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ECONOMIC PAYOFF FROM RESEARCH THAT REDUCES THE INCIDENCE OF DARK-CUTTING BEEF IN AUSTRALIA

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ABSTRACT

An important quality problem facing the Australian beef industry is dark-cutting (DC) beef. DC meat appears dark or brown in colour with firm and dry texture. It has inferior eating and keeping qualities which make it unsuitable for vacuum packaging and export.

In this paper, an aggregated, partial equilibrium trading model is developed for estimating research benefits from a reduction in the incidence of DC in beef in Australia. Research-caused reduction in DC causes a reallocation of beef from a lower quality DC market to a higher quality primal beef market. Price changes in the two markets resulting from such reallocation give rise to distributional effects between producers and consumers.

The analysis suggests that it is profitable for Australia to invest a large sum of money in research that reduces DC. The analysis indicates that the benefits from such research accrue to producers.

Economic Payoff from Research that Reduces the Incidences of Dark-cutting Beef in Australia

Introduction

Dark-Cutting (DC) beef is a quality problem in the Australian beef industry. The affected meat appears dark in colour with firm and dry texture (DFD). It has inferior eating and keeping qualities. For these reasons, dark meat is less acceptable to the retail meat market (Porter and Todd, 1985). DC beef is also unsuitable for vacuum packaging and export (Brownlie, 1988).

The incidence of DC in beef in Australia has been reported to be in the range 1-16% (Warner et al., 1988). This variability is caused by the different ways in which DC beef are classified, and differences arising from animal,spatial and abattoir factors. The mean incidence has been reported to be about 8% (Shorthose, 1988).

There is a sizable literature on scientific studies of DC in beef in Australia (see Shorthose 1988 for a review). Economic evaluation of the DC problem, on the other hand, has received little attention. There has been no previous attempt to measure the economic returns from a reduction in DC in beef in Australia.

A reduction in the incidence of DC can be achieved by undertaking scientific research which shows how to lower the stress level in beef animals during transport and handling, and by implementing the changes in these marketing processes which are suggested by the research. Research and development in electronic marketing of beef cattle (e.g. the Computer-Aided Livestock Marketing (CALM) in Australia)[1] could also possibly bring about a reduction in DC if the technology could be sucessfully assimilated into the Australian beef marketing system (DARA, pers. comm.).

In this paper, an economic model is developed for evaluating research payoff from a reduction in the incidence of DC beef in Australia. The analysis is performed at the carcass level. A reduction in the incidence of DC causes a movement of beef meat from the poorer quality DC market (market 2) to the better quality primal beef market (market 1). Price changes in the two markets resulting from the reallocation of beef give rise to distributional effects between producers and consumers. The level and distribution of gains from research are measured as changes in economic surpluses.

The analysis presented in this paper attempts to throw light on the size and the distribution of benefit from research that reduces the prevalence of DC in Australia. The major implication is for investment in research that reduces DC.

The Model

In this section, we provide a conventional market-clearing, partial equilibrium model that allows an illustrative calculation of gains from research that reduces the incidence of DC in beef. The model allows for effects on world prices via an excess demand curve. The model is

[1] The CALM is based on sales by classification which requires the adoption of a uniform trading language. The electronics allow particular action in the market by both sellers and buyers from all over Australia. It is widely accepted that beef sold through this system suffer lower level of stress because the system entails shorter transport distances, hence less handling and shorter marketing time. In addition, the holding time at abattoirs is reduced since the delivery period can be arranged.

