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FACULTY OF AGRICULTURE

AN ANALYSIS OF THE ROLE OF
UNCERTAINTY IN THE MARKETING
OF PERISHABLE PRODUCTS*

✓
R.W. Fraser

Agricultural & Resource Economics
Discussion Paper: 1/94

Nedlands, Western Australia 6009

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*I would like to thank David Dole for his views on negative correlations

ABSTRACT

This paper analyses the problem of marketing uncertainty for producers of perishable products. It argues that there are two main features to this marketing uncertainty: uncertainty of demand at the market price due to quality considerations; and uncertainty of transport services associated with the independence and cost of such services. It is suggested that a negative correlation between the uncertainties of demand and transport services is viewed as an additional cost by producers, and as such may be sufficient to create a reversal of supply response to a given change in market conditions. It is also suggested that elimination of this type of negative correlation may be a relatively low-cost way of stimulating an industry.

INTRODUCTION

This paper analyses the problem of uncertainty in the marketing of a perishable product. It is a problem that may have been thought of marginal importance ten years ago. But with a continuing trend towards the consumption of fresh, as opposed to processed, produce, an increasing number of producers are involved in supplying to such markets.

Moreover, there are markets where quality considerations are central to a product's saleability: products which do not appear fresh, or in some way lack appearance, are likely to perish unsold. Consequently, many producers are obliged to incur considerable marketing costs in order to maintain the product's condition from farm gate to market place. For example, air transport costs are increasingly being incurred in the marketing of fresh fruit, vegetables, flowers and fish.

It is in connection with this potential for unsaleable product that the problem of uncertainty in marketing is thought to be of particular significance. In a previous paper the author examined the problem of uncertain demand for a perishable product, with demand forgone should it turn out to be in excess of production, and perished product should the reverse apply (Fraser, 1986). The sale price is taken to be given in this context, with quality considerations dominating the purchasing decision. The aim of this paper is to extend Fraser (1986) in two ways. First, the previous analysis only considered the implications for the producer's behaviour of an increase in the uncertainty of demand. However, it is more often the case, particularly with export markets for fresh produce, that the change in demand conditions faced by the producer is one of an increase in both expected demand and the uncertainty of demand. Consequently, in section 1 of this paper, the results of Fraser (1986) are briefly reviewed and the analysis is extended to consider the more complex change in demand conditions outlined above.

The analysis of Fraser (1986) is also extended to consider a new type of uncertainty: uncertainty of transport services. This type of uncertainty is thought to be of importance to producers for two reasons. First, it is common for the size of production unit for fresh produce to be quite small - the family farm is a typical entity. The capital requirement for vertical integration from farm gate to market place is therefore likely to be excessive, and the producer will typically be dependent on an intermediary for transport services. Second, that even for relatively large production units, they may be serving overseas, or even domestic, markets where air transport is required. In this context, the nature of the airline industry makes vertical integration impossible. Consequently, reliance on independent transport services is thought to be a common situation for growers of fresh produce. Add to this the previous recognition that such services are likely to be an important cost consideration because of the role of quality in marketing, and the problem of uncertainty of transport services is clearly of significance to the growers of fresh produce. The analysis of section 2 extends that of section 1 to include this additional source of marketing uncertainty. In particular, this section considers the consequences of a negative correlation between the two types of uncertainty: that times of relatively low market demand are typically associated with times of relatively high availability of transport services.

The paper ends with a brief consideration of the policy consequences of the analysis.

SECTION ONE: DEMAND UNCERTAINTY

The analysis of Fraser (1986) is based on a simple model of risk averse producer used by Newbery and Stiglitz (1981, ch 6). It was shown that the response of the producer to increased uncertainty of demand is essentially independent of this risk aversion, and rather depends on the relative levels of expected benefits and costs of extra production. For this reason, risk aversion is dispensed with as a feature of the analysis in this paper, and instead a simpler model which nevertheless preserves the basic features of the results in Fraser (1986) is used.

As indicated above, the producer is assumed to face a fixed market price (p). This is a producer price and is therefore taken to be net of marketing costs. Unit costs of production (c) are assumed for simplicity to be constant. Because of the perishable nature of the product, sales (A) will be the lesser of uncertain demand (x) and production (y).

