, represented in government deliberations, need not coincide exactly with producer interests. We rule out the possibility of producers making Pareto-improving trades with the representative consumer on capital markets; this extreme (but standard) assumption, which exaggerates the problem of incomplete risk markets, is necessary for resource misallocation under uncertainty.

From the above discussion, it may appear that our assumptions would bias our analysis towards an interventionist result. Yet, interestingly, we find that in spite of our assumptions, no intervention (or free trade in a general equilibrium context) will still be optimal for a sensible range of parameter values.

If the consumer has the same degree of risk aversion as the producer, then not surprisingly, no intervention will be required. But we also obtain a no intervention conclusion when the degrees of aversion to income risk differ but both are below a certain finite critical value.

Now when the coefficient of risk aversion for the representative consumer is greater than that critical value, while the producer's remains below, we get the interesting result that the government will be indifferent between taxing or subsidising the monopolist. When the producer also becomes sufficiently risk averse, we find that she becomes indifferent to equilibrium prices which are higher or lower than the certainty-equivalent price. In this case however, the qualitative nature of the government intervention will not be contingent upon what the monopolist actually decides to do, although the size of the intervention will. In fact, the

intervention will be a tax if the producer is the more risk averse agent - this is the result that contradicts the conventional wisdom mentioned above.

If we allow some domestic consumption, however, a subsidy component will be added to the above results. This is because, from the domestic consumer's viewpoint, the monopolist will overprice in the standard way, and so a subsidy will be needed to correct this distortion.

The layout of the paper is as follows. Section I spells out the behaviour of the monopolist while Section II analyses the questions of optimal public policy. Finally, Section III summarises the main contributions of this paper.

SECTION I The Price-Setting Monopolist

We consider a monopolist facing a constant marginal (and average variable) cost³, c , and a demand function comprising a deterministic domestic component, $d(p)$, and a foreign component, $f(p)$, which is subject to multiplicative random shocks, i.e.

$$y = d(p) + f(p)\varepsilon \quad ; \quad \partial y / \partial p = y_p = d_p + f_p < 0 \quad (1)$$

where y and p are output and price respectively and ε is a (non-negative) random variable with

$$E\varepsilon = 1, \text{ var}(\varepsilon) = \sigma^2 \quad (2)$$

We shall define the share of domestic consumption of the monopolist's production as

$$\alpha = d(p)/y(p)$$

and shall assume for simplicity that the price elasticities of the two components are identical. This means that α is independent of p . To simplify the analysis further, we shall primarily focus

below on the policy implications of the model when $\alpha=0$. At the end of the paper we explain how $\alpha>0$ affects the results.

Ex-post, the producer has a choice between adjusting the price or the quantity or both from their ex-ante values. Here, we shall assume that the monopolist will adjust quantity and retain the ex-ante price. This is what is meant by price-setting in this paper.

The level of after-tax profit is given by:

$$\Pi_t = (p-c-t)y \quad (3)$$

where t is a specific production tax.

The monopolist is assumed to be risk averse and must construct an ex-ante plan based upon the expected value of its utility which is given by the function $W(\cdot)$. In general, this indirect utility function of the producer will depend on profit⁴. For simplicity, we shall restrict ourselves to the mean-variance form⁵ of the utility function so that

$$EW(\Pi_t) = E\Pi_t - \frac{1}{2} A \text{var}(\Pi_t) \quad (4)$$

where A is the coefficient of absolute risk aversion for the monopolist.

If we denote the ex-ante values of price and quantity by \bar{p} and \bar{y} respectively, then the expected after-tax profit, $\bar{\Pi}_t$, is given by:

$$E\Pi_t = \bar{\Pi}_t = (\bar{p}-c-t)\bar{y} \quad (5)$$

Ex-post after-tax profit can be expressed as:

$$\Pi_t = \bar{\Pi}_t [\alpha + (1-\alpha)\epsilon] \quad (6)$$

Similarly, ex-ante and ex-post pre-tax profit are related by:

$$\Pi = \bar{\Pi} [\alpha + (1-\alpha)\epsilon] \quad (7)$$

and it follows then that:

$$\bar{\Pi} = \bar{\Pi}_t + t\bar{y} \quad (8)$$

The variance of after-tax and pre-tax profit are simply

$$\text{var}(\Pi_t) = \bar{\Pi}_t^2 \delta^2 (1-\alpha)^2 = \bar{\Pi}_t^2 \sigma^2 \quad (9)$$