different from the disaggregated commodity supply and demand model with separate sectors for the home country and the rest of the world (ROW) used for evaluating research benefits (e.g. Edwards and Freebairn, 1984) in that it allows welfare changes to be determined for country A (Australia) only. Use of the disaggregated commodity supply and demand model is inappropriate in our case for the following reasons. First, beef is a non-homogenous commodity. For example, the grass-fed beef produced by Australia is viewed as being different from the grain-fed beef produced by the US. Second, the frequently-used assumption that the elasticities of demand and supply in ROW bear the values for the elasticities of demand and supply in country A can be unrealistic. One obvious reason in our case is that Australia's demand for beef at the carcass level is inelastic, but the ROW demand (which comprises the ROW demand for Australia's production and ROW demand for ROW production) for beef can be highly elastic if the ROW (excess) demand for Australian beef is extremely price elastic. Third, data on the incidence of DC in ROW and data on consumers' evaluation on DC beef in ROW are difficult to obtain. In the absence of these data, even the use of a disaggregated model disallows calculation of the economic surplus gains for ROW and the world as a result of a reduction in the prevalence of DC in Australia.

In constructing the model we assume linear supply and demand curves for beef and competitive price behaviour. The model has two separate parts: the market for primal beef and the market for DC beef. A research-caused reduction in the incidence of DC results in an increased supply of primal beef in market1 and a proportionate decreased supply of DC beef in market 2. Welfare changes in the two markets are quantified separately. The net economic benefits are the sum of the welfare gains/losses in markets 1 and 2.

The model for appraising producer, consumer and social gains from research is depicted in Figure 1. Consider first the price change in market 1 (see Figure 1(a)). Under free trade, the linear supply curve for primal beef is represented by S_1, domestic demand by D_{dd_1} and total demand by D_{td_1} (with $D_{td_1} - D_{dd_1}$ being export (excess) demand for primal beef). In the absence of research, primal beef price is P_1, the quantity supplied by Australia is Q_{s_1}, the quantity demanded domestically is Q_{dd_1}, and the excess quantity demanded by ROW is $(Q_{s_1} - Q_{dd_1})$. A reduction in the incidence of DC gives rise to an increased supply of primal beef; this is reflected by a downward shift in the supply curve for primal beef from S_1 to S_1' in Figure 1 (a). The supply shift is assumed to be parallel. The size of the supply shift is measured vertically as representing a fall in per unit production costs. The cost reduction estimate is determined from the 'product increase' (or the 'projected output change') estimate since a 1% increase in production per unit input can be interpreted as a 1% reduction in the per unit output cost of production.

With a research-induced downward shift in the supply of primal beef, price decreases from P_1 to P_1', domestic consumption increases from Q_{dd_1} to Q_{dd_1}' and the quantity exported to ROW increases from $(Q_{s_1} - Q_{dd_1})$ to $(Q_{s_1}' - Q_{dd_1}')$. The domestic consumers' surplus, CS, increases by area P_1adP_1', and domestic producers gain area $P_1'cfk$ (i.e. area ($bchg$ plus cef less P_1beP_1'). The social surplus equals the sum of the consumer and producer surpluses.

The demand and supply equations in the absence of the supply shift in market 1 are specified as follows

$$Q_{dd_1} = a - \alpha_1 P_1 \tag{1}$$

$$Q_{ed_1} = b - \theta_1 P_1 \tag{2}$$

$$Q_{td_1} = c - \gamma_1 P_1 \tag{3}$$

$$Q_{s_1} = d + \beta_1 P_1. \tag{4}$$

The domestic demand is represented by equation 1; export demand by equation 2; total demand by equation 3; total supply by equation 4; a, b, c, and d are the intercept terms; and α_1, θ_1, γ_1, and β_1 are the demand and supply price slopes. Subscript 1 denotes market 1. Note that the total demand function is a horizontal summation of the domestic and the excess demand functions. Hence, the total demand price slope, γ_1, equals $\alpha_1 + \theta_1$. Equations 1-4 can be solved to determine the 'without research' quantities and price.

Now introduce the supply shift caused by R&D-induced technological change in Australia. The size of the supply shift in market 1 is denoted by v_1. Then, the 'with research' supply equation becomes

$$Q'_{s_1} = d + \beta_1 v_1 + \beta_1 P'_1 \tag{5}$$

where all terms are defined above except that the prime superscript denotes 'with research'. Equations 3 and 5 can be solved for the unknown variable P'_1. The quantity variables Q'_{s_1}, Q'_{dd_1} and Q'_{ed_1} can then be obtained by substitution. These variables can be expressed in terms of initial price and quantity.