Consequently, expected profit ($E(\pi)$) is given by:

$$E(\pi) = p \left(\int_0^y x f(x) dx + \int_y^\infty y f(x) dx \right) - cy \quad (1)$$

where: $f(x)$ = probability distribution function of demand.

Differentiating (1) with respect to y gives the first order condition for optimal production:

$$p \int_y^\infty f(x) dx = c \quad (2)$$

or:

$$p(1-F(y)) = c \quad (3)$$

where: $F(y)$ = cumulative probability of demand exceeding production.

Equation (3) shows that the producer chooses output to be such that the expected revenue from extra production is equal to the marginal cost of that production. Moreover, it was shown in Fraser (1986) that in this situation if increased uncertainty of demand is of the "Sandmo" type, then the farmer's optimal production increases or decreases as initial production exceeds or is less than expected demand ($\bar{x}$).¹ In general terms this result follows from the realisation that if profit margins (ie c/p) are large enough to justify:

$$y > \bar{x}$$

then an increase in the uncertainty of demand will increase the probability of demand exceeding production ($1-F(y)$), and the balance in (3) is therefore restored by increasing y . Whereas if profit margins are smaller such that:

$$y < \bar{x}$$

then the reverse shift of probability weight occurs (ie $(1-F(y))$ decreases) and so optimal production is reduced.

However, as suggested in the Introduction, it is more common in the context of fresh produce for a change in demand conditions to feature both an increase in expected demand and in the uncertainty of demand, such as would occur with the opening of a new export market.

For a producer with high profit margins such that production is initially in excess of expected demand, the consequences of such a development are unambiguous: both the increase in expected demand and in the uncertainty of demand will increase the probability of demand exceeding initial production. Therefore, such a producer will clearly respond to the change in demand conditions by increasing production.

But for a producer with low profit margins such that initial production is less than expected demand, the two features of the change in demand conditions have conflicting effects on the production decision: the increase in expected demand will tend to increase the probability of demand exceeding production, while the increase in the uncertainty of demand will decrease this probability. Although no general result can be obtained in this situation, a numerical example can be used to show that the optimal response of the producer is determined by two factors:

- (i) the size of the profit margin.
- (ii) the relative size of the increases in expected demand and the uncertainty of demand.

Specifically, the lower is the profit margin, the more important are the consequences of the increase in uncertainty in determining the production response. Moreover, the larger is the increase in expected demand relative to the increase in the uncertainty of demand, the more likely the producer is to increase output.

The role of these two factors is illustrated by the numerical example represented in Table 1. In the situation of an increase in expected demand of 10% and in the uncertainty of demand (represented by the standard deviation) of 20% (column (2)), optimal production is increased if profit margins are at the higher level (0.540) but decreased if at the lower level (0.885). However, even if profit margins are at this lower level, but the increase in demand uncertainty is only 10% (column (3)) instead of 20%, then optimal production is increased (row (2)).

Consequently, as in Fraser (1986), profit margins play a significant role in determining the producer's response to a change in demand conditions, with lower profit margins making it more likely a producer will reduce output in response to a given change in the expected level and uncertainty of demand.

SECTION TWO: DEMAND AND TRANSPORT SERVICES UNCERTAINTY

The addition of transport services uncertainty to the producer's overall marketing uncertainty means that a situation may arise where even though demand may be sufficient to sell all that is produced, the facility is not available to transport all the output to the market. This new possibility means that sales will in general be the lesser of production, demand and transport services (z). In this case, expected sales are given by:²

$$\begin{aligned}
 E(A) = & \int_0^y \int_{z=x}^{\infty} xw(x,z)dzdx + \int_{x=z}^{\infty} \int_y^{\infty} zw(x,z)dzdx \\
 & + \int_y^{\infty} \int_y^{\infty} yw(x,z)dzdx
 \end{aligned} \tag{4}$$

where: $w(x,z)$ = joint probability distribution governing x and z .