$$\text{var}(\Pi) = \bar{\Pi}^2 \delta^2 (1-\alpha)^2 = \bar{\Pi}^2 \sigma^2 \quad (10)$$

where we have defined σ as the weighted risk factor

$$\sigma = (1-\alpha)\delta$$

In view of (9) and (10), equation (4) can be rewritten as

$$EW(\Pi_t) = \bar{\Pi}_t - \frac{1}{2} A \sigma^2 \bar{\Pi}_t^2 \quad (11)$$

Therefore, the price-setting monopolist's first order utility maximisation condition is given by:

$$dEW(\Pi_t)/dp = (1-A\sigma^2\bar{\Pi}_t) d\bar{\Pi}_t/dp = 0 \quad (12)$$

where

$$d\bar{\Pi}_t/dp = [\bar{p}(1-1/\eta) - (c+t)] y_p \quad (13)$$

with η being the price elasticity of demand and y_p representing $\partial\bar{y}/\partial\bar{p}$. Expected profit is clearly concave in the price level and is depicted in Figure 1.

Before analysing the properties of the optimal tax, it will be helpful to look into the nature of the solution for the monopolist's maximisation problem.

Let $\bar{p}=p_t^*$ be the solution of equation (13) with the right hand side set to zero. Clearly this would be the ex-ante solution for a risk neutral monopolist, i.e. $\bar{\Pi}_t$ will attain its maximum at $\bar{p}=p_t^*$. In other words p_t^* is the certainty-equivalent profit maximising price. Let us also denote by A^* the value of the risk aversion coefficient of the producer such that⁶

$$1 - A^* \sigma^2 \bar{\Pi}_t^* = 0 \quad (14)$$

where $\bar{\Pi}_t^*$ is the value of $\bar{\Pi}_t$ evaluated at p_t^* .

From (14) it should be evident that for all values of the risk-aversion coefficient A such that $A < A^*$, one has

$$1 - A \sigma^2 \bar{\Pi}_t^* > 0$$

Therefore, in this case, from (12), it follows that P_t^* also maximises the monopolist's utility maximisation problem, assuming concavity of the profit function. Thus, if the coefficient of absolute risk aversion is less than $1/(\sigma^2 \bar{\Pi}_t^*)$ the monopolist will not make any correction for the existence of risk, and will simply set expected marginal revenue to marginal cost including the tax⁷.

However, for values of $A > A^*$, p_t^* will be a point of local minimum for the utility problem. This is because at p_t^*

$$d^2EW(\Pi_t)/dp^2 = (1 - A\sigma^2\bar{\Pi}_t^*) d^2\bar{\Pi}_t^*/dp^2 > 0$$

Since $\bar{\Pi}_t$ has its maximum at p_t^* , $1 - A\sigma^2\bar{\Pi}_t$ will decrease in value as the price is increased or decreased from p_t^* . Therefore, even though $1 - A\sigma^2\bar{\Pi}_t^*$ is negative, it will increase in value if \bar{p} is increased as well as decreased and it will attain the value zero for two values of p , one of which is larger than p_t^* and the other smaller. Thus for $A > A^*$, as shown in Figure 1, there will be two local maxima, one to the left and the other to the right of p_t^* - we shall refer to these two solutions as the 'low price' (p^L) and 'high price' (p^H) equilibrium respectively (defined relative to the certainty-equivalent one). For both of these values of \bar{p}