Algebraically, the gain for domestic consumers, CS_1, gain for domestic producers, PS_1, and aggregate national gain, TS_1 in market 1, from R&D-induced supply shift can be expressed as

$$\begin{aligned} CS_1 &= 1/2(P_1 - P'_1)(Q_{dd_1} + Q'_{dd_1}) && (6)\\ &= \frac{\beta_1 v_1}{\alpha_1 + \beta_1 + \theta_1} Q_{dd_1} + \frac{\alpha_1 \beta_1^2 v_1^2}{2(\alpha_1 + \beta_1 + \theta_1)^2} && (7)\end{aligned}$$

$$\begin{aligned} PS_1 &= 1/2[v_1 - (P_1 - P'_1)](Q_{s_1} + Q'_{s_1}) && (8)\\ &= \frac{(\alpha_1 + \theta_1) v_1}{\alpha_1 + \beta_1 + \theta_1} Q_{s_1} + \frac{\beta_1 (\alpha_1 + \theta_1)^2 v_1^2}{2(\alpha_1 + \beta_1 + \theta_1)^2} && (9)\end{aligned}$$

$$TS_1 = CS_1 + PS_1 \tag{10}$$

where all terms are defined above.

In increasing the supply of primal beef in market 1, a reduction in the incidence of DC causes a corresponding decrease in the supply of DC beef in market 2; this is reflected in an upward shift in the supply curve for DC beef (see Figure 1 (b)). An upward shift in supply of DC beef gives rise to increased price and decreased quantity of DC beef carcasses. Now, by introducing some changes in the first part of the model, the economic surplus change resulting from decreased supply of DC beef can be determined.

The main changes are as follows. The total demand for DC beef in market 2, D_{td_2}, consists of the domestic demand only since the export meat orders in Australia prohibit the export of DC beef to ROW (Brownlie, 1988). In the absence of research, the price for DC beef is given by P_2 and quantity by Q_{dd_2}. With research, the supply curve for DC beef shifts up vertically from S_2 to S'_2 by a magnitude v_2 (see Figure 1 (b)). The 'with research' price and quanity are denoted by P'_2 and Q'_{dd_2} respectively.

Using similar procedures as those used in market 1 but incorporating the above changes, economic benefits accrued to market 2 are expressed in algebraic forms, as

$$CS_2 = 1/2(P'_2 - P_2)(Q_{s_2} + Q'_{s_2}) \tag{11}$$

$$= \frac{\beta_2 v_2}{\alpha_{\cdot} + \beta_1} Q_{s_2} + \frac{\alpha_2 \beta_2^2 v_2^2}{2(\alpha_2 + \beta_2)^2} \tag{12}$$

$$PS_2 = 1/2[v_2 - (P_2' - P_2)](Q_{s_2} + Q_{s_2}') \tag{13}$$

$$= \frac{\alpha_2 v_2}{\alpha_2 + \beta_2} Q_{s_2} + \frac{\beta_2 \alpha_2^2 v_2^2}{2(\alpha_2 + \beta_2)^2} \tag{14}$$

$$TS_2 = CS_2 + PS_2 \tag{15}$$

where all terms are defined above and subscript 2 denotes market 2.

Net changes in consumers' surplus, CS, producers' surplus, PS and total surplus, TS are expressed as

$$CS = CS_2 + CS_1 \tag{16}$$

$$PS = PS_2 + PS_1 \tag{17}$$

$$TS = TS_2 + TS_1. \tag{18}$$

Parameters and Data

The values of key variables required for empirical estimations are listed in Table 1. The data used for the analysis correspond to the carcass level. Price and quantity data refer to 1988 conditions. Beef exports constitutes about 60% of the total beef production in 1988.