So that expected profit is given by:

$$E(\pi) = pE(A) - cy \tag{5}$$

and the optimal production level is found by differentiating (5) with respect to y :

$$p \int_y^{\infty} \int_y^{\infty} w(x,z)dzdx = c \tag{6}$$

Equation (6) shows that when faced with uncertainty of both demand and transport services, the producer will choose output such that expected marginal revenue based on the joint probability of demand and transport services exceeding output is equal to the marginal cost of production.

One point that is clear from (6) is that, compared with a situation of zero or positive correlation, a negative correlation between demand and transport services will reduce optimal output. This follows from the realisation that the introduction of a negative correlation must reduce the joint probability of demand and transport services exceeding a given level of production.

However, what is not clear from (6) is the important role that a negative correlation can play in altering a producer's response to a change in marketing conditions. In particular, that two producers with the same profit margins may respond in opposite ways to the same change in marketing conditions even though their initial marketing conditions differ only in respect of the correlation between their demand and transport services uncertainties.

This role of the correlation between demand and transport services uncertainties can be seen by consideration of the following numerical example. In this example, as in the previous section, it is assumed that the random variables are normally distributed. In this case, tables for finding the volumes of the normal bivariate surface with a range of correlation coefficients can be used to evaluate:³

$$W((y-\bar{x})/\sigma_x, (y-\bar{z})/\sigma_z, \rho) = \int_y^\infty \int_y^\infty w(x,z) dz dx \quad (7)$$

where: ρ = value of the correlation coefficient
 σ_x = standard deviation of demand
 σ_z = standard deviation of transport services.

Note that such tables are constructed on the basis of the truncation point (y) exceeding the expected value of the two random variables ($\bar{x}$, $\bar{z}$). In order to consider a situation where the truncation point is below these expected values, it is necessary to use the following identity in association with the tables:⁴

$$W(-(y-\bar{x})/\sigma_x, -(y-\bar{z})/\sigma_z, \rho) = 1 - F(y) - G(y) + W((y-\bar{x})/\sigma_x, (y-\bar{z})/\sigma_z, \rho) \quad (8)$$

where: $F(y)$ = cumulative probability of production exceeding demand

$G(y)$ = cumulative probability of production exceeding transport services.

Consider first the situation where only the uncertainty of demand and transport services increases. The results in Table 2 show the situation where, if the producer's marketing conditions feature a zero correlation between demand and transport services, then an equal percentage increase in the level of uncertainty of both these variables leads to an increase in optimal production. But if instead the producer's marketing conditions feature a negative correlation ($\rho = -0.5$), then even though all other parameter values are identical, optimal production is decreased.

This contrast may be understood by observing that for the producer with a zero correlation the profit margin is sufficient for an initial level of optimal production which exceeds the expected levels of demand and transport services, whereas for the producer with a negative correlation this same profit margin is insufficient for optimal production to exceed these levels. In this sense, the negative correlation is like an additional cost to be borne by the producer and in the numerical example, this "cost" is enough to reduce optimal production from the region where it is stimulated by an increase in the uncertainties of marketing, to the region where it is discouraged by such an increase.

Consequently, this example highlights the notion of a negative correlation as a cost, and that as such it may shift optimal production from a region of one type of behavioural response to a region where the opposite response occurs. This point may be extended to the more complex change in uncertain conditions analysed in section 1: an increase in both the expected level and the uncertainty of the random variable.

The results in Table 3 consider three situations: where the expected levels alone of demand and transport services increase; where the levels of uncertainty alone of demand and transport services increase; and where the two increases occur simultaneously. They show that for two producers who differ only with respect to the correlation between the uncertainties of demand and transport services that they face this difference of correlation can be sufficient to reverse the output response of the two producers to the same change in marketing conditions. In particular, the results in column (4) show that whereas the producer with a zero correlation would respond to the nominated increases in the expected levels and uncertainties of demand and transport services by increasing production, the reverse applies in the case of the producer with a negative correlation.

Moreover, the significance of this reversal is highlighted by noting that, as indicated by the results in columns (2) and (3), the qualitative response of the two producers is the same for the changes in expected levels and uncertainties considered separately.