$$1 - A\sigma^2\bar{\Pi}_t = 0$$

which implies that

$$\bar{\Pi}_t = 1/(A\sigma^2) \quad (15)$$

which implies that

$$\bar{\Pi}_t = 1/(A\sigma^2) \quad (15)$$

and from (11) that

$$EW(\Pi_t) = 1/(2A\sigma^2) > 0 \quad (16)$$

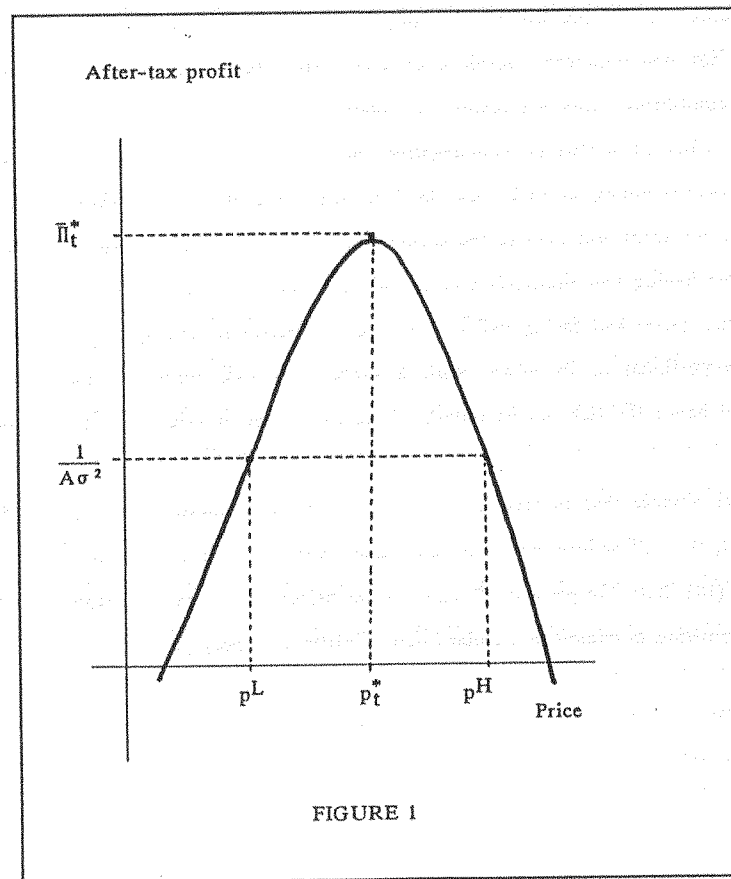


FIGURE 1

There are four important points to note about (15) and (16). Firstly, the optimal values of expected post-tax profit and utility are independent of the production tax: whatever the tax, so long as A remains greater than A^* , the producer will choose a price so that expected profit and utility are constant. As we shall see later, this feature is crucial for the understanding of our paradoxical results.

Secondly, the value of expected profit and thus of utility are identical at both points of local maxima. The 'very risk averse' firm is therefore indifferent to the 'low price' and 'high price' equilibrium. The actual equilibrium that the firm chooses will depend on the initial step in the implicit iterative process that determines the firm's move to a utility maximum. In a fully-fledged dynamic analysis, this will be an example of a hysteresis equilibrium.

Thirdly, while our non-uniqueness result does derive from the mean-variance framework, nevertheless each equilibrium does not involve a violation of concavity or of the requirement that the marginal utility of profits be non-negative. Nor is it true that the marginal revenue curve is not downward-sloping in each case. In fact, these equilibria come about because a sufficiently risk-averse agent will push to the corner solution where marginal expected utility is zero. The reason for having two equilibria yielding identical expected utility to the producer is simple. Being a price-setter and facing risk which is multiplicative to demand, the variance of profit must be proportional to its mean. With a sufficiently risk averse producer ($A > A^*$) expected profit and hence the risk can be reduced from its maximum value (at p_t^*) by a higher or a lower price.

Fourthly, we observe that an increase in the share of safe domestic consumption of the monopolist's output, α , will reduce σ^2 and thus raise expected after-tax profit in (15) and expected utility in (16). Both the p^L and p^H equilibrium prices will be raised because the firm will be in a better position to exploit its standard deterministic monopoly power.

SECTION 2 The Government's Behaviour

Turning now to the government, we assume that it maximises the expected value of $V(p, \Pi)$ where V is an indirect utility function based on the preferences of the representative consumer which is some (sub)aggregate of all households. As mentioned above, we shall begin by suppressing the domestic consumption of the monopolist's good (i.e. we set $\alpha=0$). It is to be noted that the representative consumer's indirect utility is a function of its pre-tax and not after-tax share of profits. The reason for this is that the tax revenues are simply assumed to be redistributed in a non-distortionary manner. Once again, we shall restrict ourselves to a simple mean-variance analysis i.e.