Price data for dark beef were obtained from Porter and Todd (1985), who used a hedonic price analysis of beef carcass characteristics. The categorical variables for meat colour (i.e. reading on the brightness-darkness scale) used by Porter and Todd in their hedonic price analysis consist of bright red (control colour), mature red, and dark red colour. The mature red meat occurred in about 20% of the samples used by Porter and Todd, and is often regarded as meat from an older animal (see, for example, Warner, 1988). The dark red meat, on the other hand, has an incidence lower than that of mature red meat (occurred in only 4% of the samples used by Porter and Todd), and is often considered to be meat caused by the presence of DC. Thus, it is appropriate to use the implicit price for dark red beef (i.e. DC beef), as a basis of our empirical estimation. The price for dark beef (or DC beef) is obtained by subtracting the per unit price discount for DC beef from the normal primal beef price. It is approximately 9% lower than the price of primal beef. The quantity of dark beef corresponds to the current incidence of DC in beef in Australia (i.e. 8% of total Australian beef production).

Data on demand and supply elasticities for beef in Australia were obtained from various sources. The highest and the lowest reported values for demand elasticity are used in our analysis. For supply elasticity, both longrun and shortrun estimates are used. The export demand for Australian beef has been reported to be highly elastic (Cronin, 1979; Scobie and Johnson, 1979). For empirical purposes, we adopt the values of export demand elasticity in the range -4 to -20.

The current mean incidence of DC beef in Australia has been estimated to be 8%. In this paper, research is assumed to reduce the average incidence of DC beef by 50% (i.e. by 4 percentage points). This results in a reallocation between markets 1 and 2 of beef equivalent to 4% of total beef.

Table 1: Values of Variables for Estimating Research Gains from a Reduction in the Incidence of DC in Australia

Variable	*Value*	*Description*
Q	1510 kt	Commercial beef production (carcass weight)[a]
Q_{s_1}	1389.2 kt	Quantity of primal beef produced in Australia (carcass weight)[b]
Q_{dd_1}	555.68 kt	Quantity of primal beef consumed domestically (carcass weight)[b]
Q_{ed_1}	833.52 kt	Quantity of primal beef exported (carcass weight)[b]
Q_{s_2}	120.8 kt	Quantity of DC beef produced in Australia (carcass weight)[b]
P_1	$2.4[illegible]/kg	Average carcass price for primal beef[c]
P_2	$2.19/kg	Average carcass price for DC beef[d]
η_l	-0.05	Lowest value of demand elasticity for Australian beef carcasses[e]
η_h	-0.50	Highest value of demand elasticity for Australian beef carcasses[f]
E_a	-1, -10, -16, -20	Export demand elasticity for Australian beef carcasses[g]
e_l	0.16	Shortrun supply elasticity for beef carcasses[h]
e_h	0.34	Longrun supply elasticity for beef carcasses[i]
v_1	9.64 cents/kg	Vertical shift in the supply of primal beef carcasses[j]
v_2	8.76 cents/kg	Vertical shift in the supply of DC beef carcasses[j]

[a] From Australian Bureau of Statistics, quarterly publications, Canberra.
[b] From Commodity Statistical Bulletin and Shorthose (1988).
[c] From The Victorian Meatwork Association.
[d] From The Victorian Meatwork Association and Porter and Todd (1985).
[e] From Papadopolous (1973).
[f] From Marceau (1967).
[g] From Scobie and Johnson (1979); Cronin (1979).
[h] From Wicks and Dillon (1978).
[i] From Hall and Menz (1985).
[j] Assuming 4% reallocation of beef from market 2 to market 1.