Once again, the explanation for this reversal lies in the notion of the negative correlation as a cost. As recognised in section 1, in the more complex case of an increase in both the expected level and the uncertainty of a random variable, the level of profit margin can determine whether the production response to such a change is positive or negative, with lower profit margins making a negative response more likely. It is this response reversal that has been used in the numerical example underlying the results in Table 3, with the negative correlation being a sufficiently large additional "cost" to shift the producer from one response region to another.

CONCLUSION

This paper has considered the problem of marketing uncertainty for producers of perishable products. It has been argued that recent consumption trends mean such uncertainty is a significant problem faced by many producers of fruits, vegetables, flowers and fish. Moreover, it has been argued that there are two main features to this marketing uncertainty: uncertainty of demand at the market price because of the role of quality in the purchasing decision; and uncertainty of transport services associated with the independence and cost of such services.

The approach taken here has been first to extend the analysis of Fraser (1986) to the more realistic case of a change in demand conditions which features both an increase in the expected level and the uncertainty of profits (section 1). And second, to consider the more complex case of marketing conditions which feature uncertainty of both demand and transport services (section 2).

The general result of section 1 was that producers may respond differently to the same change in demand conditions depending on their profit margin, with lower profit margins making a negative output response to a given change more likely. The general result of section 2 was that a negative correlation between the uncertainties of demand and transport services (so that, for example, in times of low demand, transport services are readily available) is viewed as an additional cost by producers. In this context, numerical examples were used to show how two producers with the same profit margin and market conditions, differing only in terms of the correlation between the uncertainties of demand and transport services that they face, may exhibit the opposite supply response to the same change in market conditions.

From the policy point of view, it is important to recognise at this point that such a negative correlation is only perceived as an additional cost. Moreover, as such it makes negative

output responses to changes in market conditions more likely, even though these changes may feature an overall expansion in the average size of the market. Consequently, the potential exists for the elimination of a negative correlation of this type, simply by the provision of marketing information, to be a relatively low cost method of stimulating activity in an industry.

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Table 1

Numerical example of the effects of
changing demand conditions on optimal production^a

		(1)	(2)	(3)
		Base Case	$\Delta\bar{x} = +10\%$ $\Delta\sigma_x = +20\%$	$\Delta\bar{x} = +10\%$ $\Delta\sigma_x = +10\%$
c/p				
(1)	0.540	0.950	1.040	1.045
(2)	0.885	0.400	0.380	0.440

Notes a: Demand assumed to be normally distributed

b: Base Case parameter values:

$$\bar{x} = 1$$

$$\sigma_x = 0.5$$

Table 2

Numerical example of the effects on optimal production
of increasing the uncertainty of demand and transport services^a

	Base Case	$\% \Delta \sigma_x = +50\%$ $\% \Delta \sigma_z = +50\%$
$\rho = 0$	1.050	1.075
$\rho = -0.5$	0.947	0.921

Note a: Base Case parameter values:

$$c/p = 0.212$$

$$\bar{x} = \bar{z} = 1$$

$$\sigma_x = \sigma_z = 0.5$$

Table 3

Numerical example of the effects on optimal
production of various changes in marketing conditions^a

	(1)	(2)	(3)	(4)
	Base Case	$\% \Delta \bar{x} = +5\%$	$\% \Delta \sigma_x = +50\%$	(2) + (3)
		$\% \Delta \bar{z} = +5\%$	$\% \Delta \sigma_z = +50\%$	
(1) $\rho = 0$	0.950	1.000	0.925	0.975
(2) $\rho = -0.5$	0.866	0.916	0.799	0.849

Note a: Base Case parameter values:

$$c/p = 0.292$$

$$\bar{x} = \bar{z} = 1$$

$$\sigma_x = \sigma_z = 0.5$$

FOOTNOTES

¹See Sandmo (1971) for details. Basically, the increase in uncertainty must be a mean-preserving spread of probability weight to the tails of the distribution.

²See Fraser and Van Noorden (1983) for a previous attempt to analyse this type of situation.

³See Pearson (1931).

⁴See Johnson and Kotz (1972 p94).