$$EV(\Pi) = \bar{\Pi} - \frac{1}{2} B \text{ var}(\Pi) \quad (17)$$

where B is the coefficient of absolute risk aversion for the representative consumer. This risk aversion coefficient is not necessarily the same as that for the monopolist, A . On a priori grounds, it is not clear which should be larger, A or B . In the principal-agent literature, managers of firms are assumed to be more risk-averse than their owners. But in any event that literature has aspects that we do not model, in particular asymmetric information. Thus the clear presumption in that area does not necessarily apply here. Further Kihlstrom and Laffont (1979) have suggested that less risk-averse agents are more likely to become entrepreneurs. Here we shall make no presumption about the relative sizes of A and B . Should the two coefficients be different, we shall need to assume away the possibility of Pareto-improving trade (e.g. in shares and debentures) between the two groups of agents. Otherwise the optimal allocation of risk bearing can be resolved through trades in perfect capital markets. The fact that capital markets are manifestly imperfect and incomplete (especially in developing countries) lends support for our assumption.

The results of this section can be summarised formally as:

Proposition

There exists a positive and finite value of the coefficient of absolute risk aversion for the monopolist, A^* , and for the representative consumer, B^* , such that we have the following alternative outcomes:

- (i) If the actual values of the risk coefficients A and B satisfy $A < A^*$ and $B < B^*$, or if $A=B$, no intervention is the optimal policy
- (ii) If $A < A^*$ and $B > B^*$, the government will be indifferent between optimally taxing or subsidising the monopolist.
- (iii) If $A > A^*$ and $B < B^*$, the optimal tax is positive.
- (iv) If $A > A^*$ and $B > B^*$, the optimal tax is positive provided A is larger than B .

We shall now provide the proof and intuition of this proposition.

The control variable in the government's maximisation problem is the tax rate. Using (10), the first order condition for such a maximisation problem is given by:

$$dEV(\Pi)/dt = (1 - B\sigma^2\bar{\Pi}) d\bar{\Pi}/dt = 0 \quad (18)$$

Now we have already shown that for $A < A^*$ the monopolist acts in a certainty-equivalent manner; in this case it is easy to verify that pre-tax profit $\bar{\Pi}$ is maximised at $t=0$. Therefore, from (18), we can observe that $t=0$ is also a point of maximum for the optimisation problem of the government, provided $B < B^*$ ($=1/\sigma^2\bar{\Pi}^*$) where $\bar{\Pi}^*$ is the maximum value (evaluated over t) of the producer's utility-maximising pre-tax profit (i.e. from (8), $\bar{\Pi}^* = \max(\bar{\Pi}_t + t\bar{y})$).⁸ Put differently, if the risk aversion coefficient $A < A^*$, while $B < B^*$, then $A^* = B^* = 1/(\sigma^2\bar{\Pi}^*)$, and no intervention will be optimal even though A and B may take different values. Thus imperfect risk markets and different risk preferences between producers and consumers are not sufficient conditions for government intervention.

Now suppose $A < A^*$ and $B > B^*$. In this case, we know that pre-tax profit is maximised at $t=0$. However, from (18) it should be clear that $t=0$ will be a local minimum for the government's optimisation problem. Following the same kind of argument used for the analysis of the monopolist's maximisation problem, one can easily establish that, in the present case, the

optimal policy is where

$$1 - B\sigma^2\bar{\Pi} = 0 \quad (19)$$

which can be achieved by either a tax or a subsidy, and the two alternative policies will yield the same level of pre-tax profit and of utility for the representative consumer i.e.

$$\begin{aligned} \bar{\Pi} &= 1/(B\sigma^2) \\ EW(\bar{\Pi}) &= 1/(2B\sigma^2) \end{aligned} \quad (20)$$

The monopolist selects one price, p_t^* , which is a unique global maximum, but its value depends on whether the government happened to move to an optimal tax or a utility-equivalent optimal subsidy. Of course p_t^* would be higher with a tax.

The reason for this equivalence of the optimal tax and subsidy is simply that the government perceives that the representative consumer is extremely (income) risk averse and so it is obliged to intervene to reduce the expected value and thereby the variance of profit. Both a tax or subsidy will do because expected profit is always at a maximum with no intervention.

When $A > A^*$, the problem of finding an optimal tax rate becomes more involved because, now, the monopolist will be, as discussed earlier, indifferent between two alternative actions. However, as we shall soon see, the qualitative nature of the government's behaviour will not be contingent upon what the monopolist actually decides to do, although the size of the intervention will.