Results

Values of the level and the distribution of benefits from research that reduces the incidence of DC in beef in Australia were calculated for the various combinations of demand and supply elasticities. The results are tabulated in Table 2. The main observation is that Australian research that lowers the incidence of DC provides large national gains. It has been estimated that the Australian beef industry has the potential to derive an economic benefit up to $1200 million in present values over 30 years, or up to $40 million per year, from a 50% reduction in the total incidence of DC in Australia. The economic benefit accrues entirely to the Australian beef producers. Consumers were observed to lose but only marginally from a research-caused reduction in the incidence of DC.

The overall industry's gain from research is due to the large gain from the downward shift in the supply of bright beef in market 1. The level and the distribution of research benefits accruing in market 1 are little affected by the different values assumed for the elasticities of export demand and the elasticities of demand and supply in Australia. The highest estimate of research benefits is only 20% larger than the lowest estimate. In the more likely case where the implied world demand for Australian beef is extremely price elastic (i.e. Australia has negligible importance in the world market), the economic benefits accruing in market 1 are affected only slightly by elasticities of supply and demand for beef in Australia. In the less likely case where the world demand is less price elastic, the gains from research in market 1 are somewhat more sensitive to the demand and supply elasticities. Producers' benefits are observed to be larger and consumers' benefits smaller for larger E_a than for smaller ones (see Table 2). Where the implied export demand is highly elastic, Australian consumers derive very small amount of research benefits.

In market 2, both producers and consumers lose from research that while lowering the supply curve in market 1, concomittantly raises the supply curve for DC beef in market 2. The economic losses occurring in market 2 are small compared with the gains occurring in market 1. The level of benefit from research for market 2 is unaffected by changes in E_a because DC beef is non-tradable. It is also observed that the producers' losses are small relative to consumers' losses in market 2 because demand for beef carcasses in Australia are price inelastic.

Concluding Comments

The major implication of this analysis is for investment in research that reduces the incidence of DC beef in Australia. The analysis suggests that it is profitable for Australia to invest a large sum of money (up to $40 million a year) for research which halves the incidence of DC. Since the benefits from research accruing entirely to producers, it might be suggested that producers bear the costs of research.

Consideration of time lags in the research and adoption process, and perhaps of international spillovers from adoption of Australian research advances in ROW, could reduce the estimated net benefits from research and hence the profitable level of research outlays. It is our hope that the evidence provided of large economic payoffs from reductions in DC in beef will stimulate scientific and industry interest in the matter.

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Table 2: Estimated level and distribution of benefits from research that reduces the incidence of DC beef in Australia (PV in millions of dollars summed over 30 years)

	Elasticities of Export Demand for Australian Beef															
	-4.0				-10.0				-16.0				-20.0			
	Elasticities of Supply and Demand in Australia															
	0.16 -0.05	0.16 -0.5	1.34 -0.05	1.34 -0.5	0.16 -0.05	0.16 -0.5	1.34 -0.05	1.34 -0.5	0.16 -0.05	0.16 -0.5	1.34 -0.05	1.34 -0.5	0.16 -0.05	0.16 -0.5	1.34 -0.05	1.34 -0.5
PS_1	1184	1190	813	833	1222	1224	988	995	1242	1242	1108	1110	1246	1246	1136	1138
CS_1	31	29	180	172	16	16	110	107	8	8	61	60	7	7	51	50
TS_1	1215	1219	993	1005	1238	1240	1098	1102	1250	1250	1169	1170	1253	1253	1187	1188
PS_2	-24	-25	-4	-27	-24	-25	-4	-27	-24	-25	-4	-27	-24	-25	-4	-27
CS_2	-76	-75	-96	-73	-76	-75	-96	-73	-76	-75	-96	-73	-76	-75	-96	-73
TS_2	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
PS	1160	1165	809	806	1198	1199	984	968	1218	1218	1104	1083	1240	1240	1132	1110
CS	-45	-46	84	99	-60	-59	14	34	-68	-67	-35	-12	-70	-69	-45	-23
TS	1115	1119	892	905	1138	1140	998	1002	1150	1151	1069	1071	1170	1171	1087	1087

Negative (-) indicates a loss in surplus.

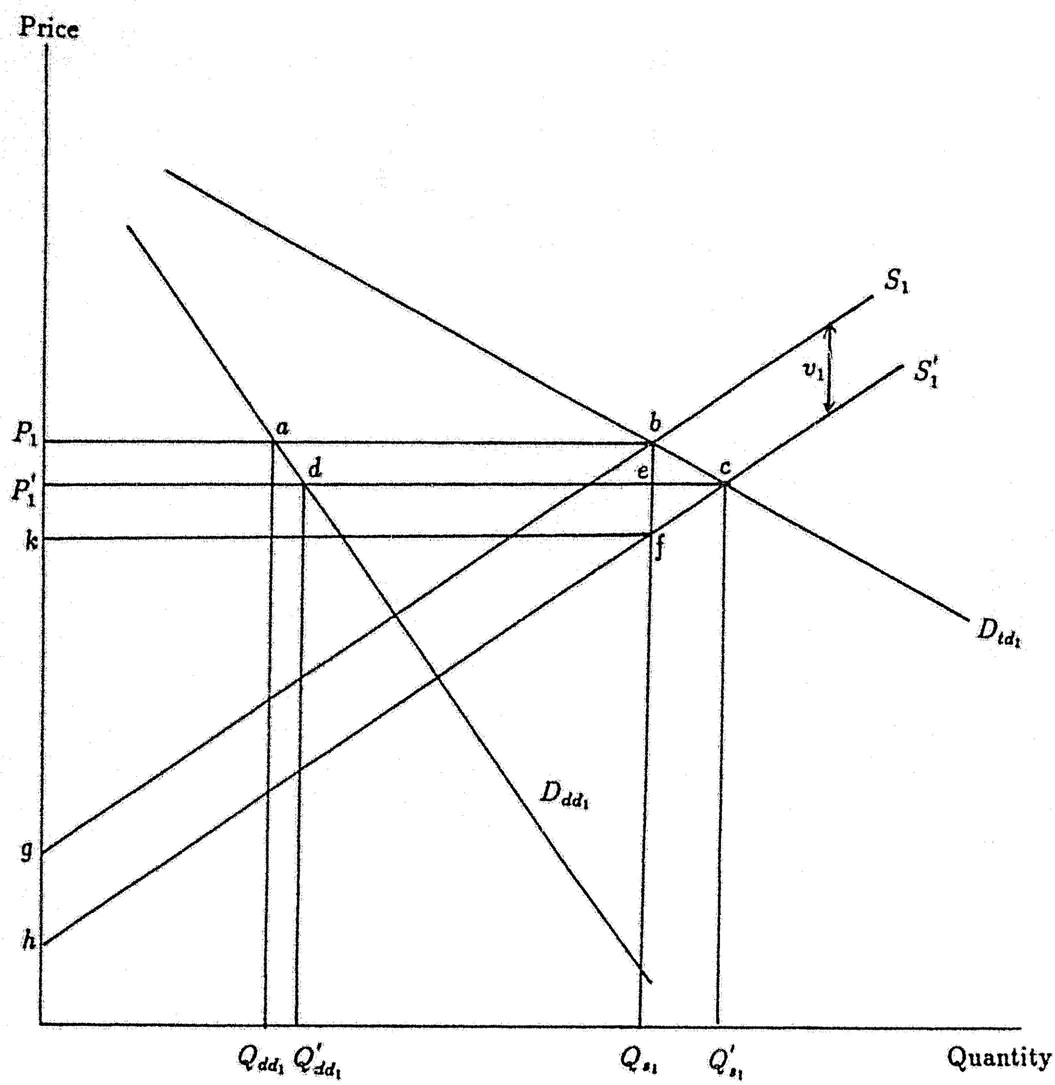

Figure 1(a). Effect of a downward shift in supply of primal beef in market 1.