In this case, using (15) and (8), (18) can be rewritten as:

$$dEV(\Pi)/dt = [-tA\sigma^2y(\bar{p}) - (B-A)\sigma^2\bar{\Pi}] d\bar{\Pi}/dt = 0 \quad (21)$$

If we have $B < B^*$, it follows directly from (18) that the optimal tax is obtained by setting $d\bar{\Pi}/dt=0$. Now, from (15), we know that $\bar{\Pi}_t$ is a constant so that $d\bar{\Pi}_t/dt=0$. Therefore from (8), the optimal tax must be that which maximises tax revenue. Assuming the tax revenue function to be single-peaked we can conclude that if $A > A^*$ and $B < B^*$, the optimal policy will be to tax the monopolist. In this case, it is easy to show that $A > B$ because when $A > A^*$, then B^*

becomes $A/(1+A\sigma^2 \max(\bar{y}))$ which is less than A .

In Figure 2, the tax revenue function is presented and an interior maximum is shown at t . The size of the optimal tax will be lower if the monopolist chooses a 'low' rather than a 'high' price equilibrium.

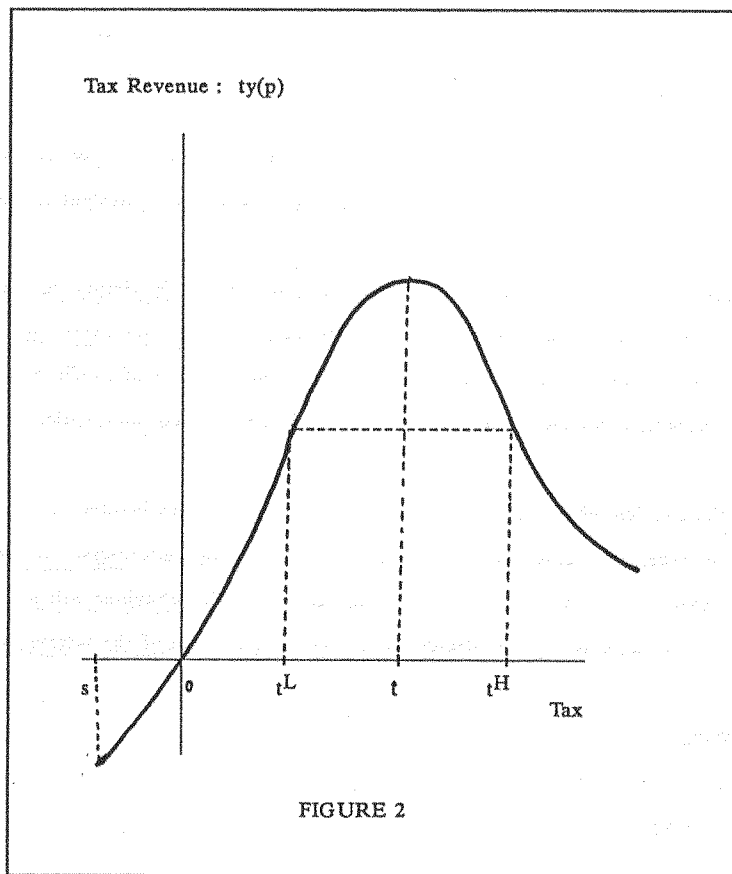


FIGURE 2

When $A > A^*$ and $B > B^*$, the optimal policy is found from setting the term in square brackets in (21) to zero, which (using (5), (7) and (15)) gives

$$t = (A-B) / (A\sigma^2 y(\bar{p})) \quad (22)$$

Concerning (22), we will make six points. Firstly, we observe that the total expected tax revenue [subsidy payment], $ty(\bar{p})$, is held constant by the government: if average sales increased, the government will reduce the tax [subsidy] proportionately. The reason for this is simply that the monopolist fixes $\bar{\Pi}_t$ at $1/(A\sigma^2)$ when $A > A^*$, while the government fixes $\bar{\Pi}$ at $1/(B\sigma^2)$. From (8) the difference must be $ty(\bar{p})$.

Secondly, the optimal policy depends on whether or not A is larger than B : a tax is optimal if the firm is more risk averse than the consumer. This surprising result comes from the fact that tax revenues will have to be raised if $\bar{\Pi} > \bar{\Pi}_t$ i.e. if $A > B$. Conversely, a subsidy is optimal if $A < B$.

Thirdly, from Figure 2, it is apparent that when a tax is needed (i.e. when $A > B$), two values of the tax, one above the revenue maximising value t , and one below, will achieve the required value. These two values, t^H and t^L respectively, are shown in Figure 2. Instead, when $A < B$ in which case a subsidy is needed, only one value of the subsidy, s , will do. This asymmetry in the outcome can be explained as follows. From the definition of B^* we know that $1 - B^* \sigma^2 \bar{\Pi}^* = 0$ and therefore $1 - B \sigma^2 \bar{\Pi}^* < 0$. Now, as the tax revenue, and thus $\bar{\Pi}^*$, is maximised at t , increasing or decreasing the value of t from t will clearly lower the value of $\bar{\Pi}^*$ which in turn will raise the value of $1 - B \sigma^2 \bar{\Pi}^*$. One may then expect that two values of t will solve the equation $1 - B \sigma^2 \bar{\Pi}^* = 0$ always. This is indeed true when A is greater than B . However, when $A < B$, $1 - B \sigma^2 \bar{\Pi}^*$ will be bounded away from zero for all positive values of t . This can be seen by observing that $1 - B \sigma^2 \bar{\Pi}^*$ can be rewritten as the term within the square in equation (21) which is clearly strictly negative for all positive values of t when $A < B$. Therefore, in this case, by increasing the value of t beyond t one can never raise the value of $1 - B \sigma^2 \bar{\Pi}^*$ to zero; the only way one can achieve that is by lowering t to a unique value below zero.

Fourthly, the size of the optimal policy will again depend on whether the monopolist has chosen the 'low price' or the 'high price' equilibrium: since $y(\bar{p})$ will be lower for the latter, the tax [subsidy] rate will be lower for the latter.

Fifthly, when $B = A$, as one would expect, the optimal policy will be no intervention.

Finally, when $B \neq A$, the optimal production tax/subsidy forces the producer to behave 'as if' she had a coefficient of risk aversion of B . To see this, observe that the government chooses t

to obtain a maximum $E\hat{V}[p] = \bar{\pi} - \frac{1}{2}B\bar{\pi}^2\sigma^2$, while the producer must choose p to maximise $EW = (\bar{\pi} - ty) - \frac{1}{2}A(\bar{\pi} - ty)^2\sigma^2$. With the optimal policy in place, (22) holds and substituting this into the above expressions leads to

$$\max_p EW = \frac{B}{A} \max_p E\hat{V}[p] + (A^2 - B^2)/(2AB\sigma^2) \quad (23)$$

Consequently, the monopolist's optimal plan is made to reflect the government's interests.

2.1 Introducing Domestic Consumption

We shall now outline how the above results will change if part of the monopolist's output is consumed by the representative consumer. Further analytical details are provided in the Appendix. As mentioned above, the indirect utility of the representative consumer will now depend on the price of the monopoly good as well. The presence of this price variable on its own warrants a government subsidy to reduce the monopoly distortion by increasing output and thus lowering price. Therefore in our case, the qualitative nature our results will be expected to shift towards, but not necessarily to, a subsidy prescription.

In other words, if $A < A^*$ a subsidy will be the optimal policy irrespective of the value B . When $A > A^*$ and $B > B^*$, a subsidy will once again prevail as long as A is less than or equal to B . In all other cases the outcome will in general be indeterminate. That is to say the optimal policy will be a subsidy or a tax depending on the relative magnitude of the price effect and of the effect of α on σ^2 operating through (22).

SECTION 3 Concluding Comments

In this paper, we have constructed a model of a risk averse price-setting monopolist whose

profits and price have an influence on risk averse consumers. The risk preferences of these two types of agent are assumed to differ in general, and the existence of incomplete capital markets is assumed to foreclose the possibility of an optimal reallocation of risk-bearing. This would appear to be a certain recipe for making a case for government intervention.

In fact, it has been shown that this is not true, provided the good is not consumed at home and that both the producer and the representative consumer are not unduly income risk averse. In this particular equilibrium, the producer's marginal expected utility of profit is positive, and so she chooses a price that maximises certainty-equivalent profit. The government chooses not to intervene because its representative consumer's marginal expected utility of profit is also positive, and expected profit is maximised at the no intervention point.

When risk aversion becomes sufficiently large, the chosen equilibrium will be determined at the point where marginal expected utility of profit is zero. In this event, it turns out that the monopolist will be indifferent to a higher or a lower price equilibrium, relative to the certainty-equivalent one. This is a fundamental feature of a model with a price-setting monopolist facing constant marginal cost and multiplicative demand risk. The form of intervention now depends on whether one or the other or both of the two agents is sufficiently income risk averse, upon their differential risk aversion, and finally upon whether the good is consumed at home.