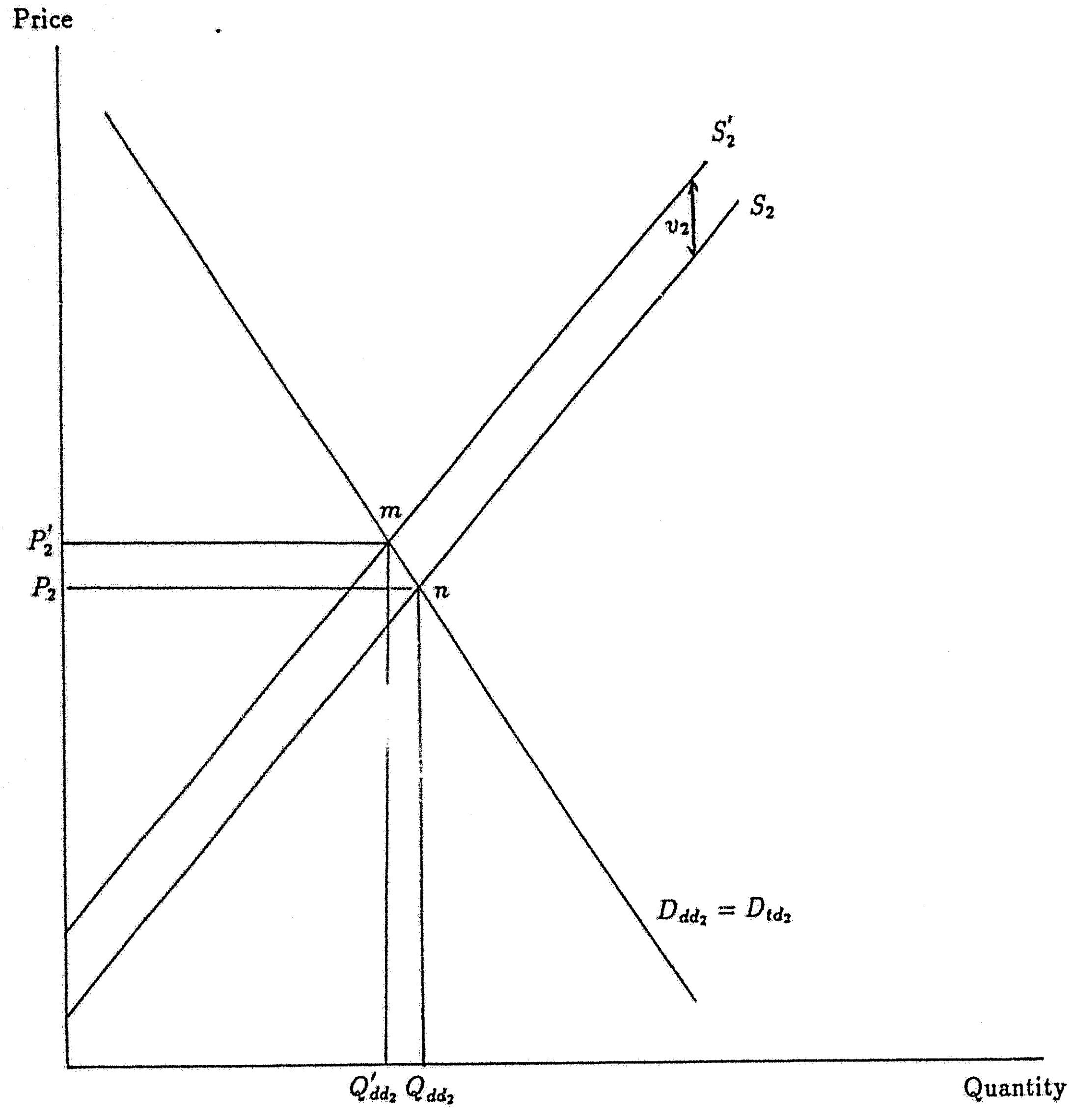

Figure 1(b). Effect of an upward shift in supply of DC beef in market 2.