A production tax is needed to the extent that the monopolist is more income risk averse than the consumer. This is perhaps surprising because, as mentioned in the Introduction, one might have thought that the government would want to tax a producer who cares less about risk than is considered to be socially desirable.

NOTES

1. It is generally accepted that multiplicative risk is a more natural and plausible specification than additive risk when dealing with demand systems - for further discussion, see Newbery and Stiglitz (1981, p120).

2. Price-setting is likely for firms that suffer a large fixed cost and low and more or less constant marginal variable costs. An obvious example would be a natural monopoly, such as a public or private utility.

3. The inclusion of a fixed cost would not affect our results.

4. $W(\cdot)$ may also depend directly on p if the producer is also influenced by her possible role as a consumer of the risky good. However we abstract from this issue on the grounds that profits will be dominant in the calculus of the producer.

5. We choose to use a mean-variance technology because it is so tractable and widely understood. Its weakness is that it can only be reconciled with von Neumann-Morgenstern utility theory when the utility function is quadratic or when the stochastic process is normally distributed. Quadratic utility has the undesirable property that the marginal utility of profit eventually becomes negative. While this property also arises for expected utility under normality, there is nothing unreasonable about marginal expected utility becoming negative. Nevertheless agents will never choose to be in that negative range. The problem with the normality assumption is that one ought to rule out shocks that could make demand (or profits) negative or unreasonably large. This means that mean-variance analysis is approximately correct provided the distribution has small tails. Finally, we restrict ourselves to the very simple constant absolute risk aversion utility function which means that there are only substitution effects of risk. For further discussion, see Hey (1981, p149-51) and Newbery and Stiglitz (1981, p85-92).

6. Note that A^* depends on t .

7. This certainty-equivalence result was discussed by Leland (1972,p.286) although he conjectured that it would hold for all values of A .

8. Note that B^* is defined as independent of t . However, B^* will have one value when $A > A^*$ and another when $A < A^*$.

APPENDIX

In a price-setting model, the price, p , is deterministic while pre-tax profits, Π , are stochastic. On the assumption of an underlying two parameter distribution for ε , expected utility of the representative consumer can be written as:

$$EV(p, \Pi) = V(\bar{p}, \bar{\Pi}) + \frac{1}{2} V_{\Pi\Pi}(\bar{p}, \bar{\Pi}) \text{var}(\Pi) \quad (A1)$$

Differentiating the above equation and using Roy's Identity ($V_p = -d(\bar{p})/V_{\Pi}$) and (10), we get:

$$(1/V_{\Pi}) dEV/dt = - [d(\bar{p}) - \frac{1}{2} B_p \bar{\Pi}^2 \sigma^2] / V_{\Pi} d\bar{p}/dt + [1 - B \sigma^2 \bar{\Pi} + \frac{1}{2} V_{\Pi\Pi\Pi} \bar{\Pi}^2 \sigma^2 / V_{\Pi}] d\bar{\Pi}/dt \quad (A2)$$

where $B = -V_{\Pi\Pi\Pi}/V_{\Pi}$. Given $V_p < 0$, it is reasonable to assume that, ceteris paribus, an increase in \bar{p} will decrease welfare. Further it is reasonable to expect $V_{\Pi\Pi\Pi}/V_{\Pi}$ to be of second-order significance.

When $A \leq A^*$, (13) set at zero indicates that $d\bar{p}/dt = 1/(1-1/\eta) > 0$ and that $d\bar{\Pi}/dt = -\eta \bar{y} t / [\bar{p}(1-1/\eta)]$. When $A > A^*$, (15) with (3) implies $d\bar{p}/dt = 1/[1-\eta/(\bar{p}A\sigma^2\bar{y})] > 0$ and that $d\bar{\Pi}/dt = \bar{y}(1-t/\bar{p}[1/\eta - 1/\bar{p}A\sigma^2\bar{y}])$. These are then substituted into (A2) which then gives the results discussed in the text. Note that if $\alpha=1$, then $\sigma^2=0$ and there would be no risk at all and the optimal intervention is simply $t=d(\bar{p})/y_p < 0$.

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